RULES OR REGULARITIES? THE HOMOPHONE DOMINANCE EFFECT IN SPELLING AND READING REGULAR DUTCH VERB FORMS

REGELS OF STATISTISCH LEREN? HET EFFECT VAN HOMOFOONDOMINANTIE TIJDENS HET SPELLEN EN LEZEN VAN REGELMATIGE WERKWOORDSVORMEN IN HET NEDERLANDS

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‘And thus, the actions of life often not allowing any delay, it is a truth very certain that, when it is not in our power to determine the most true opinions we ought to follow the most probable.’

René Descartes
DISCOURSE ON METHOD
INTRODUCTION

The Dutch spelling system presents us with an intriguing paradox: both experienced and inexperienced Dutch spellers produce a considerable number of homophone intrusions on regularly inflected verb forms. These intrusion errors involve the substitution of two inflected verb forms from the same verbal paradigm that have an identical pronunciation, but exhibit a different spelling pattern (e.g., *hij meld* instead of *hij meldt*; both pronounced as *[mElt]*; ‘he *report*’ instead of ‘he reports’). These errors remain omnipresent, even after extensive training from a young age onward and, more importantly, despite the descriptively transparent nature of the spelling rules (i.e., stem + suffix).

Given the simplicity of these rules, it is not surprising that errors on regular, rule-based forms are associated with negligent writing behavior and are the cause of much frustration, not only among teachers, but also among the general public. Due to their persistence in even thoroughly checked texts, such as essays or newspapers, these notorious spelling errors have even been given their own name, namely *d/t-errors*. While this paradoxical observation already received attention almost sixty years ago in a Dutch book with the significant title *The tragedy of verb forms* (van der Velde, 1956; personal translation), the issue is still extremely relevant today. Indeed, these errors continue to fuel heated discussions in educational circles and to inspire people to devise new teaching methods. They also make researchers wonder at regular intervals how well a particular age group performs on these verb forms (the underlying implicit assumption often being that this is a persistent problem). For instance, recent research has shown that Flemish students in the first year of their education program for becoming a teacher (who will have to teach these spelling rules themselves) only scored 63.6% on verb spelling (Speltincx & Venstermans, 2010).

While negligence is certainly responsible for a proportion of the errors on the spelling of regularly inflected Dutch verb forms, not all errors are the
result of a careless attitude. Previous research has shown that the reason for the persistence of these errors is threefold (Assink, 1985; Frisson & Sandra, 2002b; Sandra, Frisson, & Daems, 1999; Sandra & van Abbenyen, 2009). Firstly, the large majority of errors pertain to verbs with two homophonous forms in their inflectional paradigm\(^1\). In other words, two competing orthographic representations (e.g., meld-meldt; ‘report(s)’) map onto a single phonological representation (e.g., [mElt]). These two spelling forms are occasionally interchanged, leading to so-called homophone intrusions. Secondly, the spelling of homophonous verb forms requires the application of a morphosyntactic rule, whose execution takes place in working memory and whose goal is to identify the grammatical properties of the word determining the suffix spelling. In cognitively demanding situations (e.g., under time pressure), working memory might fail to identify the relevant grammatical information (e.g., 3\(^{rd}\) person singular subject). Hence, it might fail to correctly apply the spelling rule, and select the incorrect spelling for the suffix. This will inevitably lead to errors on a number of occasions. Thirdly, the pattern of errors is not random, but governed by what has been called Homophone Dominance (Sandra, Frisson, & Daems, 1999): intrusion errors are more likely when the target form is the lower-frequency (LF) homophone than when it is the higher-frequency (HF) one. This preference for the dominant homophone reflects the involvement of a second memory system, namely the mental lexicon (i.e., part of long-term memory), in which whole-word representations of both homophones (or at least the most frequent one) are apparently stored. The large number of homophone intrusions on LF homophones indicates that the HF form is activated more quickly and, hence, is most likely to act as an intruder.

\(^1\) We do not wish to deny that there are other types of verb errors, such as non-existent word forms (e.g., *gevormdt instead of gevormd ‘formed’, resulting from the concatenation of a prefix, a stem and a morphologically illegal suffix). However, we will restrict our attention to intrusions involving two homophonous inflected forms (i.e., two morphologically legal word forms) or two sublexical homophonous clusters straddling the morpheme boundary, including the suffix (see below).
Because even careful spellers occasionally run into the trap set up by our cognitive infrastructure, homophone intrusions make for an intriguing object of investigation. More particularly, they provide us with an interesting psycholinguistic question: do people rely solely on the conscious application of explicitly taught rules when spelling homophonous verb forms or do they also make use of frequency information and, more generally, any form of statistical regularities in the written language? Note that reliance on statistical properties, which will naturally result in probabilistic spelling behavior, will inevitably give rise to errors in a domain that is governed by strict rules.

This dissertation will extend the previous experimental findings in two ways. Our first objective is to demonstrate that these errors are not only the inevitable by-products of the workings of our memory systems during the writing process, but also during the reading process. If the Homophone Dominance effect indeed transfers to visual perception, the HF homophone is expected to be recognized more quickly than its LF counterpart and, hence, to be perceived as a more familiar form. The familiarity of the HF homophone would cause readers to more readily accept it as a correct spelling form, even in cases where it is a homophone intrusion. If this indeed turns out to be the case, the Homophone Dominance effect would create a double trap for language users. Just as spellers are tricked by their working memory and lexical memory into writing down the most frequent form of a verb homophone, these same memory systems will cause readers to overlook an intrusion error when it involves the HF form.

Importantly, the Homophone Dominance effect suggests that whole-word representations for regularly inflected verbs are stored in the mental lexicon, although these forms are strictly rule-based and can be constructed on the fly each time they are needed. This finding is compatible with a statistical learning view, according to which frequent co-occurrences between letter patterns (e.g., whole-word patterns) are stored. However, it cannot reject a rule-based account enriched with a mechanism that is sensitive to the frequency with which each spelling rule is applied, i.e., where a counter keeps track of the number of times a particular stem and a particular suffix spelling
have been combined. For instance, spellers can be sensitive to the frequency of the pattern *meldt* because the computation of this form takes into account how often the stem has previously been connected to the t-spelling of the suffix (*meld + t*).

Therefore, our second objective is to disentangle these two accounts by comparing error patterns in the lexical and sublexical domain. We aim to show that the effect of Homophone Dominance is not restricted to homophones at the level of the whole-word form (henceforth: lexical intrusions), but also manifests itself on word forms whose homophonous relationship is restricted to their final grapheme cluster (henceforth: sublexical intrusions). For instance, even though the final sound sequence [st@] of the Dutch regular past tenses *suste* (‘hushed’) and *rustte* (‘rested’) is exactly the same, it has two distinct spelling patterns in these two forms (*ste* and *stte*)². This leads to intrusions of the type *sustte* and *rustte*, respectively. We label these intrusions ‘sublexical’ because the substituted letter string represents neither a word, nor a morpheme. As a matter of fact, the intrusion involves orthographic patterns that straddle the morpheme boundary; more particularly, they comprise the stem-final consonant(s) and the past tense suffix. This makes them impossible errors within a rule-based account whose basic representational units are morphemes and which is enriched with a frequency-sensitive mechanism for morpheme combinations. Rather, these errors fit well within a statistical learning view, which postulates that the recurrence of patterns in the input is the major driving force behind the development of mental representations.

Just as for lexical intrusions, we will investigate whether the pattern of sublexical homophone intrusions in spelling is determined by Homophone Dominance. If so, more errors should be made when a homophonous orthographic pattern is frequently attested in other words than when a

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² Note that this difference in spelling is not due to different spelling rules for past tenses of different verb classes, but to the fact that the past tense suffix -te (always following a voiceless phoneme) is attached to a verb stem that does not end in a t as in *sus-te*, whereas it is attached to a verb stem that does end in a t as in *rust-te.*
homophonous competitor is non-existent. Moreover, we will examine whether sublexical errors involving a familiar homophonous orthographic pattern are processed more quickly during perception and are therefore overlooked more often than errors containing a non-existent pattern.

In Chapter 1, we will describe the rules behind the spelling of regular Dutch verb forms and elaborate on the three above-mentioned issues that have been argued to explain the persistence of homophone intrusions (Sandra et al., 1999). We will also review the evidence in favor of and against morphological decomposition and whole-word storage of regular morphologically complex words, both in the spelling and perception literature. Finally, we will discuss how the phenomena can be modeled, either in an instance-based or connectionist framework.
CHAPTER 1

HOMOPHONE INTRUSIONS IN DUTCH: RULES VS. REGULARITIES

1. A DUTCH PARADOX: HOMOPHONE INTRUSIONS IN SPELLING

1.1. The Dutch spelling system

Regularly inflected verb forms in Dutch are based on a concatenative morphological system, which involves the simple addition of a suffix to a verb stem. In this section, we will limit ourselves to the rules behind the singular present tense and the past participle (implicated in intrusions at the lexical level) and the simple past (implicated in intrusions at the sublexical level).

The singular present tense consists solely of the stem for the 1st person, 2nd person inverted and imperative forms (e.g., *ik bel*; ‘I call’). In contrast, a t-suffix is added to the stem for the 2nd person non-inverted and 3rd person (e.g., *hij belt*; ‘he calls’). This is comparable to the contrast between the English zero suffix for 1st and 2nd person and the s-suffix for the 3rd person singular of the present tense (e.g., call-calls). The past participle requires a ge-prefix and a d-suffix, similar to the ed-suffix in English (e.g., *gebeld*; ‘called’). If the stem already contains a weak (i.e., unstressed) prefix\(^4\), this ge-prefix is omitted (e.g., *gebesteld*; ‘ordered’). Finally, the rule for forming simple past tenses is even less complex: the verb stem is concatenated with a te-suffix after an underlying unvoiced stem-final phoneme (e.g., *suste*; ‘hushed’) or de-suffix when the stem-final phoneme is voiced (e.g., *brulde*; ‘yelled’). Note that if the verb stem

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\(^3\) The d-suffix only applies for verbs whose stem ends in a voiced phoneme. If the verbal stem ends in one of the consonants t, k, f, s, c, h, p, the correct suffix is a -t instead of a -d. If the stem ends in a -d, the d-suffix is omitted.

\(^4\) Weak prefix verbs contain one of the following prefixes: be-, ge-, ver-, her- or ont-.
already ends in -t or -d, the past tense form contains a doublet (e.g., rustte ‘rested’ or dulde ‘tolerated’).

The descriptive elegance of these rules suggests that people might rely on the conscious application of spelling rules that match these descriptions\(^5\). From an analytical perspective, this implies that the spelling of homophonous verb forms in Dutch should be error-free, as is for instance the case for the 3\(^{rd}\) person singular present tense in English. However, even the explicit instruction of these morphology-based spelling rules as early as the fourth year of primary school, does not appear to guarantee their correct use. As a matter of fact, errors continue to be made and persist in texts written by high school and even university students. While these errors show that the spelling of regular homophonous verb forms in Dutch is not strictly rule-based, a systematic study of the error pattern indicates that a number of clearly identifiable factors are at play. Firstly, errors are confined to homophonous verb forms (Section 1.2)\(^6\). Secondly, the error risk increases as working memory has fewer resources available (Section 1.2.1). Thirdly and most importantly, the errors most often involve substituting the low-frequency homophone or homophonous pattern by its high-frequency counterpart (Section 1.2.2). The next section will discuss these sources of homophone intrusions.

1.2. **Sources of homophone intrusions**

1.2.1. **The nature of intrusion errors: homophony**

The *nature* of both lexical and sublexical intrusion errors is determined by the co-existence of two homophones or homophonous patterns (Frisson & Sandra, 2002b). Firstly, *lexical intrusion errors* in the spelling of regular Dutch verb

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\(^5\) Note that these are not the same type of mental rules that are used in the context of spoken language acquisition (see Section 1.2.3.1 for a more elaborate discussion).

\(^6\) Section references always pertain to sections of the chapter they appear in, unless indicated otherwise.
forms are restricted to a specific set of verbs involving homophony within their inflectional paradigm. This is for instance the case for 1st and 3rd person singular present tense forms of some verbs (e.g., meld-meldt; [mElt]). This partly results from the constraints of the Dutch spelling system. Although the large majority of verb forms in Dutch adhere to the phonological principle (i.e., spell what you hear), the latter can sometimes be overridden by the morphological spelling principle. In such a case, a word form’s orthography reflects its morphological structure, but not its pronunciation. Although this might suggest that some verb forms obey the phonological principle, whereas others conform to the morphological principle, this is not the case. Regular verb forms like *bel (‘calls’), reflect both their morphological make-up (stem bel + suffix -t) and pronunciation ([bElt]). However, when application of the morphological principle violates the phonological principle, priority is given to the former.

Such is, for instance, the case in the present tense form meldt (‘reports’; [mElt]). If the phonological principle were the only determiner of its spelling, the form would be written as *melt, i.e., the sound [t] would be spelled as t. However, the correct spelling form ends in the cluster dt, consisting of a stem-final d and a t-suffix. Note that the terminology used to refer to the letters in the dt-cluster implies the application of the morphological principle. Indeed, the d-spelling of the stem-final sound [t] is derived from its spelling in morphologically related words such as infinitival melden, pronounced as [mElEd@n]. The morphological spelling principle requires the stem morpheme to preserve its d-spelling across all forms in which it appears. The same principle holds for spelling suffixes. The t-suffix is spelled as a t because it consistently signals the (non-inverted) 2nd or 3rd person singular present tense. This is obvious in the spelling of forms whose suffix is clearly pronounced (e.g., bel; [bElt]; ‘calls’). Due to devoicing of the stem-final obstruent (d is pronounced as [t]), however, the t-suffix is spelled
but not pronounced in a number of verb forms, such as *meldt*. This is due to the process of degemination (i.e., only one [t] is pronounced). Regular verbs whose stem ends in a *d* (henceforth *stem-final d verbs*; e.g., *melden*) therefore have two homophonous forms in the singular present tense: the stem or zero-suffix d-form (e.g., *meld; [mEl]t*; for imperative, 1st and 2nd person inverted) and the dt-form (e.g., *meldt; [mEl]t*; for 2nd person non-inverted and 3rd person). A second group of verbs, the so-called weak prefix verbs (e.g., *bestellen*, ‘to order’), also yield two homophonous forms. As the result of devoicing the word-final *d*-suffix in the past participle (e.g., *besteld; [b@stEl]t*), this past participle d-form and the t-form in the 2nd/3rd person singular present tense (e.g., *bestelt; [b@stEl]t*) have an identical pronunciation.

For these two types of verbs, the correct spelling of their homophonous forms can only be achieved in two ways: either by means of a morphosyntactic analysis, resulting in the identification of grammatical information required for spelling the suffix (e.g., grammatical properties of the subject) or by means of an analogy with the spelling of a non-homophonous verb form (e.g., *hij meldt* is spelled with a *t* because the pronunciation of *hij belt* as [bEl]t reveals the existence of a t-ending). When spellers are unable to engage in either process, the co-existence of two homophones in a verb’s inflectional paradigm may cause homophone intrusions at the lexical level, i.e., the substitution of one homophonous form by another (e.g., *hij *meld*; ‘he *report*’).

Interestingly, verbs with a homophonous competitor constitute a small minority in Dutch. Except for stem-final *d* and weak prefix verbs, Dutch inflected verbs can be spelled by relying on the way they sound. Homophones of stem-final *d* verbs and weak prefix verbs only account for about 5% each (both in a type and token count) of all Dutch verb forms in the same grammatical functions (based on Baayen, Piepenbrock, & Gulikers, 1995; Sandra & van Abbenyen, 2009). Since only such a small minority requires

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7 There is only one exception to this rule: verbs whose stem ends in *t* do not get a *t*-suffix because *t* doublets cannot appear in word-final position in Dutch (e.g., *hij laat* instead of *hij *laatt*; ‘he leaves’).
morphosyntactic analysis or analogy-based reasoning, Dutch spellers have very limited practice with these processes, which prevents them from becoming automatic. Arguably, the combination of homophony within the verbal inflectional system, necessitating a conscious analysis or analogy, and the very low occurrence of homophonous verb forms creates a considerable error risk.

Secondly, *sublexical intrusions* result from homophony within the past tense paradigm. Again, a very straightforward rule underlies the formation of these forms: add a te-suffix or a de-suffix to the verb stem. Here, too, an analogy to a non-homophonous regular past tense form yields the correct spelling (e.g., *suste*, ‘hushed’ because of *werkte*, ‘worked’). Failure to apply the rule or to rely on the analogy may lead to a homophone intrusion. Importantly, these sublexical intrusions stand in sharp contrast with intrusions at the lexical level. Here, homophony is not situated at the whole-word or morpheme level. Rather, the homophonous patterns are sublexical strings (henceforth sublexical homophones), one of which does not coincide with any linguistic unit. The final sound sequence of regular past tenses, namely [t@] or [d@], is spelled with a doublet (*tte* or *dde*) in case the stem-final letter is a *t* or *d*, but with a singleton (*te* or *de*) after all other consonants. Whereas the singleton spelling of the homophonous substring matches the spelling of the morpheme (note that it also matches the phonological spelling), the doublet spelling is a letter sequence that straddles the morpheme boundary (the first *t/d* being the stem-final letter and the remaining letters being the suffix spelling). As the two spelling patterns sound exactly the same, this may result in the substitution of one homophonous pattern by another (e.g., *sustte* instead of *suste*).

Crucially, the choice between these two sublexical spelling patterns is not determined by the grammatical characteristics of another word in the sentence as is the case for lexical homophones, but depends solely on the stem-final letter and, hence, on a morphological analysis. As lexical homophones require the identification of morphosyntactic relationships and sublexical homophonous patterns only require a morphological analysis, the former process may be more time-consuming. If this were the case, the risk of
working-memory overload (see Section 1.2.2) will be larger in the case of lexical homophones, making them more vulnerable to homophone intrusions than sublexical homophonous patterns. If this line of reasoning were correct, it would predict that homophone intrusions at the sublexical level will be more difficult to demonstrate than at the lexical level.

1.2.2. The error risk: the role of working memory

Whereas the nature of intrusion errors is determined by the presence of homophonous forms or patterns, it is short-term or working memory that affects the number of errors. As already mentioned, (partially) homophonous verb forms (lexical and sublexical homophones) cannot be spelled correctly by relying on the phonological principle. Rather, a conscious and time-consuming morphosyntactic analysis is essential in the case of lexical homophones and a process of morphological analysis is mandatory in the case of sublexical homophones. In the former case, working memory needs to identify the word whose properties determine the suffix spelling as well as retrieve and apply the corresponding spelling rule. This requires a large amount of attentional resources from working memory, in contrast to the spelling of non-homophonous verb forms, which can be spelled by relying on the phonological principle only. The time-consuming nature of such an analysis is strengthened further by the fact that it is only relevant in a minority of cases, preventing the process from become fully automated.

In addition, working memory also needs to allocate its resources to many other operations involved in ordinary writing (meaning, syntax, word selection, etc.). This has led to the hypothesis that any factor, be it language-external or language-internal, that makes it difficult to finish the computational process within the storage space and time window made available by working memory will increase the risk of a homophone intrusion. Whereas the major determinants of these intrusions are the limited storage capacity and temporal capacity of working memory, different factors may be responsible for exhausting these limited resources.
Two language-external factors have indeed been found to determine the number of intrusions. A first factor that triggers intrusion errors is time pressure, typically imposed in speeded spelling-to-dictation tasks. These tasks have been used to experimentally induce homophone intrusions and study their distribution pattern (Sandra, Frisson, & Daems, 2004). The error risk increases as the time available to complete the computational process decreases. Therefore, more errors are found in situations where there is only limited time available. A second factor affecting the error risk is working memory overload, which occurs when this memory system has to divide its resources between multiple operations. Fayol, Largy, and Lemaire (1994) and Largy, Fayol, and Lemaire (1996) demonstrated that when the cognitive system has to handle a secondary task (e.g., serial recall of words or click counting), more proximity concord errors (i.e., verbal agreement with the nearest noun instead of the syntactically related noun that is further removed) and homophone intrusions are made (i.e., spelling of the higher-frequency noun instead of the target verb form). Both types of errors occur as the result of task requirements that exceed the storage capacity of working memory.

When (storage and temporal) resources are limited, any language-internal factor that makes it difficult to access the relevant morphosyntactic information also disturbs the spelling process. Previous research has identified two such factors affecting the spelling of homophonous forms. Firstly, finishing the computational process for suffix selection is more effortful when the relevant grammatical information has been processed some words earlier in the sentence and must be retrieved from working memory. Sandra et al. (1999) found more homophone intrusions when the verb form and its subject were separated by intervening words than when they were adjacent to each other. Intervening words made it more difficult to identify the appropriate grammatical information, as the latter had more time to decay than in the adjacent condition. This increased the risk of not finishing the process in time, causing more homophone intrusions.

A second language-internal factor concerns the presence of intervening and misleading morphosyntactic information, which may give rise to the
misapplication of a spelling rule. This issue has been studied particularly well in French. Largy et al. (1996) asked participants to write down sentences such as Le chimiste prend des liquides. Il les filtre (‘The chemist takes liquids. He filters them.’). Whereas the singular present tense form should be spelled as filtre in accordance with the singular 3rd person subject il (‘he’), the intervening definite article les suggests a plural noun interpretation (i.e., les filtres, ‘the filters’), when the verb form is homophonous with a noun (both [fIltr@]). When spellers cannot inhibit this misleading information, but rely on words that are most accessible in working memory (i.e., the article rather than the subject), homophone intrusions are observed (misspellings as filtres ‘filters’ instead of correct filtre). Similarly, Bosman (2005) found that fewer intrusions were made when homophonous Dutch verb forms were embedded in a facilitating context (i.e., no intervening words) than in a neutral context (i.e., intervening words that are not misleading) and a conflicting context (i.e., intervening words that suggest the alternative homophone spelling).

In short, the computational process underlying the correct spelling of homophonous forms is not automated, but requires a substantial amount of attentional resources, either for a morphosyntactic or for an analogy-based analysis. The heavier the burden on working memory – be it through language-external factors such as time pressure or secondary tasks, or through language-internal factors such as distant or misleading morphosyntactic information – the larger the likelihood that its limited storage and temporal capacity will prevent the computational process from finishing in time. In such cases, the orthographic form will most likely not be the outcome of a morphosyntactically driven computational process. In the next section, we will see that the time-consuming nature of spelling homophonous inflected verb forms favors the retrieval of word-specific information from long-term memory, i.e., whole-word representations in the mental lexicon.
1.2.3. The pattern of errors: the Homophone Dominance effect

1.2.3.1. The lexical level

We established that spelling errors typically occur on homophonous verbs and are more likely when working memory resources are exhausted. However, the question remains whether these errors do not only inform us on the involvement of working memory in spelling, but also shed light on the cognitive processes and representations underlying the spelling of verb homophones. Indeed, the persistence of homophone intrusions suggests that these errors are the natural effect of particular cognitive processes and representations. A study of the pattern behind the errors might elucidate this issue.

One would expect one of the following three patterns. Firstly, errors might result from random guessing. In that case, errors will affect both homophonous forms equally. Secondly, spellers might make use of a default spelling. For instance, they might prefer the least complex form (e.g., the stem form) and, hence, only make errors on the other homophone. Thirdly, the time-costly computational process might give leeway to a frequency-sensitive retrieval mechanism. In this scenario, the pattern of errors is neither random, nor based on a default spelling, but reflects the speller’s preference for the most familiar orthographic pattern of the homophone.

Previous spelling research (Assink, 1985; Frisson & Sandra, 2002b; Sandra et al., 1999; Sandra & van Abbenyen, 2009) has confirmed that the pattern of intrusion errors is neither random, nor shaped by the preference for a default form, but is determined by the frequency relationship between the two homophones. This effect, which we will refer to as the effect of Homophone Dominance, pertains to the observation that intrusions more often involve the substitution of the lower-frequency (LF) homophone by its higher-frequency (HF) counterpart rather than vice versa. This preference for the higher-frequency form implies a per-verb prediction as to which error is
more likely. For instance, the verb *melden* is more frequent in its d-form (i.e., d-dominant) and is expected to yield more intrusion errors when the LF dt-form is targeted (*hij meld* instead of correct *hij meldt*) than when the HF d-form is the correct one (*ik meldt instead of correct *ik meld*).\(^8\) In contrast, for a dt-dominant verb as *rijden* ('to drive') spellers are expected to be more prone to substitutions of the LF d-form by the HF dt-form rather than vice versa (e.g., *ik rijdt*). Note that spellers’ tendency to rely on probabilistic information (i.e., write down the higher-frequency homophone) when the online computational process is too time-consuming often results in a correct spelling, as the higher-frequency form is the one that is most likely to occur. In other words, even though spelling rules are by their very nature deterministic (i.e., apply across all verbs) and are, hence, insensitive to frequency, this frequency-sensitive spelling process will produce the smallest amount of errors. Obviously, this process is not a conscious strategy with the goal of minimizing the number of errors. However, it reflects the fact that at least some regularly inflected forms are stored and that the accessibility of their representations is determined by their frequency (as is the case for all lexical representations).

The Homophone Dominance effect has been demonstrated in a series of spelling experiments under time pressure, using different homophone contrasts. Sandra et al. (1999) established the effect in a group of 18-year-olds for both stem-final d verbs (homophones: 1\(^{st}\) vs. 3\(^{rd}\) person singular present tense) and weak prefix verbs (homophones: 3\(^{rd}\) person singular vs. past participle). Most errors were substitutions of the LF by the HF homophone. The same pattern of results was found with imperatives of stem-final d verbs, which require a d-spelling (e.g., *rijd*, ‘drive’): dt-intrusions occurred more often for verbs whose dt-form was the higher-frequency spelling of the homophone pair (Sandra, 2010).

Furthermore, the Homophone Dominance effect was not only present in spelling experiments with experienced spellers, but also with younger

\(^8\) Raw frequency counts are based on SUBTLEX-NL (Keuleers, Brysbaert, & New, 2010): *meld* (733), *meldt* (394), *rijd* (958), *rijdt* (2134).
children: Frisson and Sandra (2002b) used stem-final d verbs (homophones: 1st vs. 3rd person singular present tense) to demonstrate that the effect is already present in 12- to 14-year-olds who have had less exposure to written language.

The effect also persisted in a priming experiment performed by Frisson and Sandra (2002a). Participants listened to auditory primes that were homophonous verb forms (e.g., [v@rsirt] > versiert/d; ‘decorates/ed’), after which they were prompted to write down non-words that rhymed with the homophone but differed by one phoneme (e.g., [v@rjirt]). The frequency relation between the two homophonous forms of the prime determined the preference for spelling the non-word’s final letter as either d or t. For d-dominant verbs (i.e., more frequent in the d-form), more d-spellings were found in the priming condition relative to the control condition, whereas t-spellings were more frequent for t-dominant verbs. In short, the most frequent spelling of the homophone was activated and determined the preferred inflectional ending of the non-word, even without having been visually presented.

Bosman (2005) demonstrated that the Homophone Dominance effect can be modulated by an additional factor, namely the characteristics of the sentence context in which the verb form is embedded. University students made fewer errors on HF and equal-frequency (EF) weak prefix forms than on LF ones, both in a facilitating context (i.e., no intervening words between verb form and qualifying word) and a neutral context (i.e., intervening words do not suggest the alternative homophone). In a conflicting context (i.e., misleading intervening words), however, the spelling performance for EF forms was equal to that of LF forms (i.e., both significantly worse than for HF forms).

Sandra et al. (1999) argue that the Homophone Dominance effect is phonologically driven in the sense that the phonological representation of a homophone (e.g., [mElt]) activates its corresponding orthographic representations (e.g., meld and meldt), or at least the most frequent one. This claim was supported by the results of a study by Sandra and van Abbenyen (2009), which extended this homophone-driven activation process to all
corresponding orthographic representations, regardless of their lexical category. This conclusion was based on the finding that homophonous nouns and adjectives co-determine a verb’s preferred spelling. Sandra and van Abbenyen (2009) found that 12-year-olds made significantly more errors on the targeted dt-form (e.g., hij *kleed; ‘he *dress’) for verb forms with a homophonous noun/adjective ending in d (e.g., het kleed; ‘the dress’) compared to homophonous verb forms without a non-verbal counterpart and matched on verb form frequency. The fact that these verb forms were embedded in a sentence context that clearly required a verb form makes the observed effect all the more surprising. Homophone intrusions across parts of speech were also found for French verbs with a noun homophone ending in a silent suffix (e.g., verbal filtré – nominal filtres; both ‘filters’) (Largy et al., 1996). The critical sentences had the structure pronoun + pronoun + verb, such as Le chimiste prend des liquides. Il les filtre (‘The chemist takes liquids. He filters them’). The authors observed more noun intrusions (filtres) when the homophonous plural noun had a higher frequency than the correct verb form (filtre). This was especially the case when the noun interpretation was favored by the semantic context. Hare, Ford, and Marslen-Wilson (2001) also observed the activation of homophonous forms outside the verbal paradigm in an English dictation task. They reported that participants preferred regular past tense forms (e.g., allowed) when their frequency was higher compared to their monomorphemic and non-verbal homophone (e.g., aloud).

Importantly, Sandra (2010) was able to reject a radically different account of the Homophone Dominance effect. According to this view, writers’ preferred spelling coincides with the spelling of the verb homophone that they last encountered. This is likely to be the higher-frequency homophone, as the probability of this form is higher on each encounter with the homophonous pronunciation. Hence, this view makes the same prediction as the view that assumes stored lexical representations of the verb forms: a strong tendency to spell the higher-frequency homophone, causing most intrusion errors on the lower-frequency form. This alternative view would have considerably less theoretical importance, as the effect of Homophone Dominance would reflect a
recency effect, originating in episodic memory, rather than an effect mediated by the mental lexicon. However, Sandra (2010) found that participants performed at chance level when having to choose which of two homophonous verb forms they had read in a series of short texts some minutes before. Across texts, there were an equal amount of HF and LF homophones, to ensure that correct performance could not depend on frequency, but had to depend on recency. On the basis of this outcome, he concluded that the effect of Homophone Dominance does not reflect access to episodic memory traces and is, hence, not a recency effect. Importantly, an analysis of participants’ actual choices revealed that they preferred the HF homophone, whether this was the form they had actually read or not. This confirms the view that Homophone Dominance stems from a feeling of familiarity with the higher-frequency form, due to its stronger lexical representation.

Further evidence for frequency-sensitive representations of regularly inflected forms in the mental lexicon comes from studies on written production in French and Russian. As already mentioned, Largy et al. (1996) found that French homophonous singular present tenses were more often misspelled when they had a noun homophone of higher frequency (e.g., filtre vs. filtres). The finding that the whole-word frequency relation between the two homophones determined which intrusion error was more likely, mimics the Homophone Dominance effect in Dutch. There are, however, also two differences between the experiments in Dutch and French. Firstly, the use of the plural personal pronoun les created a local bias towards a noun interpretation, as les is also frequently used as a definite article. The use of an additional trigger for a particular homophone is a factor that was absent in the Dutch experiments. Secondly, errors were obtained in the French experiments by having participants perform a secondary task (e.g., click counting), whereas errors in Dutch were elicited using the speeded dictation task only. Nevertheless, both paradigms (speeded dictation and a secondary task) tax working memory and thus trigger retrieval of the higher-frequency homophone. Whereas the former often results in the abortion of the relatively
slow computational process in working memory, the latter places a heavy burden on working memory’s limited attentional resources.

Similarly, Pacton and Fayol (2003) asked 10-year-old French children to write down sentences containing inflections that end in the ambiguous [A~]-sound, spelled either as -ent (in the case of adverbs) or -ant (in the case of past participles). The children who had to spell the homophonous verb forms in a sentence context (e.g., Elle pleura en comprenant la situation; ‘She cried while understanding the situation’) produced more correct spellings in comparison with the children who had to spell the verb forms in isolation (e.g., comprenant). This indicated that the children took the syntactic context into account and were able to make use of explicitly taught spelling rules (i.e., -ent is attached to adverbs and -ant to present participles). Notwithstanding this reliance on spelling rules, significantly fewer errors were made on HF forms. In line with the results of Homophone Dominance in Dutch, this finding in French suggests that explicit instruction of morpheme-based spelling rules does not guarantee their use on all occasions, as the data revealed both the use of rules and a dependence on the frequency of (homophonous) whole-word forms.

A whole-word frequency effect was also found for the written production of homophonous regular past participles in French (e.g., L’amí a trahi le secret; ‘The friend betrayed the secret’; [trAhI]) (Negro, Bonnotte, & Lété, 2014). The authors studied how children of different ages as well as adults performed on these forms in a spelling-to-dictation task. The errors of younger spellers most often involved homophone intrusions on low-frequency past participles (e.g., L’amí a *trahis le secret; [trAhI]). Negro et al. (2014) argue, however, that reliance on automatic retrieval of the most frequent orthographic form decreases with increasing age or reading level, while application of the morphosyntactic rule becomes more prevalent from 5th grade of primary school onward. Indeed, 6th and 8th graders with a high-literacy level as well as adults no longer exhibited a frequency effect. To minimize the number of spelling errors, these expert writers applied the morphosyntactic rule, requiring them to inhibit the automatic activation of the
most frequent orthographic form. However, the authors concede that the whole-word frequency effect might re-emerge for adults in more complex sentence structures, as has been shown by Fayol, Hupet, and Largy (1999).

In a morphologically complex language such as Russian, Kapatsinski (2010) also observed a whole-word frequency effect for derived adjectives containing the fully regular prefix bez-. Russian spellers are explicitly instructed on the spelling rule involved: the prefix-final consonant z is written as s instead of z before a voiceless consonant. Both in a corpus study based on Google counts and in a dictation task, fewer errors were made (i.e., *bez- instead of bes-) as the word’s whole-word frequency increased. The author concludes that Russian spellers rely (at least sometimes) on the orthographic representation of the full form, which is more quickly activated for HF forms. He also argues that such a retrieval mechanism is especially resorted to when there is (temporary) uncertainty as to which rule should be applied. This proposal is reminiscent of the limitations on working memory proposed by Sandra et al. (1999) and Largy et al. (1996) with regard to distant or misleading morphosyntactic information.

The effects of whole-word frequency found in the spelling of regularly inflected forms in French and Russian support the effect of Homophone Dominance found in Dutch. Taken together, they suggest that (at least HF) regular inflections are stored in the mental lexicon and compete with rule application. Note that the storage of such forms is not obvious, as regular forms can be generated by rules (i.e., storage is redundant).

Even though there are many differences between spelling and speaking (see below), it is striking that several studies on speech production too have suggested the existence of regularly inflected forms in the mental lexicon. Stemberger and MacWhinney (1986) found that adults made fewer no-marking errors when having to produce high-frequency regular past tenses in English (e.g., *need instead of needed) compared to low-frequency ones (e.g., *mend instead of mended). Since whole-word frequency affected the deletion rate, the results favor an interpretation in terms of the independent storage of high-frequency regularly inflected forms. Similarly, Tabak, Schreuder, and
Baayen (2010) found a facilitatory whole-word frequency effect for Dutch past tenses in a picture naming study with university students: shorter naming latencies were found for verb forms with a high frequency. The converging results from spelling and speaking suggest that storage is the rule rather than the exception (i.e., an item is not only stored when it cannot be generated by a rule, as is the case for irregulars). If this is true, storage is the automatic result of a sufficiently high exposure frequency.

It is tempting to use the Homophone Dominance effect in Dutch and the whole-word frequency effects reported in other languages to make statements on the processing of regular forms. More particularly, the finding that even regularly inflected verb forms are stored (at least homophonous ones) might suggest that storage is at the core of language use, which is the tenet of, for instance, exemplar-based models (e.g., Eddington, 2000; Keuleers et al., 2007; Krott, Baayen, & Schreuder, 2001) and connectionist models (e.g., Moscoso del Prado Martín, Ernestus, & Baayen, 2004; Rumelhart & McClelland, 1986). This would make our findings bear on the relative importance of (symbolic) rules and stored representations in language use (e.g., the dual-mechanism account of the English past tense inflection by Pinker, 1999), supporting the strong role of storage. However, such an implication would be unwarranted.

There are two crucial differences between the production of regularly inflected verb forms (e.g., past tenses) in spoken word production and the production of regularly inflected verb forms (e.g., homophonous verb forms) in spelling. Firstly, it is a priori obvious that the production of the written forms necessarily implies the existence of spelling rules, deliberately designed for the purpose of mapping the spoken language onto the written one. These rules are explicitly taught in schools and their application is trained in large numbers of exercises. The use of these conventional rules is also required if we want to be able to spell the lower-frequency homophone: if we always spelled verb homophones by writing down the orthographic form that most quickly comes to mind (i.e., the higher-frequency form), we would never be able to spell the lower-frequency form correctly. In contrast, it is not a priori clear that
regularly inflected forms in speech production require a symbolic rule in the
cognitive system underpinning language use. Obviously, (morphological) rules
for the spoken language have never been explicitly designed, but result from
systematicities at, among others, the morphological level. In the process of
language acquisition, we have interiorized these systematicities and
represented them in our cognitive system at a very early age by a process of
implicit learning, not by means of any form of explicit instruction. The
existence of such systematicities is at the basis of the question whether our
cognitive system derives a rule from the language input or not. This is by no
means necessary. In principle, they can be produced either by applying a rule
or by relying on a memory system that stores all words and word forms that
we encounter and on an analogy-based process that compares the form that
must be inflected to all similar forms in memory (see the exemplar-based
account in for instance Eddington, 2000; Keuleers et al., 2007).

Secondly, it is highly likely that the rules for spelling Dutch
homophonous verb forms are consciously applied, as a result of the low
occurrence frequency of these forms and the consequent lack of familiarity
with the computational process, which prevents them from becoming
automatic. The use of attentional resources (i.e, conscious rule application) is
demonstrated by the finding that the number of homophone intrusions
increases when it becomes more difficult to use working memory resources
(see Section 1.2.2). In contrast, the morphological ‘rules’ in spoken language
have been over-trained, resulting in a high degree of automaticity. As a result,
they do not require working memory resources.

Due to these fundamental differences between spelling rules for regular
inflections and the ‘rules’ for these forms in speech production, the findings of
spelling experiments cannot inform us on the existence of symbolic mental
rules in language production, which is the issue addressed in Pinker’s (1999)
dual mechanism account and publications criticizing this approach.
Notwithstanding the fact that these results do not bear on the issue of
symbolic rules in language use, the theoretical implications with respect to the
balance between the storage and processing of (homophonous) regularly
inflected verb forms in Dutch spelling are warranted. A conscious computational route (consuming attentional resources in working memory) runs alongside an automatic and fast whole-word retrieval route that is frequency-driven (see Kahneman, 2011 for a similar distinction between automatic and conscious processes outside the language domain). The latter route is logically superfluous, since regularly inflected verb forms can easily be computed online by making use of a set of simple rules (e.g., add a -t to the stem). Nonetheless, the orthographic representations of these forms (or at least of the most frequent one) are automatically stored. This is evident from the finding that the LF homophone is more often substituted by the HF one than vice versa (Bosman, 2005; Frisson & Sandra, 2002b; Sandra et al., 1999, 2004). There can be no frequency effect without storage. In all models of the mental lexicon, frequency is intimately related to storage. Higher-frequency representations that are stored in the mental lexicon are more easily accessible. Note that storage may be restricted to verb forms that reach a sufficiently high frequency. For that reason, we do not wish to deny the involvement of consciously applied rules in the spelling of regular forms. However, in the particular case of homophonous verb inflections in Dutch, the whole-word retrieval route is sometimes quicker than the time-costly rule-based mechanism.

While we argue that the Homophone Dominance effect implies the existence of full-form representations for regular forms (a storage account), the findings cannot entirely reject a rule-based account in which rules are enriched with a frequency-sensitive mechanism. This mechanism would keep track of the number of times a particular rule (i.e., suffix) has been used for a particular verb. According to such a words-and-rules account (Largy et al., 1996), only the verb stem (and not the full form) has an independent orthographic representation in the mental lexicon. Suffixes linked to a large number of verb stems are stored in a separate subcomponent of the mental lexicon. According to this view, whole-word frequency effects reflect the connection strength between stems and their permissible suffixes, i.e., the
number of times they have been combined. To disentangle these two accounts, we will compare error patterns at the lexical and sublexical levels.

1.2.3.2. The sublexical level

Errors at the sublexical level cast doubt on the validity of a words-and-rules account. Sublexical intrusion errors pertain to words whose final grapheme cluster is homophonous rather than their entire letter string. For instance, while the word-final phoneme cluster /st@/ sounds exactly the same in regular past tenses as *suste (‘hushed’) and *rustte (‘rested’), it has two different orthographic realizations, namely *ste and *stte. This sometimes causes sublexical intrusions (e.g., *sustte for suste or *ruste for rustte). These errors are of theoretical interest as they are morphologically impossible. Depending on how one wants to describe them, they involve the combination of a non-existent verb stem and the past tense te-suffix (e.g., *sust+te or *rus+te) or the combination of an existing verb stem and a non-existent orthographic form of the past tense suffix (e.g., *sus+tte or *rust+e). Consequently, the error itself is also a non-existent orthographic form, which cannot be stored in the mental lexicon, or at the very least has a very weak representation due to exposure to such errors. Neither the notion of connection strengths between stems and suffixes nor the concept of erroneous rule application can be invoked to generate such errors, as any attempt to describe the error in terms of morphological units ends up with non-existent morphemes. In other words, the existence of these errors seems to rule out the hybrid architecture that a words-and-rules model proposes to account for frequency-sensitive homophone intrusions at the lexical level: a rule involving morphological units and a frequency-sensitive mechanism. Thus considered, sublexical homophone intrusions might provide the litmus test for rejecting the morpheme-based account. Indeed, a morpheme-based account can never explain intrusions that involve homophonous letter strings that straddle the morpheme boundary.

However, it can also be argued that a conceptual framework in which
only full-form representations are postulated cannot accommodate these errors either. A form that does not exist obviously has no (or a very weak) orthographic representation and is unlikely to cause intrusion errors. A more fruitful perspective on these intrusions is to focus on the linguistic level at which the homophonous relationship can be correctly described. This is neither the whole-word level nor the morpheme level (both of which would require reference to a non-existent representation), but the orthographic level. In the examples above, the homophonous relationship involves two existing orthographic strings in Dutch: ste and stte. Such sub-word and sub-morphemic (hence: sublexical) errors can be accounted for by two different, yet conceptually related views. A first possibility is that these intrusions arise through analogy with full-form representations of phonologically similar regular past tense forms (e.g., suste being misspelled as *sustte due to its phonological similarity to the orthographic patterns of words with a homophonous ending as in rustte ‘rested’, testte ‘tested’, …).

A second possibility posits the independent representation of non-linguistic (i.e., orthographic) units (e.g., stte). In this case, the preference for an orthographic pattern depends on the associative strength between a single phonological pattern and multiple corresponding orthographic patterns. Such a system, capturing the co-occurrence frequencies between phonological and orthographic representations, is reminiscent of connectionist models (with the proviso that the representations should not be considered as localist units but rather as distributed patterns). In connectionist models, print exposure leads to sensitivity for the frequency with which letter strings are mapped onto phoneme strings, so that a high-frequency phonology-to-orthography mapping can override a correct, but lower-frequency mapping. A connectionist system, which is based on the implicit learning of statistical regularities in the input, is able to capture the frequencies of these mappings and can thus explain competition between orthographic representations corresponding to either full-forms (for lexical intrusions) or non-linguistic units (for sublexical intrusions).

Previous spelling studies have already examined intrusion errors at the
As with lexical intrusions, the pattern of sublexical intrusion errors was modulated by Homophone Dominance, i.e., the high recurrence of (homophonous) sublexical patterns caused intrusions. Sandra and van Abbenyen (2009) demonstrated that the pattern of errors on the past tense inflection in Dutch was determined by the presence or absence of homophony at the sublexical level. Although the rules for the Dutch past tense inflection are very simple (stem + suffix -te or -de depending on the voice characteristics of stem-final phoneme; see Section 1.1) and apply across the board, 12-year-olds made significantly more errors on verb forms whose stem ended in a short vowel-consonant structure (e.g., *melde for meldde, ‘reported’), compared to verbs with a digraph-consonant (e.g., *leide for leidde, ‘led’) or a reduplicated vowel-consonant structure (e.g., *brade for braadde, ‘fried’). Sublexical homophony is virtually non-existent for the latter two categories. In contrast, the former category receives competition from past tenses spelled with a single d (e.g., belde, ‘called’), which is the more frequent orthographic pattern among past tenses ending in this sound cluster. Competition among spelling patterns for word-final clusters consequently results in sublexical intrusion errors. This study provided a first indication that homophonous clusters at the sublexical level (i.e., crossing the morpheme boundary) can lead to intrusion errors that are non-existent word forms.

Further evidence from a Google corpus study supports this conclusion (Sandra, 2010). It revealed that the pattern of errors on Dutch regular past tenses ending with the te-suffix ([t@]) is governed by the dominant orthographic pattern (te or tte) within the set of verbs with homophonous word endings. While the orthographic pattern tte is more frequent than the homophonous te-pattern after the ch-cluster (pronounced as [x]), this frequency relation is reversed for the s-cluster (i.e., te is the more frequent orthographic pattern after an s). Hence, if the occurrence frequency of orthographic patterns affects writers’ spelling preference, one would expect that the orthographic sequence tte (i.e., the past tense ending of verbs with a stem-final t) is more often misspelled as te in the set of verbs whose stem ends in st (e.g., *ruste for rustte, ‘rested’) than in the set of verbs whose stem ends
in *cht (e.g., *wachte for wachtte, ‘waited’). The Google counts indeed showed that the proportion of errors for verbs with a stem ending in -cht (the correct pattern chtte being the most frequent spelling of the homophonous cluster [xt@]) was significantly lower compared to verbs with a stem ending in -st (the incorrect spelling ste being the most frequent realization of the homophonous cluster [st@]). Since a rule account cannot explain these findings (*ruste = non-existent verb stem *rus + te-suffix or verbal stem rust + *e, a non-existent past tense suffix), the author hypothesized that the errors are due to competition between orthographic realizations of a homophonous cluster. Although other factors might affect the spelling output, this competition is generally won by the higher-frequency homophone. This probabilistic spelling behavior mimics the effect of Homophone Dominance at the lexical level: spellers prefer the orthographic pattern that occurs most frequently.

Across different grammatical domains and languages, evidence has accumulated that spellers do not make use of explicitly taught and descriptively simple morpheme-based spelling rules, even though this would lead to a 100% success rate. Rather than always relying on such deterministic rules, spellers exhibit probabilistic behavior by often preferring the most frequent spelling pattern. To accomplish this, they make use of (a) analogy with phonologically or morphologically related words or (b) their knowledge of statistical regularities (i.e., phoneme-to-grapheme mappings) on the basis of visual print exposure, namely through implicit learning of letter co-occurrences.

The idea that regular inflections are spelled on the basis of analogy with phonologically similar items has received support from a study in Dutch with regular past tenses (Ernestus & Baayen, 2004). The authors showed that the choice between the suffixes -te or -de was determined by a verb’s similarity to its phonological neighbors. The correct past tense form krabde (‘scratched’), for instance, was often substituted by *krabte. As the letter b is pronounced as [p] in the stem krab (due to word-final devoicing), this makes the incorrect spelling phonologically identical ([pt@]) to other past tenses whose word-final cluster is spelled as pte (e.g., stapte ‘walked’, repte ‘rushed’, glipte ‘slipped’,

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...). Notwithstanding the clear rule (i.e., a voiceless stem-final phoneme is followed by the suffix -te and a voiced one by the suffix -de), more non-standard forms were found if the phonological neighborhood provided strong support for the incorrect spelling.

The hypothesis that regular inflection is achieved through analogy with existing word forms was confirmed by a study of another fully regular inflectional type in Dutch (Ernestus & Sandra, in preparation). In a spelling task, participants were required to write down regular past participles that were used as inflected adjectives (English example: the hunted animals). As the final letter of regular past participles is either d or t (depending on the voicing characteristics of the stem-final letter) and an adjective is inflected by adding the suffix –e (spelled as e), the spelling rule is straightforward: add e to the spelling of the past participle. Hence, one would not expect a spelling problem for forms like gewiede in de gewiede tuin (‘the weeded garden’) or omgeprate in de omgeprate ouders (‘the persuaded parents’). However, participants often spelled a double t or d, due to an analogy with the spelling of these verbs’ regular past tenses. The latter end either in tte or dde, due to the concatenation of the stem-final letter t or d and the past tense suffix -te or -de (e.g., wiedde and praatte). As a result, errors like *gewiedde for gewiede and *omgepraatte for omgeprate were made, which reflect participants’ preference for the higher-frequency spelling of the homophonous part of these forms. Note that the intrusions are orthographically impossible forms in Dutch, as the past tense suffixes -te and -de are never attached to a past participle. As was the case for the sublexical intrusions in Dutch past tenses discussed earlier (e.g., *ruste, ‘rested’), spelling performance was determined by the frequency of homophonous orthographic clusters in phonologically similar words.

Findings like the ones discussed above can be explained in terms of an instance-based processing model, but also fit well into a statistical learning account, according to which regularities in letter co-occurrences are implicitly learned. A large body of evidence, especially from experiments with children, supports the idea that orthographic regularities are used during spelling.
Treiman and Cassar (1997) found that implicit knowledge of orthographic regularities is already present in young children (2nd and 3rd graders): they ‘know’ which consonants can appear as doublets (e.g., vessel, ball but not *never, *tramm) and are aware that doublets can never appear word-initially (e.g., *ssing) (see also Pacton, Perruchet, Fayol, & Cleeremans, 2001). Similar results were found in judgment and production tasks with French children (Pacton, Fayol, & Perruchet, 1999). The results showed that with older children the preference for the orthographic realization of [o] as au or o in pseudo-words depended on the consonant preceding/following the [o]-sound (e.g., faute ‘mistake’, dorénavant ‘henceforth’). This finding clearly confirms children’s sensitivity to untaught orthographic regularities of the French language. While these experiments show that implicitly learned regularities can be used to a speller’s advantage in some situations, the question remains whether spellers also rely on this type of information (at least sometimes) when they can make use of explicitly taught morpheme-based spelling rules.

Kemp and Bryant (2003) showed that both 5- to 9-year-olds and adults do not always make use of a very simple spelling rule for a regular form like the English plural (add s to the stem in the majority of cases), but sometimes rely on untaught and complex information about orthographic patterns. When the plural ending was pronounced as [z], it was spelled correctly more often as s after a consonant (e.g., buns) than after a long vowel (e.g., bees). Apparently, the spelling of the sound [z] as ze after a long vowel in non-plurals (e.g., breeze) acted as a homophonous competitor that could cause intrusion errors. If spellers relied exclusively on a spelling rule, their spelling of the [z]-sound in the two types of plurals should not have differed. The fact that it did indicates that they sometimes relied on their knowledge of frequent letter co-occurrences, i.e., the co-occurrence of the spelling pattern ze with a preceding long vowel but not with a preceding consonant.

Similar results were obtained by Pacton, Fayol, and Perruchet (2005) in a study on the spelling of French pseudo-words. They found that the French sound sequence [Et], which is always spelled as ette at the end of a diminutive, was spelled correctly more often when a sentence context indicated that the
morphological structure of a diminutive noun was required (e.g., a little [vitAf] is a [vitAfEt]). More importantly, even though the spelling rule for diminutives is insensitive to the orthographic context (“if diminutive, spell the suffix as -ette”), 8-to-11 year olds and adults could not ignore that the orthographic sequence vette is much more frequent in French than fette. Consequently, they produced more spelling errors when pseudo-words ended in f (e.g., vitafette) than when they ended in v (e.g., vitavette), revealing a strong sensitivity to the recurrence of orthographic strings, despite a strictly rule-based spelling environment.

The studies discussed above support the effect of Homophone Dominance at the sublexical level and suggest which factors are responsible for its occurrence. Although spellers can rely on explicitly taught rules, they do not do so systematically but are misguided (a) by the activation of phonologically similar words or (b) their implicit knowledge of frequent letter co-occurrences.

2. FROM SPELLING TO PERCEPTION

Spelling experiments under time pressure have made it possible to explain why so many errors are made on regularly inflected verb forms in Dutch, when these forms are themselves homophonous or contain a homophonous letter pattern, despite the simplicity of the rules that govern their spelling. Firstly, the presence of homophony within the inflectional system of some verbs or the presence of sublexical homophonous patterns across verbal paradigms creates a trap that may lead to intrusion errors. Secondly, the limited capacity of working memory makes it more likely for spellers to fall into this trap. As it becomes more difficult for the speller to identify the morphosyntactic information that is required to spell the suffix (e.g., identification of a distant subject in a spelling task under time pressure), the number of (lexical) intrusion errors increases. Finally, the relative frequencies of the homophonous spellings determine the pattern of intrusions: the higher-
frequency form causes more intrusions when the lower-frequency one must be spelled than vice versa.

Obviously, texts are not only written but also read. Therefore, the question arises what the effect of homophone-mediated intrusions on regular verb forms will be when reading these forms. No study has ever examined whether the effect of Homophone Dominance at the lexical and sublexical level also transfers to perception. If this effect also occurs in perception, most failures to notice an intrusion error will occur on homophones (whole-word forms or sublexical patterns) that correspond to the higher-frequency spelling of the homophone. Fast processing of the higher-frequency form will cause a feeling of familiarity, which will make readers accept the spelling pattern more readily and, hence, make them overlook the spelling error. If that hypothesis were true, homophones in regular verb forms would create a double trap. During writing, spellers whose working memory runs out of resources would be tricked into writing down the most frequent homophone, leading to the predominant type of intrusion error. During perception, readers would more often overlook this ‘preferred’ error type, such that the homophone intrusions that occur most frequently are also missed most often.

Both lexical and sublexical intrusion errors in the spelling of regular verb forms are morphologically incorrect forms, either because they mismatch the verb’s morphosyntactic properties (lexical level) or because they cannot be analyzed into an existing verb stem and an existing suffix (sublexical level). Therefore, it is important to know whether readers make a morphological analysis of a word form or whether they recognize the form as a whole (or attempt both simultaneously). Hence, it is essential to review the existing literature that addresses the issue of morphological decomposition in visual word recognition. Although the Homophone Dominance effect only pertains to inflections, we will not limit our discussion on morphological decomposition to these forms, but also include evidence for derivations. In contrast to derivational affixes, which affect the meaning and (often) the grammatical class of the novel word’s stem, inflectional affixes merely serve a grammatical
purpose (e.g., signal a verb’s tense). In this respect, regular inflections are semantically transparent and fully predictable, making them prime candidates for decomposition. Therefore, decomposition effects found for derivations are assumed to be directly transferable to inflections.

2.1. Evidence in favor of decomposition

A large body of evidence on visual word recognition suggests that morphologically complex words are automatically decomposed into their constituent morphemes. In a seminal study by Taft and Forster (1975), bound stems such as *juvenate* (from *rejuvenate*) were dismissed more slowly as non-words compared to matched pseudo-stems such as *pertoire* (from *repertoire*). They argue that a response delay was observed for bound stems because of a response conflict: a match for the existing stem was found in the mental lexicon, suggesting a yes-response, while a no-response was required. In contrast, no such response conflict was present for pseudo-stems, because they do not have a representation in the mental lexicon. This was seen as evidence for the idea that prefixes of derived words (e.g., *re-*) are automatically stripped off their stem. In the search model by Forster (1976), a stem-based search mechanism consequently provides access to the central lexicon, where a lexical representation matching the full form is stored. In other words, decomposition is a prerequisite for achieving access to full-form representations. Following this study, two major methods have been applied to answer the question of how morphologically complex words are processed.

A first line of research varies a word’s stem frequency\(^9\) (i.e., the summed token frequencies of all words in which the target’s stem appears as a

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\(^9\) Stem frequency has been operationalized in a number of ways (e.g., (cumulative) root frequency, base frequency, stem frequency, lemma frequency, ...). While they refer to different frequency counts, they are intrinsically linked to the same concept: these frequency measures are not based on whole words but on a unit that can only be defined in morphological terms. To avoid confusion, we will use one umbrella term, namely stem frequency, to cover all morpheme-based frequency counts.
constituent) or its whole-word frequency (i.e., its surface frequency), while keeping the other frequency measure constant. The effect of stem frequency is thought to be indicative of morphological decomposition and the subsequent activation of a complex word’s stem. In contrast, whole-word frequency effects bear witness to the existence of full-form representations for morphologically complex words. Both frequency effects are believed to result from easy accessibility due to a high resting-level activation in a lexical representation and do not mutually exclude each other. They may be accessed sequentially, as in Taft and Forster’s (1975) account discussed above, or in parallel, as in morphological race models (e.g., Schreuder & Baayen, 1995).

Taft (1979) manipulated the stem frequency of regularly inflected English nouns and verbs, while keeping all other factors constant. Words with high-frequency stems were responded to more quickly in a lexical decision task compared to words with low-frequency stems. This finding supports the concept of obligatory prelexical morphological decomposition: after prelexical morphological parsing, access to the lexicon is stem-based. As already mentioned, Taft’s (1979) account allows whole-word representations to affect processing but only in later processing stages, i.e., after lexical access. The stem frequency effect was replicated across a variety of languages: for regularly inflected verbs in Italian (Burani, Salmaso, & Caramazza, 1984), as well as for suffixed, but not prefixed, derivations in French (Colé, Beauvillain, & Segui, 1989). Beauvillain (1996) confirmed that the effect is more pronounced in suffixed words than in prefixed words, suggesting that the sequential order of stem and affixes is crucial for morphological decomposition.

A second line of research makes use of the masked priming paradigm, in which a prime word is presented so briefly that it cannot be consciously perceived and is immediately followed by a visual target. If a masked derived word prime facilitates responses to a following visible stem target, this should be evidence for automatic morphological decomposition of the derivational prime. Rastle, Davis, Marslen-Wilson, and Tyler (2000) showed that the visual recognition of a stem was facilitated by the prior brief (i.e., 43 ms) presentation of a derivationally related word (e.g., departure > depart),
independently of semantic and/or orthographic similarity (see also Rastle, Davis, & New, 2004). Such morphological priming effects were also found in Spanish. Sánchez-Casas, Igoa, and García-Albea (2003) demonstrated that both inflectionally (e.g., niño; ‘boy’) and derivationally (e.g., rama; ‘branch’) related words had a facilitatory priming effect on stem targets (e.g., niña; ‘girl’ or ramo, ‘bunch’) compared to purely orthographically or semantically related controls. Longtin, Segui, and Hallé (2003) found comparable effects in French: stems were recognized faster after derived word primes (gaufrette-GAUFRE; ‘wafer’-‘waffle’) relative to orthographic controls (abri-ABRICOT; ‘shelter’-‘apricot’). The authors argued that morphological decomposition is prelexical and blind, since it was irrelevant for the magnitude of the priming effect whether derived primes were semantically transparent (gaufrette-GAUFRE) or opaque (fauvette-FAUVE; ‘warbler’-‘wildcat’) and whether the prime was the combination of a real stem and real suffix or of a pseudo-stem and pseudo-suffix (baguette-BAGUE; ‘little stick’-‘ring’). What mattered was not the morphological function of the prime word in the target word but the fact that the prime could be decomposed into the orthographic sequence of the target word and an existing suffix (potential morphemes, i.e., the word’s surface morphological structure). Effects of such purely form-based decomposition were also found in Hebrew (Boudelaa & Marslen-Wilson, 2005) and Dutch (Diependaele, Sandra, & Grainger, 2005). Facilitatory morphological priming was even found for English stems primed by high-frequency derivations, which are prime candidates for whole-word retrieval and, hence, are not expected to be subject to morphological decomposition (McCormick, Brysbaert, & Rastle, 2009).

The consistency of morphological priming effects across languages and their disregard for the semantic and/or morphological status of a derivation, have been taken as evidence in favor of blind (i.e., automatic) morphological decomposition (Longtin et al., 2003). Any word-final orthographic pattern that corresponds to a possible suffix is automatically removed, thus providing access to the representation of the stem. It is “blind” in the sense that it is purely form-driven and unaffected by high-level processes such as morphology.
and semantics. Therefore, morphological decomposition is thought to be involved in early processing stages.

The interpretation of morphological priming as an indicator of automatic prelexical decomposition was questioned by Giraudo and Grainger (2000). In a series of lexical decision tasks, response times for stems were affected by the whole-word frequency of their masked derivational primes. While high-frequency derivations (e.g., amitié, ‘friendship’) primed responses to their stem target (e.g., ami, ‘friend’) in comparison with orthographic (e.g., amiral, ‘admiral’) and unrelated controls (e.g., juillet, ‘July’), this effect was absent for low-frequency derivations (e.g., amiable, ‘amiable’). If the decomposition process were purely form-driven, the availability of the stem should not depend on the derivation’s whole-word frequency, but on its stem frequency. In contrast, morphological priming effects were equally large for primes with a low and high stem frequency (but matched surface frequency). These findings undermine the idea of a purely prelexical decomposition process predicting larger morphological priming effects for high-frequency stems than for low-frequency ones. Because the priming effect was sensitive to the prime’s whole-word frequency and not to its stem frequency, the authors argued that the representation of the derived word activates the representation of the stem and not the other way around. They suggest that morphologically related words (in this case derivations) are connected to each other in a supralexical network. A bottom-up process activates whole-word representations resulting in whole-word frequency effects. These whole-word representations in turn activate morphemic representations situated at the post-lexical level, i.e., above the level of whole-word representations (Giraudo & Grainger, 2000). Priming between morphologically related words results from activation of shared morphemic representations that send positive top-down feedback to compatible whole-word representations. In sum, the model proposed by Giraudo and Grainger (2000) states that morphological processes can only affect word processing at later processing stages, i.e., after lexical access.
One may wonder to what extent these findings are relevant when studying the effect of Homophone Dominance in perception. In the sublexical domain, when a reader is confronted with a regular form that is misspelled due to a homophone intrusion, the results on morphological decomposition have an explanatory value. For instance, a blind prelexical process that removes the past tense suffix -te or -de would yield a word-initial letter string that either does not exist as a word or exists but does not coincide with the stem of the verb. For instance, incorrect *rus-te (instead of rustte, ‘rested’) would be segmented as the non-existent verb stem rus + te, whereas rust is the stem. Similarly, incorrect *sus-te would be segmented as sust + te, with sust (‘hushes’) being another inflected form of the verb, but not the stem sus (‘hush’). When the output of morphological decomposition fails to reveal the orthographic pattern of the verb’s stem, readers may immediately recognize a spelling error in the sublexical domain. In addition to morphological processes, a process of phonological recoding can also play a role (see below).

The situation is rather different for homophone intrusions at the lexical level. When a verb form like word (‘become’), is misspelled as wordt (‘becomes’), a process of blind morphological decomposition will yield a possible morphological structure (word + t). That is why it is a lexical intrusion: the intruder is a form within the verb’s inflectional paradigm. Hence, the decomposition process itself cannot reveal the spelling error. In order to detect the error, a second processing step is required: syntactic analysis. Homophone intrusions at the lexical level are incorrect because their suffix is syntactically inappropriate. When the verb form word is misspelled as wordt the t-suffix suggests the presence of for example a 3rd person singular subject, whereas the subject might be the 1st person singular. In order to identify such an error, the process of morphological decomposition must be complemented by a checking mechanism. The latter needs to identify the relevant grammatical information and determine whether its properties match those encoded by the inflectional suffix. As this checking process is only relevant for a small number of Dutch verb forms (i.e., only for verb forms that are homophones, but not for verb forms that are phonologically transparent),
it cannot become fully automated. As a result, it will absorb attentional resources and, because it is a conscious process, be time-consuming. In the face of a non-automated and time-consuming checking mechanism, it is highly likely that a quick whole-word retrieval process is also operative when reading homophonous verb forms. If the retrieval process terminates before this checking mechanism, which is likely when a homophone intrusion corresponds to the higher-frequency spelling, such fast access may cause a feeling of familiarity and a consequent tendency to overlook the error. Alternatively, fast lexical access will cause fast access to the verb meaning, which will make readers move on to the next word before they can check the verb form's syntactic properties and cause them to overlook the error. Because of the time-consuming nature of the composition process in spelling and the checking mechanism in reading, it would seem that a quick whole-word retrieval mechanism should be able to manifest itself in both modalities.

This extra processing component, a checking mechanism, for cases where the suffix is determined by another word in the sentence has not received much attention in the literature. Two such studies, however, have been reported in French. The results obtained by Largy and Dédéyan (2002) and Largy, Cousin, and Dédéyan (2005) showed that young children make use of a time-consuming procedure based on revision rules to check (erroneous) subject-verb agreement when the verb form contains silent suffixes (e.g., *La copine des vendeuses *rêvent; ‘The friend of the merchants *dream’). When asked to indicate whether sentences contained a spelling error, errors were noticed less often when a response was required as soon as possible as opposed to when no time restriction was present. Moreover, the decline in performance due to this time restriction was more pronounced for the younger participants. Older participants, however, are said to have also developed a quick and automated mechanism that relies on the direct retrieval of probabilistic co-occurrences of inflectional morphemes or orthographic patterns (e.g., the -s and -nt morphemes often go together as in *les vendeuses rêvent). This latter strategy is particularly resorted to when faced with cognitively demanding situations (e.g., when spelling silent suffixes).
study by Luke and Christianson (2011) yielded an effect of stem frequency for regular past tenses in English, when these verb forms were presented in isolation in a lexical decision. In contrast, the effect interacted with whole-word frequency when the same items were embedded in a sentence context (see Section 0 for a more elaborate discussion). The emergence of a whole-word frequency effect is said to be due to the fact that a sentence context requires people to check whether the inflection is a legal combination of stem and affix, while such a check is not necessary in isolated word recognition. In the lexical decision task, non-words were never illegal combinations of stem and affix. If a decomposition route identified two existing morphemes, it always represented an existing word (i.e., a yes-response). Word recognition in the lexical decision task, therefore, did not require checking whether stem and affix were a correct combination, resulting in stem frequency effects only. A syntactic context, however, necessitates the deployment of a checking procedure to ensure that the combination of morphemes (i.e., the full form) is appropriate (e.g., land is a morpheme in landing but not in bland). Consequently, both whole-word and morphemic representations become active, especially whole-word representations of inflected forms with a high frequency. While the checking procedure proposed by Luke and Christianson (2011) is of a morphological nature, it is still of special relevance to the research reported in this work, as homophonic regular present tenses or past participles used in experiments on lexical intrusions in a sentence context also require a morpheme-based checking mechanism. Crucially, this checking process is of a morphosyntactic nature (i.e., the correctness of the stem-affix combination also depends on the properties of another word in the sentence). The necessity to use a checking mechanism for these inflected forms may allow their whole-word representations (especially for high-frequency forms) to become active. When working-memory resources do not suffice to finish this checking process in time, these whole-word representations may be the only guide in processing (see also, Fayol et al., 1994; Largy et al., 1996).

The effect of whole-word frequency in the visual recognition of homophonous (regular) verb forms has never been studied in the context of a
conscious morphosyntactic checking mechanism. Nonetheless, considering the importance of whole-word representations in our account of homophone intrusions when spelling and reading these forms, we will review a number of visual word recognition experiments that have found evidence for the existence of full-form representations for regularly inflected forms.

### 2.2. Evidence in favor of whole-word storage

The study by Taft (1979) discussed earlier in the section on the stem frequency effect has also sought to demonstrate that processing regular noun and verb forms in English is likewise affected by their whole-word frequency. When keeping the stem frequency constant, reaction times were significantly shorter when the whole-word frequency was high than when it was low (see also Colé et al., 1989; Katz, Rexer, & Lukatela, 1990). Taft (1979) interprets the effect of whole-word frequency as follows: the speed with which the word is accessed in the central lexicon depends on the frequency with which stem and suffix have been associated. Reference to a stem-suffix association is necessary because whole-word frequency effects can only arise when the word’s stem has been accessed before, following prelexical morphological decomposition. Sereno and Jongman (1997) corroborated Taft’s conclusion and also reported an effect of whole-word frequency for English inflected nouns. Burani et al. (1984) found the same pattern of results for regularly inflected verbs in Italian.

As already mentioned, stem frequency and whole-word frequency effects do not mutually exclude each other. As we have seen, Taft (1979) found an effect of both stem and whole-word frequency for regular verb and noun forms in English. Colé, Segui, and Taft (1997) argue for the interplay between stem frequency and whole-word frequency. Free stems in French (e.g., *plume* ‘feather’ > *plumage* ‘plumage’, *plumer* ‘to pluck’, *plumier* ‘pencil case’) did not exhibit a cumulative frequency effect (i.e., the summed token frequencies of the stem and all words sharing that stem). However, when the whole-word frequency of a free stem was low, an effect of morphemic frequency surfaced (i.e., the summed token frequencies of the stem in derived forms only,
excluding the frequency of the stem itself. In contrast, whole-word frequency was a significant predictor when it was higher than morphemic frequency, suggesting that both whole words and morphemic representations can act as units for lexical access. This agrees with research by Alegre and Gordon (1999), who found that regularly inflected forms are only accessed as full forms when their whole-word frequency exceeds a certain threshold, namely six occurrences per million. For inflected forms whose frequency is below this threshold, the decomposition route is preferred, whereas the whole-word retrieval route is faster for those whose frequency is above this threshold. However, conflicting evidence has been found with regard to such a frequency threshold: whole-word frequency effects have also been reported in the frequency range below the threshold set by Alegre and Gordon (1999), both for Dutch (Baayen, Dijkstra, & Schreuder, 1997; Baayen, Schreuder, De Jong, & Krott, 2002) and for English (Baayen, Wurm, & Aycock, 2007).

The interplay between a whole-word retrieval process and a decomposition mechanism has also been studied for regular inflections in Dutch. Bertram, Schreuder, and Baayen (2000) showed that stem frequency was a significant predictor for verb forms with the past tense te-suffix (e.g., suste, ‘hushed’), while surface frequency was not\(^\text{10}\). However, the reverse pattern was found for the less frequent and unproductive derivational suffix -te, which converts an adjective into a noun (e.g., diepte, ‘depth’). These results can be explained in terms of a dual-route model (see below) in which both a decomposition and whole-word route are simultaneously involved in processing of morphologically complex words. Because the te-suffix is more frequently used as part of an inflected verb form, semantic integration following morphological decomposition is more easily achieved for the most frequent (i.e., verbal) interpretation of the suffix, giving rise to stem frequency effects for verbs with the te-suffix. For nouns with the te-suffix, however, the

\(^{10}\)Note that an effect of stem frequency does not exclude the existence of sublexical effects, as both effects can be modeled by the same type of architecture (i.e., either connectionist or analogical processing models).
decomposition process is very time-costly compared to the whole-word retrieval route, leading to whole-word frequency effects.

The same ambiguity between verbs and nouns is associated with the fully regular suffix -en in Dutch: it can point to the plural of nouns (e.g., *flessen*, ‘bottles’) or the infinitival form of verbs, which is moreover homographic with the plural present tense (e.g., *melden*, ‘report’). The relative importance of both routes for this ambiguous suffix was studied in a series of three visual lexical decision tasks targeting nouns whose plural is formed with the suffix -en (Baayen et al., 1997). The results showed (a) that RTs for singular nouns were determined by their stem frequency (i.e., the summed frequencies of their singular and plural form) and (b) that RTs for plural nouns were determined by their whole-word frequency (see New, Brysbaert, Segui, Ferrand, & Rastle, 2004 for comparable results with regularly inflected French nouns). This pattern of results suggests that the decomposition and whole-word route are initiated for both singular and plurals and compete with each other from early on. While the decomposition route is faster for singulars (i.e., leading to stem frequency effects), the whole-word route was shown to be quicker for plurals (i.e., leading to whole-word frequency effects). The results for nouns were compared with those for verbs in the plural present tense, which also takes the suffix -en. As the suffix has a higher overall frequency in its verbal use than in its nominal use, the orthographic sequence *en* is a more reliable indicator of verbs than nouns. In a visual lexical decision task, the whole-word frequency effect was absent for irregular past tenses: verbs more frequent in their singular form were not processed more quickly in their singular compared to their plural form (e.g., *liep* – *liepen*; ‘ran’), suggesting that the parsing route is quicker than the whole-word route for verbs with the en-suffix (Baayen et al., 1997). Taken together, the findings in Dutch suggest that both a decomposition and whole-word route are operative during recognition of morphologically complex words. When a suffix is homonymic, the relative speed of both routes depends on the semantic integration of that suffix: when the function of the suffix is the one with the lowest probability, the parsing route becomes very time-consuming because it needs to
disambiguate between the two possible interpretations (e.g., between a noun and verb interpretation of the en-suffix). In that case, the whole-word route provides a faster processing route, leading to whole-word frequency effects even for words with fully regular affixes. In contrast, the more frequent interpretation of the suffix does not delay the parsing route, leading to an effect of stem frequency.

A similar pattern of results was found in Finnish, a morphologically complex language. Bertram, Laine, Baayen, Schreuder, and Hyönä (2000) demonstrated that reaction times for inflected nouns with the homonymic Finnish suffix –jA (marker for the partitive plural or subject noun) varied according to their whole-word frequency. However, no effect of stem frequency was found. They come to the same conclusion as for the Dutch suffix -te (past tense and deadjectival derivation of a noun) and the Dutch suffix -en (noun plural and present tense plural/infinitive) (Baayen et al., 1997; Bertram, Schreuder, et al., 2000). Full-form representations provide lexical access because the morphological route incurs a processing delay due to the computational confusion between the two functions of the jA-suffix.

These results fit well into a dual-route model, according to which both a direct whole-word retrieval and a decomposition route operate from early processing stages. In contrast to Taft’s (1979) account, morphologically complex words in a dual-route model have full-form representations at the access level rather than at the central level. An implementation of such a model is the Parallel Dual-route model which posits that both routes operate in parallel in a sort of race (Baayen et al., 1997; Schreuder & Baayen, 1995). This means that the decomposition and whole-word retrieval route are activated in parallel and compete until lexical access is achieved in one of the routes. Arguably, the parsing route is relatively time-consuming since it involves three steps, namely (a) segmentation into morphemic units, (b) licensing (i.e., checking whether the combination of morphemes is a legal one) and (c) composition (i.e., deriving the meaning of the whole word or word form on the basis of its morphemes). Therefore, the direct whole-word retrieval route wins the race in most cases, leading to whole-word frequency
effects, especially for high-frequency words. For low-frequency words, however, this whole-word route is not always faster than the decomposition route, so that stem frequency effects can arise. The speed relationship between the two routes is further determined by word formation type, suffix productivity and affixal homonymy (Bertram, Schreuder, et al., 2000).

2.3. Decomposition vs. storage in a sentence context

The studies reported so far focus on visual word recognition in isolation. However, the topic of this dissertation, namely perception of homophonic verbs in Dutch differs from these studies in an important respect. As we have already mentioned, a conscious checking mechanism must unravel the syntactic structure of a sentence to determine whether the suffix spelling is correct. Therefore, we are not only interested in whether the stem and whole-word frequency effects emerge in visual word recognition, but also whether they are modulated by a sentence context during reading.

An eyetracking study by Niswander, Pollatsek, and Rayner (2000) examined this question for derivationally suffixed and regularly inflected English words embedded in a sentence context. They varied stem frequency or whole-word frequency while keeping the other frequency measure constant. The stem frequency of derivations modulated first fixations, whereas their surface frequency only had an effect from the second fixation onward. As far as inflected word forms are concerned, stem frequency had an impact from first fixation duration on plural nouns but not on inflected verb forms. In contrast, whole-word frequency did influence first fixations for both inflectional types. The authors conclude that whole-word and morphemic representations are both involved during the visual processing of derivations and inflected word forms when these are embedded in a sentence context.

frequency would appear when these inflected nouns were embedded in a sentence context that makes them highly predictable. This would make the interpretation of the suffix less unambiguous, speeding up the decomposition procedure. To test this hypothesis, they performed both an eyetracking and self-paced reading experiment. In the eyetracking experiment, stem frequency had a lagged effect (i.e., emerged on the word following the inflection), while whole-word frequency effects were found both on the target and following word. Because the lagged effect might have been due to a high skipping rate, leading to many missing observations for the target word, a self-paced reading study was conducted. This revealed the same lagged effect for base frequency, but now also for whole-word frequency. The authors suggest that access to whole-word representations for inflected nouns in Finnish precedes access to its constituent morphemes when embedded in a sentence context, confirming their earlier finding in lexical decision that whole-word representations are key determinants in the processing of morphologically complex words with a homonymic suffix.

Luke and Christianson (2011) also contrasted tasks targeting the perception of isolated inflections and tasks targeting these word forms in a sentence context. In a lexical decision task, English regular past tenses did not exhibit a whole-word frequency effect. In contrast, stem frequency did affect the RTs. When these forms were embedded in sentences in a self-paced reading task, an effect of whole-word-frequency was observed that interacted with stem frequency. Whereas stem frequency did not have a main effect on RTs, whole-word frequency had a facilitatory effect on words with a low-frequency stem. For words with a high-frequency stem, the effect became slightly inhibitory. This suggests that when the frequency of morphemic units is high, they compete with full-form representations. In this study, the sentence context clearly modulated how regular past tenses were processed. The absence of a whole-word frequency effect in isolated word recognition is said to be due to the fact that identification of two existing morphemes (without checking the legality of their combination) sufficed to give a correct yes-response, leading to stem frequency effects only. However, a sentence
context necessitates a checking process (i.e., is the word a legal combination of stem and affix?), resulting in the activation of both whole-word and morphemic representations for regular inflections.

### 2.4. Sublexical intrusions: instance-based or connectionist processing

From these findings, one is likely to conclude that both a decomposition and whole-word route are operative for morphologically complex words, depending on a number of factors. However, sublexical errors challenge the traditional view that processing is exclusively morpheme-based (i.e., that there exists a list of stems and affixes). Since these errors fall apart either into an illegal stem and legal suffix or a legal stem but illegal suffix (e.g., *lacht-te* ‘laughed’ or *rus-te* ‘rested’), they are unpredictable from a decomposition perspective. They can only be predicted by a mechanism that takes into account that not only morphemes but also high-frequency letter strings that do not coincide with morphemes or other linguistic concepts (i.e., sublexical patterns) are ‘perceptual units’ in the reading process. To test this hypothesis, we will study whether sublexical homophone intrusions that frequently occur as a letter string in other words often go unnoticed during reading. Whereas a truly morpheme-based decomposition mechanism should be indifferent to the frequency of a sublexical string that does not match a morpheme spelling, we hypothesize the existence of a sublexical effect of Homophone Dominance in perception. This effect can be integrated within two different models: an instance-based or a connectionist model (see below).

Evidence supporting such a claim comes from neighborhood effects. The visual presentation of a word can activate that word’s orthographic neighbors, phonological neighbors, or both. Traditionally, orthographic neighborhood (N) has been defined as the number of words differing one letter from the target word: *tin*, for instance, has orthographic neighbors such as *bin*, *tan* and *tip* (Coltheart, Davelaar, Jonasson, & Besner, 1977). Different predictions have been made with respect to neighborhood effects. A first
possibility is that activation of orthographic neighbors could lead to inhibition due to the process of lexical competition (Grainger & Jacobs, 1996). A second possibility states the exact opposite: facilitation will arise due to an overall increased level of activation. The bulk of the evidence converges on facilitatory effects when words have many orthographic neighbors (Andrews, 1989, 1992; Forster & Shen, 1996; Sears, Hino, & Lupker, 1995). However, null effects (Coltheart et al., 1977) and inhibitory effects for the highly correlated neighborhood size and/or neighborhood frequency measures (i.e., number of neighbors of higher frequency) have also been found (Grainger, 1990; Huntsman & Lima, 1996; Perea & Pollatsek, 1998), especially in French and Spanish (Carreiras, Perea, & Grainger, 1997; Grainger & Jacobs, 1996; Grainger, O'Regan, Jacobs, & Segui, 1989, 1992). Ziegler and Perry (1998) singled out the reason for the discrepancy between facilitatory effects in English and null/inhibitory effects in French and Spanish. They found that facilitation in English was due to the fact that most English neighbors are body neighbors (i.e., sharing an orthographic rhyme, which makes them rhyming words), which was not the case in French or Spanish. This observation hints at the possibility that phonological neighbors can also affect processing in visual word recognition. Yates (2005) indeed found that the number of phonological neighbors, created by changing one phoneme of the target word, facilitated visual word recognition in an English lexical decision task: words with a large phonological neighborhood were processed more quickly. This effect shows that the visual perception of a letter string suffices to activate its phonological neighbors.

While these studies indicated that orthographic and phonological neighbors have an effect on visual word recognition, the data of Grainger, Muneaux, Farioli, and Ziegler (2005) in French support the idea that both types of neighbors interact. More specifically, RTs were influenced by the compatibility between co-activated phonological and orthographic representations. The concept of cross-code consistency, often defined in terms of the degree of spelling consistency among rhyme neighbors, supports their findings: words with consistent sound-to-spelling mappings (i.e., a word’s
phonological rhyme can only be spelled in one way; e.g., *wit) were processed more quickly compared to words with inconsistent ones (i.e., different spellings are possible; e.g., *type > hype, wipe, ripe, stripe). This means that if a word has many phonological neighbors but only few orthographic neighbors, there is much inconsistency in the sound-to-spelling mappings. In contrast, words with similar orthographic and phonological neighborhoods display a larger consistency.

If our study of sublexical homophonous letter strings reveals an effect of Homophone Dominance, the concept of cross-code consistency seems an attractive explanatory concept. This concept makes it possible to explain in terms of existing models why a homophonous orthographic string causes intrusion errors in spelling and creates a tendency to miss these errors in reading. This effect can be explained in two types of models: a model based on analogical processing and a connectionist model.

The first possibility is that the mental lexicon stores whole-word and morphemic representations and is enriched with both a morphological decomposition process and a process that not only activates the target word’s full-form, but also co-activates that of its orthographic and phonological neighbors. As a result of analogical processes, competition arises between the homophonous orthographic clusters (e.g., between ste and stte). When having to spell the past tense form suste, which ends in [st@], the orthographic patterns of its phonological neighbors are also activated. These orthographic representations include both forms with the correct ste-pattern and incorrect stte-pattern (e.g., rustte, tastte, restte, ...). These will co-determine the frequency of both sublexical strings and consequently cause homophone intrusion in spelling (e.g., *sustte) and affect the speed with which these strings are processed in visual perception. This effect of phonological

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11 It is unclear a priori how far into the word the sublexical letter string reaches. The results of our experiments confirm that our operationalization of a sublexical string as the combination of the stem-final phoneme and its inflectional suffix was a sufficiently close approximation to the information that language users appeal to.
similarity to other words can easily be captured in exemplar-based models (e.g., TiMBL; Daelemans & van den Bosch, 2005).

The second possibility is that the mental lexicon is conceived of as a connectionist network, which is ignorant of linguistic units like morphemes but captures all letter strings with frequent letter co-occurrences, encoding these in the form of connection strengths between letter representations. This would be fully consistent with an alternative account of morphological decomposition effects, in which these effects do not reflect access to morphemic representations. Rather, morphemes can also result from the probabilistic co-occurrences between letters, which are high within morphemes and generally low between morphemes (Seidenberg, 1987).

In such a connectionist model, rules are replaced by “activation patterns” emerging as a result of systematic meaning-to-form and grapheme-to-phoneme mappings (or vice versa) captured in the connection weights between the input, hidden and output layers. The strength of these connections is gradually adjusted after exposure to written or spoken language. This way, the model takes into account the statistical regularities between form and meaning and leads to rule-like behavior (Daugherty & Seidenberg, 1994; MacWhinney & Leinbach, 1991; Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986). Morphological structure is then nothing more than an emergent property of systematic mappings between the orthographic, phonological and semantic properties of an input-output pair, while morphological relations consequently result from a high degree of overlap in these mappings across morphologically related words, captured by the weighted connections. Because the frequency and consistency of the mappings is higher within than across morphemes, an effect that at first sight seems like the result of an active decomposition process can in fact be explained by the probabilistic nature of natural language.

Connectionist modeling of the past tense in English has proven to be quite successful: a single system underlying the production of both regular and irregular forms is able to mimic both the inflectional rules and the exceptions and can also simulate children’s errors (MacWhinney & Leinbach, 1991;
Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986). Clearly, a connectionist model is also capable of explaining the errors studied in this dissertation, namely lexical and sublexical homophone intrusions in Dutch. If words are conceived of as sequences of co-occurrence patterns, whose frequency is gradually captured in the network’s weight structure, a connectionist model can easily replicate the effect of Homophone Dominance at the lexical level (i.e., whole-word frequency effects for regular inflections). In addition, sublexical errors can also be explained along the same lines: these errors result from partial similarities to past tense meaning-to-form mappings of phonologically similar words. In other words, the phonological representation of the target word activates the orthographic representations of phonologically similar words, which can consequently affect processing of the target form.

3. Structure of the Dissertation

In this dissertation, we will show that Homophone Dominance at the lexical and sublexical level is responsible for the persistence of spelling errors on regular verb forms in Dutch, because it underlies both production (Chapter 2) and perception (Chapter 3). In Chapter 2, we will demonstrate that the effect of Homophone Dominance governs the error pattern in an offline spelling-to-dictation task. In addition, we will examine the error pattern and interkey intervals in an online equivalent of this task. We will conclude Chapter 2 by extending the Homophone Dominance effect to a large-scale corpus of spontaneously produced written language (i.e., text fragments from a social network site). Chapter 3 studies whether the effect of Homophone Dominance transfers to perception, causing readers to overlook both lexical and sublexical intrusions errors when they correspond to the high-frequency form or to a frequently occurring spelling pattern. Section 1 of Chapter 3 focuses on automatic processing in isolated word recognition. We examine whether the higher-frequency homophone or frequent homophonous pattern is processed more quickly outside a sentence context, namely in a lexical decision task.
Section 2 studies whether the effect of Homophone Dominance still survives when verb forms are embedded in a minimal grammatical context (e.g., the verb form is preceded by subject only), namely in a spelling decision and phonological decision task. Section 3 investigates processing of regular Dutch verb forms, when they are embedded in a sentence context. Three online reading experiments (i.e., eyetracking, self-paced reading and a maze task) as well as an offline experiment (i.e., a proofreading task) will be performed to accomplish this goal. The results and their theoretical implications will be discussed in a General Discussion (Chapter 4).

We will conclude that although the spelling rules for regular Dutch verb forms are descriptively simple and explicitly taught, language users do not always rely on these morpheme-based rules. Rather, both spellers and readers are subject to the automatic retrieval of frequent orthographic representations from our long-term memory. In production, the mental lexicon puts forward the most frequent homophone, leading to lexical homophone intrusions when the LF verb form is targeted (e.g., *hij meld). At the sublexical level, homophony with an orthographic cluster that is frequent in other word forms is responsible for spelling errors on past tenses (e.g., *hij sustte). However, the mental lexicon also causes readers to overlook errors corresponding to this high-frequency homophone or frequent homophonous cluster, such that these errors persist in perception. This “double trap”, created by the mental lexicon, makes it inevitable that intrusion errors slip through the net from time to time and persist in the writings of even highly educated people.
CHAPTER 2

THE HOMOPHONE DOMINANCE EFFECT
IN PRODUCTION

1. EXPERIMENTAL CONTEXT

1.1. Offline spelling-to-dictation task

1.1.1. Stem-final d verbs

1.1.1.1. Hypothesis

With the goal of replicating the Homophone Dominance effect found in previous production experiments (Assink, 1985; Frisson & Sandra, 2002b; Sandra et al., 1999; Sandra & van Abbenyen, 2009), we performed an offline spelling-to-dictation task with stem-final d verbs (1st vs. 3rd person homophones in the singular present tense). We created a cognitively demanding situation by having participants write down dictated sentences without leaving any opportunity to check for errors. This way, we believe to have targeted fluent writing that lays bare the automatic processes underlying lexical access, such as a frequency-sensitive retrieval mechanism. If homophonous verb forms are indeed stored and retrieved from memory during spelling, the error risk should be higher when the correct form is the low-frequency (LF) form. Therefore, we hypothesize that more errors will be made on the 3rd person dt-form (e.g., *hij meld; ‘he *report’) as verbs become more d-dominant (i.e., d-form is more frequent). In contrast, intrusions on the 1st person d-form (e.g., *ik *rijdt; ‘I *drives’) will be more likely when verbs

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12 This section is the result of a collaboration with Stephanie Wijns in the context of her master’s thesis.
become more dt-dominant (cfr. infra: interaction effect between \textit{Homophone Ratio} and \textit{Form}).

While our main objective is to replicate the Homophone Dominance effect at the lexical level, performing this task also presents two other advantages. Firstly, it allows us to directly compare effects at the lexical and sublexical level (see Section 1.1.2). If an effect is found at the lexical level, it validates this type of task for tapping into frequency-based effects during the production of regular verb forms. Consequently, we should also observe an effect at the sublexical level. Secondly, the exact same set of stimuli can be used during reading experiments to examine whether the effect of Homophone Dominance also underlies perception.

1.1.1.2. Method

Stimuli and Design

\textit{Stimuli.} We selected 48 critical stimuli, 24 of which were stem-final d verbs (to study intrusions at the lexical level) and 24 of which were past tense verb forms (to study intrusions at the sublexical level). The latter will be discussed and analyzed in Section 1.1.2. Of the 24 stem-final d verbs, half of the items were more frequent in their d-form (i.e., d-dominant), while the other half were more frequent in their dt-form (i.e., dt-dominant) (see Appendix, Table 1, ‘basic set’). None of these verb forms had a zero frequency. Selection of the critical stimuli was based on the frequency counts of SUBTLEX-NL (Keuleers et al., 2010), taken from a corpus of approximately 44 million word tokens\textsuperscript{13}. It is crucial to note that parts-of-speech information is deemed irrelevant in our specific frequency count, since it has been shown that the orthographic representations of homophonous forms are activated regardless of their lexical category (see Sandra & van Abbenyen, 2009).

The most straightforward way to operationalize Homophone Dominance would be to make use of the homophones’ whole-word

\textsuperscript{13} All frequency counts used in this dissertation are based on SUBTLEX-NL (Keuleers et al., 2010), unless mentioned otherwise.
frequencies. However, due to the extremely high correlation between whole-word frequency and lemma frequency\textsuperscript{14} ($r = .91$)\textsuperscript{15}, this would have caused insurmountable statistical problems (i.e., there being virtually no residual variance for whole-word frequency after the highly reliable effect of lemma frequency has been partialled out). This is also the reason why a binary variable (i.e., d-dominant vs. dt-dominant) was used in all previous spelling experiments (e.g., Sandra et al., 1999). Since simplifying a continuous variable into a categorical one, however, reduces statistical power (Baayen, 2004), we opted for a more sensitive measure. As the effect of Homophone Dominance can be conceived as a ratio between the HF (dominant) homophone and the LF homophone, we decided to use the frequency relation between the two homophones as a continuous measure. This measure, labeled \textit{Homophone Ratio}, was operationalized in the following way:

\[
\text{Homophone Ratio} = \log_{10}\left(\frac{\text{Frequency d form}}{\text{Frequency dt form}}\right)
\]

The distribution based on the verbs’ Homophone Ratio is visualized in Figure 1:

\textsuperscript{14} We followed the approach taken by Keuleers et al. (2010, p. 15) who argue that “because word-form frequencies are also summed over syntactic categories”, so should lemma frequencies. The lemma ‘kleed’ therefore includes the following word forms: geklede (V), gekleed, kleden (V), kleed (V/N), kleedde (V), kleedden (V), kleedt (V), klederen (N), kleedje (N), kleedjes (N). V = verb; N = noun

\textsuperscript{15} This high correlation ($r = .88$) is also present for the selected set of weak prefix verb forms (see Table 3 in Appendix).
A positive value for the Homophone Ratio measure indicates that a verb is d-dominant (i.e., more frequent in its d-form), whereas a negative value points to a dt-dominant verb. The larger the absolute value of the ratio is, the more pronounced the frequency dominance of one form over the other is. While a binary encoding considers all d- or dt-dominant verbs to be identical members of the same category, the Homophone Ratio measure allows us to take into account the fine-grained differences in the frequency relation between a verb’s homophonous forms. Indeed, the effect of Homophone Dominance might be larger for verbs with a more pronounced frequency ratio (i.e., verbs at both ends of the continuum). The set of selected d- and dt-dominant verbs were matched for Homophone Ratio ($t = 0.7; p > .05$).

For each critical verb, we created a sentence frame in which both the pronoun and the verb form for the 1st and 3rd person singular present tense
form (the d- and dt-form, respectively) could be inserted. Thus, the surrounding context was identical across both conditions (1st person d-form vs. 3rd person dt-form) and could not constitute a confounding factor. An example of a sentence frame is the following:

Al
sik/hij steeds de morele grenzen overschrijdt(t), zal ik/hij ontslagen worden als pro-Deoadvocaat.

‘If I/he always the ethical boundaries cross(es), will I/he be fired be as pro bono lawyer.

A number of other sentence manipulations were also implemented in an attempt to avert attention away from the verb forms. Firstly, the subject of the sentence was separated from the verb form by at least four other words. To accomplish this, each critical verb appeared in final position of a subordinate clause (i.e., the typical SOV order for subordinate clauses in Dutch), followed by a main clause. Previous research has shown that the error risk is higher when subject and verb are separated by other words in comparison to when they are adjacent (Sandra et al., 1999). In the case of intervening words, working memory has more difficulties computing the correct inflectional suffix as the relevant grammatical information that is needed to select this suffix is further removed from the verb form. When working memory resources are taxed, it becomes more likely that an automatic mechanism retrieves the most frequent homophone spelling from memory and leads to intrusion errors when the lower-frequency form is grammatically correct. By introducing a number of items between subject and verb, we therefore believe to have created optimal conditions for observing the Homophone Dominance effect. Secondly, an extra spelling difficulty in a non-verb form (e.g., pro-Deoadvocaat) was introduced in the main clause at a sufficient distance from the verb form, in order to avoid drawing attention to (the region around) the verb. Thirdly, we introduced filler sentences that included at least two words related to notorious spelling issues other than verb spelling. The verb forms used in these fillers were never homophones:
De guillotine was een middeleeuws voorwerp dat zelfs de grootste helden ontoverde in echte bangeriken.

‘The guillotine was a medieval object that even the greatest heroes changed into real cowards.’

All sentences had a maximum length of two lines when typed out in Times New Roman (12 points).

**Design.** We devised four different experimental versions (1A, 2A, 1B, 2B), containing 32 sentences each. These 32 sentences included twelve sentences with homophonous verbs. The 24 critical sentences containing stem-final d verbs were divided into two subsets (1 and 2), with an equal number of d-dominant \((n = 6)\) and dt-dominant \((n = 6)\) verbs in each subset. We did this to lower participants’ awareness of the aim of the dictation task, namely to target difficult (homophonous) verb forms. In each subset, half of the d-dominant and half of the dt-dominant verbs were dictated in the 1\(^{st}\) person singular present d-form, while the other half were dictated in the 3\(^{rd}\) person dt-form. For each subset, we created two counterbalanced lists (A and B): when List A targeted a 1\(^{st}\) person d-form, the counterbalanced form in list B was a 3\(^{rd}\) person dt-form and vice versa. In addition, each version contained six past tense forms (see Section 1.1.2) and fourteen fillers. These fillers differed for Subsets 1 and 2, but were identical across Lists A and B. In order to have participants write down all stem-final d verbs, participants took part in the experiment twice, with a one-week interval: once with the Subset 1 materials and once with the Subset 2 materials (the order being counterbalanced across participants). Thus, participants never saw a critical item twice.

The 32 sentences in all four versions were evenly distributed across three pages (i.e., 11-11-10 sentences per page). In a further attempt to avoid that participants would focus on verb spelling, a critical sentence was never the first or last item on a page. In addition, a maximum number of two critical sentences could follow each other. To avoid that fatigue effects always affected
the same items, we created two randomizations (R). The page sequence for R1 was 1-2-3, while it was 2-3-1 for R2. Consequently, the critical sentences did not always appear in the same position in the experiment.

Participants and Procedure

Participants. There were three participating schools: the Sint-Ursula (SU) Institute in Lier, the Atheneum Hof van Riemen (KTA) and the Heilig-Hartschool (HH), both located in Heist-op-den-Berg. All 94 students were in the sixth and final year of secondary school (i.e., ages 17 to 18) and were evenly distributed across the four versions of the experiment. This age group was chosen because they are at the peak of their grammatical knowledge in this type of education, after having been confronted with the rules for spelling regularly inflected verb forms throughout the six years of secondary school. In comparison with younger children, they have access to a fully developed spelling rule system. In addition, the explicit training on these rules is more recent for this age group compared to adults. We targeted students who attended general education (with courses whose main focus is on theoretical understanding: in mathematics, the exact sciences and languages). These students are more experienced with writing texts compared to students from Technical or Professional Education.

Procedure. Participants were told that they were taking part in a large-scale research project concerning the spelling ability of teenagers. However, the focus on homophonous verbs was not disclosed to them. Participants received a booklet consisting of four pages. A first page required them to fill in (by hand) personal information, such as their name, gender, education type, native language and whether or not they had any reading disorders. On this first page, we also provided the following written instructions:

\[\text{\footnotesize The number of participants per version were: 1A (n = 28), 2A (n = 23), 1B (n = 24) and 2B (n = 19). The difference in numbers is due to differences in class size.}\]
You will have to write down sentences dictated to you shortly on the following pages. Each sentence will be dictated once in its entirety and later in chunks. The speed at which the sentences are dictated is fairly fast, so it is important not to hesitate too much. Please do not return to previous pages to make any adjustments to the sentences.

These instructions were repeated verbally, during which the experimenter emphasized that no corrections ought to be made. On the next three pages, space was provided for the 32 sentences. The same experimenter dictated each version, for each class. Since the dictation task was performed in a class group, participants from the same class all completed the same version. Recall that participants took part in two experimental sessions, exactly one week apart: once in a session based on Subset 1 and once in a session based on Subset 2. Crucially, participants were not informed that a second session would follow the next week to prevent them from preparing for a new dictation task.

1.1.1.3. Results and Discussion

Results. Participants who did not participate in both sessions (n = 14), were non-native speakers of Dutch or had a reading disorder (n = 8) were removed from the data set. In addition, we also excluded 9 participants with a perfect score (24/24) because they do not contribute to variance in the theoretically relevant conditions (i.e., identical values for each condition). We were left with 24 observations for each of the 63 students, with one missing value.

We fitted a generalized linear mixed effects model (GLMM; mixed logit model with bobyqa optimizer) via the lme4 package (Bates, Maechler, Bolker, & Walker, 2014) and the R statistical software package (R Core Team, 2014). All models in this dissertation were fitted using these two packages. The dependent variable was binomially distributed and represented the spelling of the verb form: an incorrect spelling was coded as 0, whereas a correct spelling

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17 After removing these participants, there were 35 participants left for version A and 28 for version B.
was coded as 1. Crucially, only theoretically relevant errors, namely substitutions of two homophonous verb forms were taken up (e.g., *ik vindt instead of ik vind, but not *ik vint).

To determine which control variables were essential to take up, the same procedure was used throughout this dissertation. We started from a null model (i.e., the only fixed effect being the intercept and the only random effect being the random intercept for participants). Next, a stepwise forward procedure was used to determine which control variables had to be included as fixed effects. This was done by means of likelihood ratio tests, using $\alpha = .05$ as the significance level. In this experiment, the control variables were: Trial (rank of the sentence in the experiment), Week (1 or 2) and Log Lemma Frequency (i.e., summed token frequencies of all inflectional variants). If control variables were found to be non-significant, they were left out of the model. The independent variables of interest were: Form (1st person d-form vs. 3rd person dt-form), Homophone Ratio and, most importantly, their interaction. Recall that in statistical terms the Homophone Dominance effect amounts to this interaction: we expect an increase in errors on the 1st person d-form as the dominance of the dt-spelling increases and, in contrast, an increase in errors on the 3rd person dt-form as the dominance of the d-spelling increases. All independent variables were mean-centered to reduce possible collinearity between the predictors (as will also be the case in all subsequent analyses).

For every experiment reported in this dissertation, we followed the same approach to determine the random structure of the mixed model. We

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18 We do not dispute the possible theoretical importance of the latter type of errors. However, they are not relevant for the study of homophone intrusions between existing forms, which is the focus of this work.

19 Note that lemma frequency is implicitly matched between the d-form and (d)t-form of the same verb. Hence, Log Lemma Frequency only captures the variance across verbs.

20 Because we focus on the spelling of the suffix, the factor included in the statistical analyses will be Form (d-form vs. (d)t-form) rather than grammatical context (stem-final d verbs: 1st vs. 3rd person; weak prefix verbs: present tense vs. past participle). This will make it easier to interpret the results and use the same factors across experiments, i.e., especially when no context is provided as in a lexical decision task (cf. infra).
first sought to apply the maximal random structure supported by the design. However, if the model containing this random structure failed to converge (which was the case for this experiment) or showed a singular fit, we determined the maximal random structure supported by the data (Jaeger, 2008). This was obtained through a forward best-path algorithm (Barr, Levy, Scheepers, & Tily, 2013). Inclusion/exclusion of random effects was tested through likelihood ratio tests at the .20 \( \alpha \)-level with a base model including all fixed effects and a by-participant random intercept. For the current experiment, the random structure of the final model contained a by-item random intercept, a by-participant random intercept and a by-participant random slope for Form. For each analysis, we present a regression table for the model containing all significant control variables (i.e., there were none in this analysis) and the theoretically important variables (i.e., Form, Homophone Ratio and their interaction). We report each variable’s estimate \( \beta \), standard error and \( z \)-value (or \( t \)-value in case of a continuous dependent variable). In addition, the \( \chi^2 \)-value and \( p \)-value displayed were obtained through likelihood-ratio tests comparing (a) a model containing all predictors with (b) a nearly identical model from which only the variable under investigation was removed, but not the random effects associated with this variable. Figure 2 visualizes the partial effects of the variables of the GLMM reported in the regression table (Table 1), where logits were backtransformed into probabilities.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( \beta )</th>
<th>( SE(\beta) )</th>
<th>( z )</th>
<th>( \chi^2 )</th>
<th>( p(&gt;\chi^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.90</td>
<td>0.17</td>
<td>11.11</td>
<td>91.46</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Form</td>
<td>1.34</td>
<td>0.34</td>
<td>3.90</td>
<td>15.28</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>-0.04</td>
<td>0.15</td>
<td>-0.23</td>
<td>0.05</td>
<td>.819</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>-1.47</td>
<td>0.31</td>
<td>-4.80</td>
<td>19.54</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Table 1. Coefficients of a mixed logit model predicting the correctness of a verb form from Form, Homophone Ratio and their interaction, together with their estimate \( \beta \), standard error, \( z \)-value, \( \chi^2 \)-value and \( p \)-value.
Discussion. The results revealed a significant effect of Form indicating that fewer errors were made on 3rd person dt-forms compared to 1st person d-forms. Crucially, this effect was modulated by an interaction with Homophone Ratio. Recall that a negative value for Homophone Ratio indicates a dt-
dominant verb (left side of the plot) and a positive value marks a d-dominant verb (right side of the plot). As a verb becomes more d-dominant (i.e., as Homophone Ratio increases), the probability of a correct spelling increased when the 1st person d-form had to be spelled. However, it decreased when the 3rd person dt-form was the target. The reverse pattern was observed as verbs became more dt-dominant. In short, intrusion errors were more likely when the to-be-spelled form was the lower-frequency homophone. This finding replicates the Homophone Dominance effect for the same verb type reported in Sandra et al. (1999), i.e., homophones with a stem-final d. However, in the present experiment, more items were used and the data were analyzed with a more conservative statistical technique (Sandra et al., 1999 used simple chi-square tests). Since the effect was easily replicated with a group of highly trained spellers, we conclude that the effect is very consistent. The partial effects plot for this interaction, depicted in the right-bottom hand side of Figure 2 clearly shows that the effect is less pronounced for d-dominant verbs (right side of the plot). This might be the result of the experimental design. As already mentioned, we inserted at least four words between the subject and its verb form to create optimal conditions for finding an effect of Homophone Dominance. This was done to create a considerable processing load for working memory, which needs to compute the correct inflectional ending. It has been shown that this separation of the verb form from its subject indeed considerably increases the error rate, presumably because the attempt to retrieve the subject’s grammatical properties exhausts the available temporal resources in working memory (Sandra et al., 1999). However, this manipulation may inadvertently have caused a tendency to spell the dt-form due to misleading morphosyntactic information of one of the intervening words, which conceptually often referred to the notion of 3rd person singular. For instance, in a sentence such as

Hoewel ik/hij pas binnen enkele jaren dokter word(t) ...
‘Although I/he only in a few years doctor become(s) ...’
the word ‘doctor’, which can be misinterpreted as the subject of the verb *worden*, can activate the notion of 3rd person singular. This, in turn, will activate the dt-spelling that is used for 3rd person singular grammatical subjects. Such a tendency will counter-act the bias to spell a d for d-dominant verbs and thus both increase the number of dt-intrusions for the 1st person singular d-form (resulting in a smaller percentage correct than the Homophone Ratio would predict) and reduce the number of d-intrusions for the 3rd person singular dt-form (resulting in a higher percentage correct than the Homophone Ratio would predict). These opposite effects will result in a smaller difference in error rates between the two homophonous forms for d-dominant verbs compared to dt-dominant verbs and, hence, a less pronounced effect of Homophone Dominance for the former verb type.

This account is in line with previous research on subject-verb agreement errors. These so-called *proximity concord errors* often occur because spellers rely on the noun whose grammatical features are most accessible (i.e., the noun closest to the verb) to determine the verb form’s inflectional ending (Bock & Miller, 1991). Fayol et al. (1994) showed that this is especially the case when inflectional suffixes are silent and when working memory is overloaded (e.g., due to a secondary task). This is exactly what Sandra, Frisson, Durieux, Daelemans, and Gillis (2000) observed in Dutch: they asked participants to write down sentences containing homophonous verbs with a stem-final d (1st vs. 3rd person singular) and inserted intervening words between the subject and the verb form. These intervening words either contained a singular or a plural noun:

Het is evident dat *ik* niet graag in *onderhandeling(en)* *treed* met een
cynische advocaat.

‘It is evident that *I* do not like into negotiation(s) *to enter* with a cynical
attorney.’

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22 In this experiment, intervening singular nouns were present in 18 out of the 24 sentences.
§ 2 THE HOMOPHONE DOMINANCE EFFECT IN PRODUCTION

If it were true that the morphosyntactic information of plausible subjects interferes with the spelling of the correct suffix, more attraction errors are expected when the intervening noun is singular, simply because it is frequently associated with the third person singular. Such an association is absent for plural nouns. The authors indeed observed that more dt-intrusions were made (i.e., the 1st person singular d-form was targeted) when the intervening noun was singular, except when the verb was d-dominant. In contrast, the number of the noun did not have an impact when the dt-form was the correct one, as both nouns favored a third person singular interpretation. In the current experiment, the conflicting morphosyntactic information between the 1st person singular subject and the intervening words that favored a 3rd person interpretation is likely to have caused a high number of dt-intrusions. Except when this d-form is much higher in frequency (i.e., extreme right side of the plot), this dt-bias can be overridden. In other words, the combined effects of the d-bias induced by verbs with a dominant d-spelling and the dt-bias induced by an intervening singular noun resulted in a less pronounced difference between d-intrusions and dt-intrusions for d-dominant verbs compared to dt-dominant verbs.

The results of Experiment 1 allow two important conclusions. Firstly, our main hypothesis, stating that the pattern of errors should be modulated by the effect of Homophone Dominance, was confirmed: errors were more likely when participants had to spell the lower-frequency form of a homophonous verb with stem-final d, replicating the findings of previous spelling research (Assink, 1985; Frisson & Sandra, 2002b; Sandra et al., 1999; Sandra & van Abbenyen, 2009). This provides further evidence for the idea that full forms of Dutch homophonous verb forms are stored in the mental lexicon (or at least forms of sufficiently high frequency). The most frequent form is most easily accessible and leads to occasional errors when the computational process for the LF form cannot be finished in time. Secondly, spellers are sometimes misguided by the morphosyntactic information of intervening words (Fayol et al., 1994; Largy et al., 1996; Sandra et al., 2000). In the current experiment, we inserted at least four words between the subject and verb form. These
words were often singular nouns, favoring a third person interpretation (i.e., thus supporting the dt-form) and consequently led to a dt-bias that counteracted the bias to spell the dominant d-form for d-dominant verbs.

In the following section, we aim to show that Homophone Dominance is also a key determinant in the spelling of past tense verb forms during an offline spelling-to-dictation task.

1.1.2. Past tense verb forms

1.1.2.1. Hypothesis

We hypothesize that verbs whose homophonous relationship is not situated at the lexical level, as for verbs with a stem-final d and weak prefix verbs, but is situated at the sublexical level are also prone to frequency-induced intrusion errors, i.e., to the effect of Homophone Dominance (see Sandra & van Abbenyen, 2009). Recall that we use the term ‘sublexical’ to refer to homophonous grapheme clusters that straddle the morpheme boundary. This is, for instance, the case with singular past tense verb forms in Dutch, which end in the phonological sequences [t@] or [d@]. The rule for past tense inflection applies uniformly across all verbs, namely add -te to the verb stem if it ends in an unvoiced phoneme and -de in all other cases. This results in past tense forms like suste (sus + -te, ‘hushed’) and belde (bel + -de, ‘rang’). If the verb stem already ends in the phoneme /t/ or /d/, the spelling of the verb’s past tense form contains a doublet: a t/d from the stem-final letter and a t/d from the suffix-initial letter (e.g., rust + -te ‘rested’ or meld + -de ‘reported’). However, the difference between the orthographic sequence te/de in suste/belde and tte/dde in rustte/meldde is not audible, making both sublexical clusters homophones. Thus, the orthographic realizations of the phonological strings [t@] and [d@] in past tense forms are ambiguous between the two possible spellings te/de and tte/dde. Such an ambiguity

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23 This section is a collaboration with Stephanie Wijns in the context of her master’s thesis.
§ 2 THE HOMOPHONE DOMINANCE EFFECT IN PRODUCTION

occasionally causes substitution of one spelling pattern by the other, leading to intrusion errors. An example of such a sublexical intrusion is the Dutch spelling error *sustte instead of suste. We hypothesize that intrusion errors at the sublexical level depend on the relative frequency of the homophones’ grapheme clusters (i.e., their Homophone Dominance). To provide an answer to this question, we compare verbs with a homophonous orthographic pattern at the sublexical level (e.g., suste, with a word-final homophonous pattern in, for instance, rustte) to verbs without such a homophonous competitor (e.g., repte, the ptte-pattern being non-existent\(^\text{24}\)). We expect that the number of homophone intrusions should be larger for past tenses with a homophonous letter pattern than for verbs whose final phonological sequence can be spelled in only one way. If the risk of sublexical intrusions is indeed determined by the occurrence of a sublexical homophonous pattern, this would provide strong evidence for the claim that the spelling of regular past tenses in Dutch is not strictly rule-based, but also involves the activation of letter patterns that cut across the boundaries between morphemes, i.e., the units that are involved in the spelling rules of the language. Firstly, a purely rule-based approach cannot account for a sublexical error of this type, as there is no verb stem *sust to which the past tense te-suffix can be attached. Secondly, such an account can certainly not explain why sublexical errors are more frequent for one type of verb compared to another, based on the presence of a sublexical homophonous cluster. However, this would support a view in which any letter string can be activated in the mental lexicon as the result of its recurrence in the input, whether it matches a linguistically motivated unit (in this case a morpheme) or not. As mentioned before, this can be achieved within a connectionist architecture, which is sensitive to the strength of phonology-to-orthography mappings (and can thus capture both morphemic and non-morphemic sublexical patterns), or by an exemplar model in which an analogy-based activation process generates a set of neighbors and a selection mechanism.

\(^{24}\) Even though a sequence like *ptte does not occur in Dutch word-final position, neither in past tense forms nor in any other word form, the sequence would be pronounced as [pt\(\text{@}\)], just like the correct pattern pte.
§ 2 The Homophone Dominance effect in production

determines the response on the basis of the most dominant pattern in the set.

We tested our hypothesis by analyzing the error pattern for the past tenses incorporated in the offline spelling-to-dictation task that also examined stem-final d verbs. The effect of Homophone Dominance observed for the latter set of verbs validates the experiment in terms of its sensitivity to frequency-sensitive retrieval mechanisms. Hence, if no effects are found for past tense verb forms, the absence of an effect is unlikely to be attributable to the experimental set-up but rather to the organization of the mental lexicon as such. Recall that the spelling of past tense verb forms does not depend on the grammatical properties of another word in the sentence as for lexical intrusions (cf. the necessity for a morphosyntactic analysis). In contrast, spelling of past tenses only requires a morphological analysis (i.e., identify the stem-final letter and add the appropriate suffix). Because this type of analysis is less time-consuming (i.e., fewer constraints on the working memory), sublexical intrusions should be more difficult to observe than lexical intrusions. If homophone intrusions occur at the sublexical level as well, this would provide us with a tool for distinguishing between a rule-based account and an account in which rules play a less central role (possibly none at all) and hinges more heavily on the idea of statistical learning (as in connectionist models) or analogical processing (as in exemplar-based models).

### 1.1.2.2. Method

**Stimuli and Design**

**Stimuli.** We selected 12 singular past tense verb forms whose stem ended in -s (‘s verbs’; e.g., suste from sussen\(^25\), ‘to hush’) and 12 past tense verbs whose stem ended in -p (‘p verbs’; e.g., repete from reppen, ‘to rush’). The former represents the group of past tenses for which sublexical homophony exists. More specifically, their correct stem-pattern is homophonous with the stem-

\(^{25}\) The doublet in the stem is an orthographic convention to represent the fact that the vowel preceding a single intervocalic consonant is lax. The stem itself does not contain this doublet (e.g., sus, ‘hush’, and rep, ‘rush’).
§2 The Homophone Dominance Effect in Production

pattern (e.g., rustte from rusten, ‘to rest’). The latter pattern results from the concatenation of a stem final st cluster (‘st verbs’) and the past tense te-suffix. For p verbs, this sublexical homophony is absent since the Dutch written language does not allow the spelling pattern ptte, neither in verb forms (there are no ‘pt verbs’), nor in words from other lexical categories. Past tenses from both verb types were matched on Word Length, (log) Lemma Frequency and (log) Whole-word Frequency (Keuleers et al., 2010) (see Table 2 in Appendix). We deliberately chose verbs whose stem did not end in a t (as is the case with e.g., rustte) and whose correct past tense spelling therefore did not contain a doublet. This was to avoid two confounding factors. Firstly, errors on verb forms with a stem-final t could result from simplification, namely the spelling of a single t instead of the correct double tt (as people often do in chat sessions, for instance). In addition, there is also lexical competition within the verbal paradigm itself. The infinitive, which is spelled with a single t (e.g., rusten, ‘rest’), is homophonous with the plural past tense form with a double t (e.g., rustten). Homophony also exists with other (non-standard) inflected forms of the same verb. In communication on the internet, spellers often omit the final n of the infinitival and plural past tense forms (e.g., ruste, rusten) such that some participants will be familiar with the incorrect past tense form (*ruste for rustte) from its occurrence in non-standard language contexts (R. Vandekerckhove & Nobels, 2010, pp. 663-665). For these two reasons, we preferred to work with verbs whose stem does not end in a t (type sussen, ‘to hush’ and reppen, ‘to rush’). Although informal observations indicate that intrusions of this type are much more difficult to elicit, they are not subject to the effects of the confounding factors described above.

The 24 past tense verb forms selected were embedded in sentences of the same structure as the verbs with a stem-final d (i.e., they consisted of a subclause and a main clause that featured an extra spelling difficulty; see Section 1.1.1.2). Because the characteristics of the subject (and its position in the sentence) are irrelevant for the correct spelling of the inflectional ending, no sentence criteria were applied, except for the following two: (a) past tense forms could not appear at the beginning or end of a sentence and (b) extra
spelling difficulties on non-verbs were not allowed to occur in the verb region. An example of a sentence containing a past tense form is the following:

Hoewel ik me er zo snel mogelijk naar toe **r**epte, kwam ik toch te laat op de **p**remiére van die nieuwe film.

‘Although I over there as soon as possible **r**ushed, was I still late for the **p**remiére of that new movie.’

**Design.** In order to lower participants’ awareness of the aim of the experiment, the 24 critical sentences containing past tenses were divided over four experimental versions (n = 6 in each version). As already mentioned, each version contained 32 sentences: 6 past tense verb forms, 12 verbs with a stem-final d and 14 fillers, evenly distributed across three pages (see Section 1.1.1.2). Half of the past tense forms in each experimental version were **s** verbs (with sublexical homophony), while the other half were **p** verbs (without sublexical homophony). Recall that subjects participated twice, with one week between sessions. In other words, they were confronted with 12 past tense forms in total.

**Participants & Procedure**
Identical to Section 1.1.1.2.

**1.1.2.3. Results and Discussion**

**Results.** We excluded participants who did not participate twice, who were non-native speakers of Dutch, or had a reading disorder (n = 22). In addition, 42 participants with a perfect score (12/12) were also removed from the data set because they did not contribute to variance in the past tense data. As predicted, the number of participants that made at least one sublexical intrusion (n = 30) was lower in comparison to lexical intrusions (n = 63), due to fewer restrictions imposed on the working memory (i.e., morphological vs. morphosyntactic analysis; see hypothesis). The remaining 30 students
provided us with 360 observations\textsuperscript{26}.

We fitted a generalized linear mixed effects model (GLMM) to these observations. The spelling of the past tense form served as binomially distributed dependent variable. A zero represented an incorrect spelling while a correct spelling was coded as one. Target forms were only considered incorrect when the error pertained to the inflectional ending (i.e., tte instead of te and not, for instance, *sgrapte instead of schrapte). Control variables tested for inclusion through likelihood ratio tests were Trial (i.e., rank of the sentence in the experiment), Week (1 or 2), Log Lemma Frequency and Log Whole-word Frequency\textsuperscript{27}. If these variables were found to be non-significant, they were excluded from the final model. The variable under investigation was the main effect of Sublexical Homophony (yes vs. no). The final model included the maximal random effects structure justified by the design (Barr et al., 2013), namely a by-item random intercept, a by-participant random intercept and a by-participant random slope for Sublexical Homophony. Table 2 presents the results of the GLMM with the best fit, the partial effects of which are visualized in Figure 3.

\textsuperscript{26} The number of remaining participants per version were the following: 1A ($n = 8$), 2A ($n = 8$), 1B ($n = 7$) and 2B ($n = 7$).
\textsuperscript{27} In contrast to what was the case in the analyses of the data for verb form homophones, Log Whole-Word Frequency was also tested for inclusion as a control variable. As this factor is obviously not relevant for detecting an effect of Sublexical Homophony, it is used as a control factor. In contrast, it is directly relevant in analyses probing an effect of Homophone Dominance (being a direct function of whole-word frequency), which means that taking up whole-word frequency as a control factor would kill an effect of Homophone Dominance.
Table 2. Coefficients of a mixed logit model predicting the correctness of a verb form on the basis of Sublexical Homophony, together with the estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$z$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.18</td>
<td>1.29</td>
<td>2.47</td>
<td>43.50</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Sublexical Homophony</td>
<td>4.85</td>
<td>2.54</td>
<td>1.91</td>
<td>27.05</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Figure 3. Partial effects plot for Sublexical Homophony (see Table 2).

Discussion. The effect of Sublexical Homophony was significant: more errors were made on singular past tenses evoking competition between the orthographic patterns $te$ and $tte$ (65.56% correct spellings) compared to verbs that did not evoke sublexical competition (93.89 % correct spellings). The finding that $te$ is more often substituted by the homophonous pattern $tte$ for $s$ verbs (e.g., *sustte for suste) than for $p$ verbs (e.g., *reptte for repe) points to

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28 This $z$-value corresponds to a $p$-value that is marginally significant (0.057). However, the $p$-value (i.e., $p < .001$) obtained from the likelihood ratio test (see Table 2) showed that the Wald’s $z$-score is too strict. In addition, the confidence interval for Sublexical Homophony computed via a bootstrap simulation at the 95%-level ($n = 1000$) did not contain zero (lower limit: 2.68; upper limit: 10.94), thus confirming that the effect is indeed significant.
an effect of Homophone Dominance at the sublexical level. The probability of making an error depends on the frequency relation between the correct and incorrect homophonous spelling pattern, the frequency of the incorrect spelling being treated as a dichotomous variable (the pattern occurs or does not occur). This mimics the effect at the lexical level for verbs with a stem-final d (see Section 1.1.1.3).

We conclude that the written production of Dutch singular past tenses (i.e., fully regular inflected verb forms) is not strictly rule-based, since we observed sublexical intrusions involving the substitution of homophonous clusters that straddle morphemic boundaries. From a rule perspective, these errors are impossible: there is no stem *sust that can concatenate with the inflectional suffix -te, nor is there an inflectional suffix -tte that concatenates with the verb stem sus. The observation that the presence of a competing homophonous orthographic pattern extending across morphemes affects the risk of sublexical intrusions cannot be accounted for within the framework of a rule-based model. Moreover, such a model cannot explain that the preference for a single or double t depends on the preceding grapheme, since a rule applies uniformly to all past tenses. In contrast, the error pattern for Dutch singular past tenses found in the current experiment supports a view in which the mental lexicon is somehow sensitive to the occurrence (frequency) of letter clusters across morpheme boundaries linked to a single pronunciation (e.g., ste vs. stte for [st@]).

To rule out the possibility that the Homophone Dominance effect at the lexical level is restricted to the specific set of homophonous verbs we examined (i.e., stem-final d verbs), we designed a second experiment in which we investigated whether the same effect underlies the spelling of weak prefix verbs. For these verbs, confusion arises between singular present tense forms (stem + t; e.g., bestel + t; ‘orders’) and their homophonous past participle forms (stem + d; e.g., bestel + d; ‘ordered’; both [b@stEl]). In contrast to stem-final d verbs, whose two homophonous forms are present tense forms, the homophonous forms of weak prefix verbs do not belong to the same inflectional type (i.e., a
§ 2 The Homophone Dominance effect in production

present tense and a past participle form). Therefore, it is less likely that they will be prone to the disturbing effect of the attraction errors mentioned above. In addition, both homophonous forms of weak prefix verbs have an overt suffix in their spelling, while one homophonous form of stem-final d verbs is marked by a zero suffix (which is also the spelling of the verbal stem). To study the Homophone Dominance effect with weak prefix verbs, we administered an online version of the dictation task. Using the Inputlog software (Leijten & Van Waes, 2013), we were able to examine not only the error pattern (offline product data) for these verbs, but also the fine-grained pauses between keystrokes (online process data).

1.2. Online spelling-to-dictation task

1.2.1. Keystroke logging: a window to the mind

Although written production has long been understudied compared to speech production and especially perception, recent technological advancements have made it a prime source for studying cognitive processes. Writing research has taken recourse to computerized methods such as keystroke logging. This type of software logs all events of a writing session (e.g., keystrokes, cursors movements, etc.) and their timestamps in a chronological order, which can later be used for analysis. The popularity of this tool derives from the following three characteristics: it is non-intrusive, robust and reliable (Severinson Eklundh & Kollberg, 1996). Typically, researchers using keystroke logging as an experimental tool have examined the temporal organization of the writing process, i.e., how a text is chronologically constructed (Schilperoord, 1996). Keystroke logging has been used to examine a variety of subjects, ranging from the production of narratives by children (Asker-Arnason, Wengelin, & Sahlén, 2008) to the discrepancy between writing processes in L1 and L2 (Barbier, Piolat, Roussey, & Raby, 2008), the impact of writing profiles and modes on text production (Van Waes & Schellens, 2003) or even error detection (Leijten, Van Waes, & Ransdell, 2010).
A particularly fruitful line of research has focused on pauses between successive keystrokes, referred to as interkey intervals (IKIs). Pause analysis offers a unique insight into the cognitive processes underlying written text production. In perception, reaction times are used to examine the speed at which a certain item is processed. Pause times (i.e., the length of a pause) could be considered their equivalent in written production: an increase in pause times is indicative of an increased cognitive effort, associated with the manipulated variable (Schilperoord, 1996). Chukharev-Hudilainen (2014) even points to the similar distribution shapes of RTs and IKIs. In addition, not only the pause length, but also the location of the pause can be a rich source of information. Many researchers focus on relatively long pauses (i.e., about 1-3 seconds) to study processes at the macro-level. Their interest lies for instance with studying writing styles (Tillema, van den Bergh, Rijlaardsdam, & Sanders, 2011) or the correlation between pause length and text unit level (Janssen, Van Waes, & Van den Berg, 1996; Schilperoord, 1996). However, since our objective is to gain insight into the low-level processes underlying the spelling of inflected verb forms, shorter pauses representing micro-planning processes can be equally informative. In more detail, we are particularly interested whether whole-word frequency (i.e., Homophone Dominance) affects not only the written output (the product), but also the writer’s pause behavior (the process). Considering our overall theoretical framework – the impact of whole-word representations and the effect of a morpheme-based computational spelling process during the online spelling of homophonous (regular) verb forms – we will focus on experiments that have already addressed the importance of whole-word and morphemic representations, albeit in a different theoretical context.

Keystroke logging studies examining whole-word frequency effects have mainly focused on the production of isolated and monomorphemic words. A variety of tasks were used, such as transcription (i.e., copying words), naming (i.e., entering a picture name on the keyboard) or spelling-to-dictation tasks. A transcription task performed by Gentner, Larochelle, and Grudin (1988) showed that the center IKI of high-frequency English words (e.g.,
§ 2 The Homophone Dominance Effect in Production

*sys_tem* was typed faster compared to that of low-frequency ones (e.g., *oys_ter*), when the surrounding orthographic context was kept constant. In a picture naming task, naming onset latency (i.e., the time elapsed between picture onset and the first keystroke) was affected by the whole-word frequency of Spanish mono-morphemic words: a response was initiated more quickly when the picture conveyed a high-frequency word compared to a low-frequency word (Baus, Strijkers, & Costa, 2003). The picture naming paradigm was also used to examine whole-word frequency effects for homophones during handwriting (Bonin & Fayol, 2002). French participants wrote down heterographic homophones with one higher-frequency spelling (e.g., HF: *verre* 'glass' – LF: *ver* 'worm'). The results showed that onset naming latencies were shorter for the HF homophone of a pair. In the handwritten version of the picture naming task, Bonin, Fayol, and Chalard (2001) found that naming onset latencies for monomorphemic nouns were affected by Age of Acquisition (AoA), when whole-word frequency was kept constant, but not vice versa (see also Bonin, Chalard, Méot, & Fayol, 2002). These frequency and AoA effects in picture naming are to be interpreted as genuine lexical effects located at the level of orthographic retrieval, as they are not present in recognition or delayed written picture naming tasks (Bonin, Fayol, & Gombert, 1998). A third type of task, namely spelling-to-dictation yielded comparable results. Bonin and Méot (2002) found independent effects of AoA as well as whole-word frequency on handwritten onset latencies of monosyllabic nouns. The authors argue that these effects are in favor of the “involvement of lexical representations in writing to dictation in normals” (p. 144).

A limited body of research using keystroke logging has aimed to answer the question whether morphologically complex words are produced through activation of whole-word units and/or activation of their constituent morphemes (cf. the discussion on whole-word access or access through morphological decomposition in Chapter 1). Weingarten, Nottbusch, and Will (2004) reported a number of studies with isolated compounds. Longer interkey intervals (IKIs) were found when the interval was situated at both a morpheme and syllable boundary (so-called ‘morphosyllabic boundaries’; e.g.,
The homophone dominance effect in production

Kinder_wagen, ‘pram’) compared to other pure morphemic or syllabic boundaries (e.g., Kind_erwagen or Kin_derwagen) (Will, Weingarten, Nottbusch, & Albes, 2003, submitted). According to the authors, this finding suggests that during written production of morphologically complex words, morphemes are active units when they coincide with syllable boundaries (Weingarten et al., 2004, p. 539). At this intra-word interval, whole-word frequency effects also arose: shorter IKIs were found for high-frequency compounds (e.g., t_s digraph in Zeit_schrift, ‘journal’) compared to low-frequency ones (e.g., Kraft_sport, ‘weight training’) (Will et al., submitted). This was complemented by a whole-word frequency effect on total writing speed. Another experiment excluded the possibility that the facilitatory effect of whole-word frequency was confounded with that of stem frequency (Nottbusch, Grimm, Weingarten, & Will, submitted). The stem frequency of German compounds (i.e., that of the head or second constituent) did not modulate the IKIs at the morphosyllabic boundary, whereas whole-word frequency did. Weingarten et al. (2004) conclude that the stem morpheme was not accessed during typing of German compounds. This is surprising, given the fact that the compounds studied were situated in a low-frequency range, making them prime candidates for morphological composition. The authors believe that the effect of whole-word frequency at compounds’ morphosyllabic interval indicates “re-access to the representation of the whole word, that – in case of infrequent items – may have been composed earlier in production” (p. 541). The word copying task performed by Sahel, Nottbusch, Grimm, and Weingarten (2008), however, contradicts these findings. They found that the IKI between the two constituents of a German compound was not only determined by the whole-word frequency of the entire compound, but also by its stem frequency (again, that of the head). The IKIs were longer for compounds with a low whole-word frequency but also for compounds with a low stem frequency compared to their high-frequency counterparts. Importantly, both effects operated independently of each other. It is crucial to note that significant effects were again found at the morphosyllabic boundary. The authors conclude that the production of compounds involves a whole-
word and compositional route that ultimately converge (Sahel et al., 2008). More recently, the involvement of whole-word units was also confirmed in a picture naming experiment with Finnish compounds (Bertram, Tønnessen, Strömqvist, Niemi, & Hyönä, 2015). Naming onset latencies revealed a strong effect of whole-word frequency, while the frequency of the compound’s constituents did not. Based on these findings, the authors suggest that during written production compounds are retrieved as whole words before response execution. However, the IKIs of subsequent intervals also showed that planning was not entirely completed before the response was initiated. The authors found that IKIs increased at syllable and morpheme boundaries, indicating that additional planning processes are taking place during the motor execution phase, which are also influenced by morphological information. A final study on isolated word production provides further evidence for composition processes during (hand)writing. Kandel, Spinelli, Tremblay, Guerassimovitch, and Alvarez (2012) found that IKIs were prolonged for true suffixed words in French (e.g., *pruneau*, ‘prune’) compared to pseudo-suffixed controls (e.g., *pinceau*, ‘paint brush’). Crucially, increased pause times were only observed at the syllable boundary (e.g., *pru_neau*) and not at the morpheme boundary (e.g., *prun_eau*). The authors claim that “the cognitive load seems to be particularly important at the letter preceding the morpheme boundary and then decreases at the inter-letter interval that separates the root from the suffix” (p. 192). They conclude that suffixed French words are decomposed into their constituent morphemes (i.e., stem + suffix). In contrast, morphemes did not act as processing units for prefixed words, as their IKIs did not differ from those of pseudo-prefixed words.

In short, the majority of experiments using keystroke logging report whole-word frequency effects, also for morphologically complex words. Likewise, many experiments indicate the involvement of a morphological composition process for this type of words. These findings are compatible with our view that a whole-word process and a morphological process are operational during the spelling of morphologically complex words (in our case,
the spelling of inflectional variants of a verb).\textsuperscript{29} However, to our knowledge, all studies reported so far (a) have focused on word spelling outside a sentence context and (b) have targeted either mono-morphemic words or morphologically complex words like compounds and derivations (lexical morphology) but not regularly inflected verb forms (inflectional morphology). We are not aware of any study that has directly examined frequency effects on IKIs for (regular) verb forms embedded in a sentence context, certainly not when they are homophones (for pause analyses on subject-verb agreement in French, see also Alamargot et al., 2015; Largy & Fayol, 2001). This is the aim of the experiment reported below, which we will elaborate on in the following section.

\textbf{1.2.2. Weak prefix verbs}\textsuperscript{30}

\textbf{1.2.2.1. Hypothesis}

While keystroke logging research has found proof for whole-word frequency effects on IKIs during the written production of German and Finnish compounds (Bertram et al., 2015; Nottbusch et al., submitted; Sahel et al., 2008), we examine whether this is also the case for homophonic Dutch inflected verb forms embedded in a sentence context. The aim of the present experiment is twofold. Firstly, we aim to replicate the Homophone Dominance effect found for stem-final d verbs in the offline spelling-to-dictation task (see Section 1.1.1), but this time using weak prefix verbs and the online equivalent of this task. If the effect of Homophone Dominance can also be attested with these verbs, we expect fewer errors on the higher-frequency homophone of a

\footnotesize{Note that the terms morpheme-based process and whole-word access are descriptive shorthands to denote that one process involves morphemic representations and the other one involves the representation of whole-word strings. These terms do not make any assumptions on the nature of these representations, as they are compatible with both localized units and distributed, connectionist-like representations.

\footnotesize{This experiment was performed in collaboration with Anne Mampaey, Bénédicte Joret, Nathalie De Schepper and Lore Baeck in the context of their master’s thesis.}
verb pair in the offline data (i.e., the final product). Secondly, we will also analyze the pause behavior during the written production of these homophones (i.e., the online data). We are interested whether whole-word frequency modulates the IKIs of Dutch homophonous verb forms and if so, at which location. We expect shorter IKIs when the targeted inflectional form coincides with the more frequent form of a homophonous verb pair. As Homophone Ratio increases (i.e., as verbs become more d-dominant), we expect pause times to decrease when the HF d-form has to be written compared to when the LF t-form is targeted. Participants’ pause behavior should be reversed as verbs become more t-dominant: shorter IKIs should be observed for the dominant t-form compared to the LF d-form. The pause analysis will provide insight into the question whether the cognitive effort involved in spelling homophonous verb forms is the result of a whole-word procedure, a morphological composition process, or both. In addition, it will also show where the cognitive efforts entailed with spelling the correct inflectional morpheme take place.

1.2.2.2. Method

Stimuli and Design

Stimuli. We would first like to draw attention to the fact that this experiment targets weak prefix verbs rather stem-final d verbs not for the sole purpose of replicating the Homophone Dominance effect with a different set of homophonous verbs or in order to avoid the issue of proximity concord errors. There was an extra methodological reason. These verbs were also preferred in an effort to make the IKIs of the two homophonous verb forms as comparable as possible. For stem-final d verbs, the difference in IKIs between d-forms and dt-forms cannot be directly studied for all intervals because of a mismatch in word length. The problem resides in the word-final part of these forms. For d-forms, it is possible to analyze the following interval: d_SPACE. In contrast, dt-forms have an extra interval d_t, next to the word-final interval t_SPACE. Therefore, they present us with two IKI mismatches: a mismatching post-stem
interval (d_SPACE vs. d_t) and a mismatching post-suffix interval (t_SPACE vs. no IKI, as there is no suffix in the d-form). This would require us to make an arbitrary decision as to which of the two intervals to use in a comparison, if any one is suitable at all. Weak prefix verbs do not present us with this problem since we can directly compare the post-stem interval (i.e., stem_t and stem_d) and the post-suffix interval (i.e., t_SPACE and d_SPACE) of their t-forms and d-forms.

We selected 24 verbs with weak prefixes be- or ver- from SUBTLEX (Keuleers et al., 2010; Table 3 in the Appendix). As already mentioned, homophony exist between the present tense t-form (2nd person non-inverted or 3rd person singular) and the past participle d-form. Half of the selected verbs were d-dominant (i.e., more frequent in the d-form) and half were t-dominant (i.e., more frequent in the t-form). For a number of these verbs, however, stripping off the prefix leads to another existing verb form (e.g., be-stelt, ‘orders’ > stelt, ‘postulates’). We made sure that the frequency of this morphologically related verb form did not cause a shift in the dominance category of the verb. Figure 4 visualizes the Homophone Ratio measure for each verb, calculated in the same way as for stem-final d verbs (see Section 1.1.1.2). Again, a positive value indicates that a verb is d-dominant, whereas a negative value indicates a t-dominant verb. The absolute value represents the size of the frequency ratio. D- and t-dominant verbs were matched for their Homophone Ratio ($t = 1.63, p > .05$).
§ 2 The Homophone Dominance Effect in Production

Figure 4. Distribution of Homophone Ratio for the set of weak prefix verbs. The y-axis represents the logarithmically transformed ratio of the spelling forms’ frequencies. For translations, see Appendix (Table 3).

For these 24 homophonous verbs, we created two sentence contexts. The present tense (PT) context targets a verb’s t-form, while the past participle (PP) context targets its d-form. To avoid any confound between the two contexts, the semantic and/or syntactic context preceding the verb was equated as closely as possible. Examples of these two contexts are:

**PT context**

Doordat *mijn broer zijn oude paswoord nooit verandert* vormt zijn *e-mailaccount* een makkelijk prooi tijdens een *cyberaanval*.

‘Because *my brother his old password never changes* is his *mail account* an easy prey during a *cyber attack*.’
§2 THE HOMOPHONE DOMINANCE EFFECT IN PRODUCTION

**PP context**

Mijn broer heeft zijn oude paswoord nooit veranderd waardoor hij het slachtoffer werd van een cyberraanval op zijn e-mailaccount.

‘My brother has his old password never changed because of which he the victim became of a cyber attack on his mail account.’

Analogous to the offline spelling-to-dictation experiment, at least four items separated the marker from the verb form. The term *marker* refers to the word(s) containing the relevant grammatical information that is needed to correctly spell the inflectional ending. For the PT context, this is the subject of the sentence, namely a two-word combination (e.g., *mijn broer*, ‘my brother’). For the PP context, the marker is synonymous with the auxiliary verb (e.g., *heeft*, ‘have’). By keeping the distance between marker and verb constant, the cognitive load on working memory is assumed to be equal across both contexts. In practice, the homophonous verb form always appeared in seventh position. T-tests confirmed that the sentence length was equated between the two contexts ($t = 1.06, p > .05$; PT: average of 106 letters or 16 words; PP: average of 108 letters or 17 words). One crucial difference, however, is that d-forms appeared in main clauses, whereas t-forms had to be embedded at the end of subclauses for the purpose of using intervening words (given that an SOV word order only occurs in Dutch subclauses). Each critical sentence contained at least two extra difficult-to-spell words unrelated to verb spelling problems (e.g., *cyberraanval*, ‘cyber attack’). These words did not appear in the region around the verb form to draw participants’ attention away from the verb form and minimize the probability of revisions (as we were interested in the first spelling attack of the verb forms). In addition, we created 24 filler sentences that did not contain weak prefix verbs, but at least two difficult-to-spell words (e.g., *onmiddellijk*; ‘immediately’). Recordings of these sentences were made by a female speaker. The sentences were dictated twice: once at a normal speech rate and the second time at a slower pace and in chunks, without pauses around the verb region in the critical sentences.
Design. We devised four different experimental versions in total (1A, 2A, 1B, 2B), containing 36 sentences each (i.e., 12 with weak prefix verbs and 24 fillers). The 24 critical sentences containing weak prefix verbs were evenly distributed across two subsets (Subset 1 and 2) to avoid participants from becoming aware that our goal was to study the spelling of homophonous verb forms. In a counterbalanced design (list A and B), half of the verbs in list A were dictated in a PT context that targets the t-form \((n = 6)\), while the other half were embedded in a PP context that targets the d-form \((n = 6)\) and vice versa for list B. In each of the four versions, the 12 critical sentences containing weak prefix verbs were complemented by 24 filler sentences that were identical across all experimental versions. Consequently, homophonous verbs were targeted in only one third of the sentences. The different sentence types were evenly distributed across two experimental blocks. Critical sentences never appeared at the beginning or end of an experimental block and were always separated by at least one filler sentence. To allow participants to recuperate, the two experimental blocks were divided by a 2-minute pause.

Participants and Procedure

Participants. All participants came from the same education form and school, namely Institute Spijker in Hoogstraten (General Education). A total of 72 subjects with fluent typing skills were selected to participate in the experiment. They were taken from six different classes in the 3\(^{rd}\) grade of secondary school (mean age 17.02, SD = .06). The four experimental versions were randomly assigned across classes.

Procedure. Participants were seated individually in front of a computer with a Windows environment on which the keystroke logging software Inputlog was installed (Leijten & Van Waes, 2013; version 5.4.0.4). They were not explicitly instructed about the goal of the experiment, but were told that they were participating in a writing experiment that tested the general spelling ability of teenagers, without making any reference to verb spelling. They received both oral and written instructions as to the procedure of the experiment. They were
instructed to listen to the dictated sentences through headphones. We urged participants to listen to the sentences in their entirety first and only start writing the sentences down in a Word-document when they were repeated in chunks. We made sure that speech pauses never occurred right before or after verb forms. In addition, participants were explicitly instructed that punctuation marks were not necessary, unless dictated otherwise. This prevented verb forms from being followed by either a space or a comma at the end of a subclause for the PT context. This was of methodological importance, as a comma is known to be a location at which readers engage in a deeper processing of the preceding context (Hirotani, Frazier, & Rayner, 2006; Just & Carpenter, 1980; Rayner, Kambe, & Duffy, 2000). Therefore, it might represent a point at which the attention for the verb spelling is increased in comparison to when the verb form is followed by a space. After completing a sentence, subjects had to press enter. This automatically redirected them to the next blank page and thus prevented them from re-reading previous sentences. On this subject, they were also urged not to make any – immediate or delayed - revisions. They were further discouraged from making any revisions by the fact that sentences followed each other at a quick pace. Once they understood these instructions, they were told to open a website that contained the audio fragments. To familiarize participants with the procedure, they first had to listen to two practice sentences and type them in the already opened Word-document. If there were no questions at this point, they could move on to the actual experiment by clicking on the audio file matching the version mentioned on their instruction sheet. As already indicated, this audio file contained two experimental blocks of 18 sentences, divided by a 2-minute pause. After completing the dictation part of the experiment, participants were given a survey to complete. During this survey, we asked participants to provide their personal information (name, age, etc.), followed by three questions. The first question tested their knowledge of the rules for Dutch verb inflection, while a second and third question asked them to score themselves on a 10-point scale as to how well they thought they had performed in the
experiment with regard to spelling in general and spelling of verb forms more specifically. In total, the entire experiment took about one hour to complete.

1.2.2.3. Results and Discussion

Data processing. The events (e.g., keystrokes, mouse movements, ...) of each participant’s writing session were logged in an idfx-file. This was used as the basis for Inputlog’s built-in token analysis. We provided Inputlog with the targeted verb forms and their immediate context words (i.e., 1 word on the left and 1 on the right). The program then returned (a) the written product, (b) revision information and (c) IKIs for the verb form. Because the 24 weak prefix verbs varied in length, total writing times were not calculated. To compare IKIs across different verbs, we aligned their digraphs (i.e., the sequence of two-character substrings making up the spelling pattern of a word). For the first three digraphs, we worked in a step-forward manner. Let us take besteld as an example. The first digraph (d1; SPACE_b) represents the transition from the space preceding the verb form to the first letter of the verb form, while the second digraph (d2; b_e) represents the transition from the verb form’s first letter to its second one and so forth until the third digraph. Because verbs had variable lengths, with a minimum of 7 letters, there are five more digraphs that can be compared across all verbs. These were coded in a step-backward manner. Digraph 8 represents the transition from the final letter of the word to the space following it (d_SPACE), while digraph 7 represents the IKI between the penultimate and final letter (r_d) and so forth. By aligning digraphs in this way, we were able to analyze IKIs for digraph positions shared by all verbs. Because all but the final letter were identical across both conditions (PT context: bestelt vs. PP context: besteld), letter and digraph frequency were automatically controlled for (Weingarten et al., 2004), except for the final two digraphs. The following table gives an example of the digraph alignment for both the shortest and longest verb form:
Table 3. Examples of digraph alignment for weak prefix verbs in the online spelling-to-dictation task.

<table>
<thead>
<tr>
<th></th>
<th>d1</th>
<th>d2</th>
<th>d3</th>
<th>d4</th>
<th>d5</th>
<th>d6</th>
<th>d7</th>
<th>d8</th>
</tr>
</thead>
<tbody>
<tr>
<td>besteld/t</td>
<td>SPACE_b</td>
<td>b_e</td>
<td>e_s</td>
<td>s_t</td>
<td>t_e</td>
<td>e_l</td>
<td>l_d/t</td>
<td>d/t_SPACE</td>
</tr>
<tr>
<td>vertegenwoordigd/t</td>
<td>SPACE_v</td>
<td>v_e</td>
<td>e_r</td>
<td>r_d</td>
<td>d_i</td>
<td>i_g</td>
<td>g_d/t</td>
<td>d/t_SPACE</td>
</tr>
</tbody>
</table>

Results. Participants who did not complete the experiment, had a reading disorder or whose native language was not Dutch were excluded from the analysis (n = 9).

Product analysis (offline data)

For the analysis of the product data, we further removed participants with a perfect score since they do not contribute to variance across the experimental conditions (n = 16). Deviating verb forms (i.e., other than the two homophone spellings), were also excluded (e.g., *behaacht instead of behaagt). This resulted in 4% missing data. The remaining 542 data points from 47 participants were analyzed with a generalized linear mixed effects model (GLMM). The binomially distributed dependent variable was again whether or not the verb form was spelled correctly (0 = incorrect spelling; 1 = correct spelling). The control independent variables that were tested for inclusion by means of likelihood ratio tests were: Word length, Trial, Switch (i.e., was the digraph typed with one or two hands?), number of syllables, Self Score (i.e., the score participants gave themselves on verb spelling) and Log Lemma Frequency. The theoretically relevant independent variables were: Form (d-form in the PP context vs. t-form in the PT context), Homophone Ratio and, most importantly, the interaction between Form and Homophone Ratio (i.e., the Homophone Dominance effect). The maximal random structure as justified by the data included the following random effects: a by-item

31 The number of participants per version after removing these participants was: 1A (n = 11), 2A (n = 11), 1B (n = 14) and 2B (n = 11).
random intercept, a by-participant random intercept and a by-participant random slope for Form. Table 4 summarizes the results of the mixed logit model, while Figure 5 visualizes the partial effects of this model.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$z$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>1.34</td>
<td>0.20</td>
<td>6.83</td>
<td>38.54</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Self Score</td>
<td>0.19</td>
<td>0.08</td>
<td>2.35</td>
<td>5.43</td>
<td>.020</td>
</tr>
<tr>
<td>Form</td>
<td>-0.46</td>
<td>0.21</td>
<td>-2.20</td>
<td>4.81</td>
<td>.028</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>0.07</td>
<td>0.30</td>
<td>0.22</td>
<td>0.05</td>
<td>.831</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>-0.62</td>
<td>0.30</td>
<td>-2.11</td>
<td>4.42</td>
<td>.036</td>
</tr>
</tbody>
</table>

Table 4. Coefficients of a mixed logit model predicting the correctness of a verb form from Self Score, Form, Homophone Ratio and their interaction, including the estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.
As the value for Homophone Ratio increases on the x-axis, the d-form becomes the more dominant homophone of the verb pair, with negative values representing t-dominant verbs and positive values representing d-dominant verbs.

Discussion. The Self Score (10-point scale) that participants gave themselves as to how well they thought they had performed in the experiment with regard to the spelling of verb forms significantly predicted the probability of spelling verb forms correctly: the higher their Self Score, the higher the percentage of correctly spelled homophonous verbs. This indicates that participants are aware of their spelling abilities and can quite accurately
predict their own spelling performance. In addition, a significant effect of Form was found: more errors were made in the PT context targeting the t-form, compared to the PP context, where the d-form was targeted. Homophone Ratio was not significant as a main effect, but did interact with Form. This interaction effect indicates that as verbs became more d-dominant (i.e., as Homophone Ratio increased), more correct spellings were found when the d-form was the correct form (PP context) compared to when the t-form was the to-be-spelled homophone (PT context). In other words, the probability of producing a correct spelling is higher when the targeted form is the HF form of a homophonous verb pair, a finding that replicates the results for verbs with a stem-final d in the offline spelling-to-dictation task.

However, the visualization of the partial effects in Figure 5 shows that t-dominant verbs are less susceptible to the effect of Homophone Dominance. For t-dominant verbs, the difference between the correct number of d-spellings and t-spellings is much smaller compared to d-dominant verbs. As in the offline spelling-to-dictation task, this appears to be due to a bias towards a particular inflectional ending, in this case the d-form. This is evident in the significant effect of Form: the d-form is less prone to errors. A chi-square test confirmed that the number (312) of d-spellings is significantly higher than the number (230) of t-spellings ($\chi^2 = 12.41; p < .001$). Such a d-bias for weak prefix verbs was also observed with primary and secondary school children by Bosman (2005). This could be due to a number of reasons. Firstly, the presence of a prefix suggests a past participle interpretation, associated with the d-form. Specifically for weak prefix verbs containing the prefixes ver- or be- (as all verbs used in our materials), Frisson and Sandra (2002a) pointed out that the d-form (76452) is more frequent than the t-form (47019). This means that about 62% of weak prefix verb forms with these two prefixes have a d-spelling. Moreover, the majority of weak prefix verbs (i.e., 88%) are of the d-dominant type (based on CELEX counts; Baayen et al., 1995). Secondly, another explanatory factor might be the difference in the Homophone Ratio measure between d-dominant and t-dominant verbs. Although the set of t-dominant verbs is less dominant (average absolute Homophone Ratio: 0.46)
compared to d-dominant verbs (average absolute Homophone Ratio: 0.66), the difference is not statistically significant ($t = 1.63$, $p = .12$). Therefore, a mismatch between the frequency ratios of d- and t-dominant verbs is not responsible for the current pattern of results.

In sum, the product data (i.e., error pattern) reveals an effect of Homophone Dominance that is more pronounced for d-dominant verbs. However, it is also crucial to note that the percentage of correctly spelled verb forms suggests that, notwithstanding the effect of Homophone Dominance and the d-bias, participants also made use of the rule for spelling the inflected form. If we assumed that the rule did not play a role, all information sources (i.e., verbs’ dominance category and a possible prefix-induced d-bias) would predict an incorrect d-form for d-dominant verbs, when the t-form was the target. However, the t-form was spelled correctly 64% of the cases (i.e., well above chance level), suggesting that rule application also plays a role. This means that, at least for some verb forms, some participants succeeded in finishing the computational procedure within the time frame of working memory. This fits in with our view that spelling homophonous (regular) verb forms involves some kind of competition between a (on average) relatively slow computational process and a (on average) fast lexical retrieval process. Whereas the former taxes working-memory resources because it requires attentional resources and depends on the accessibility of morphosyntactic information, the latter is automatic and, hence, consumes no attentional resources. Note that, despite the high speed of the retrieval process, not all spelling attempts relying on this process result in errors. When the higher-frequency form is the target, this process will yield the correct form. It is also a misconception that the retrieval process is always the faster one. When the dominant homophone does not have a sufficiently high frequency and the morphosyntactic information needed to determine the suffix spelling is quickly available, the computational procedure will control the spelling output. This view of the underlying architecture is in line with the product data: both storage and computation are responsible for the performance of competent spellers on regular homophonous verb forms. In the following section, we will
examine whether participants’ pause behavior (i.e., the online process data) mirrors the effects found in the product data.

**Process analysis (online data)**

Incorrect or revised verb forms resulted in missing pause times for certain digraphs (e.g., the misspelling *bestle_d* instead of *bestel_d* leads to missing pause time for digraps *te*, *el* and *ld*). In an attempt to make a valid comparison between IKIs of different verbs, we excluded these forms from the analysis, analogous to the exclusion procedure used by Gentner et al. (1988), Alamargot et al. (2015) and Bertram et al. (2015). Excluding these forms leads to 46% missing data, with 411 observations from 63 participants left. Verb forms were typed 17 times on average. The recorded pause times were accurate at 6ms and were log-transformed to approach the normal distribution. We performed separate analyses on the pause times of each digraph by means of a linear mixed effects model (LMM). The following control variables were tested for inclusion through likelihood ratio tests and were removed from the model if found not to be significant at the 0.05 α-level: Self Score (cfr. supra), Log Lemma Frequency, Word Length, number of syllables, Switch (cfr. supra) and pause times for the digraph preceding and following the analyzed digraph (see Gentner, 1982, 1983). The theoretically important variables were Form (d-form in the PP context vs. t-form in the PT context), Homophone Ratio and the interaction between these two variables. The maximal random structure for each analysis was determined in accordance with the procedure explained in Section 1.1.1.3. After fully specifying the predictors included in the model, we removed potentially harmful outliers. We followed the approach outlined

32 The number of remaining participants per version were the following: 1A (n = 14), 2A (n = 16), 1B (n = 17) and 2B (n = 16).

33 For this and all subsequent analyses with a continuous dependent variable, we visually inspected the distribution of the variable by means of a qq-plot. If this revealed non-normality, we compared a log-transformation to an inverse transformation (RT1 = -1000/x). After determining which of the two was the most successful in reducing the skew in the data, we used the optimally transformed values to fit the model.
by Baayen (2008, p. 279) and considered data points as outliers when their absolute standardized residuals exceeded 2.5 standard deviations from zero. After outlier removal, we fitted a model with the same predictors to this subset of data. In what follows, we will only report these trimmed models for which the interaction between Homophone Ratio and Form was significant. This was the case for Digraph 6 only.

**Digraph 6**

The random structure of the model consisted of a by-lemma random intercept and a by-participant random intercept, which accounts for differences in typing speed. Table 5 presents the results of the regression analysis for Digraph 6. The partial effects of this model are plotted in Figure 6.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>z</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>5.09</td>
<td>0.07</td>
<td>78.93</td>
<td>142.26</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Self Score</td>
<td>-0.07</td>
<td>0.02</td>
<td>-2.76</td>
<td>7.30</td>
<td>.007</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>-0.19</td>
<td>0.09</td>
<td>-2.13</td>
<td>4.67</td>
<td>.031</td>
</tr>
<tr>
<td>Form</td>
<td>-0.02</td>
<td>0.03</td>
<td>-0.58</td>
<td>0.31</td>
<td>.579</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>0.14</td>
<td>0.09</td>
<td>1.48</td>
<td>2.38</td>
<td>.123</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>-0.14</td>
<td>0.04</td>
<td>-3.22</td>
<td>10.27</td>
<td>.001</td>
</tr>
</tbody>
</table>

Table 5. Coefficients of a mixed-effects linear regression model predicting log-transformed pause times for Digraph 6 from Self Score, Log Lemma Frequency, Form, Homophone Ratio and their interaction, together with the estimate $\beta$, standard error, t-value, $\chi^2$-value and p-value.
Discussion. Recall that Digraph 6 represents the transition from the antepenultimate to the penultimate letter of the verb form (e.g., beste_ld, ‘ordered’). The effect of Self Score was significant for Digraph 6, indicating that the pause time for this digraph decreased as participants rated themselves higher in terms of verb spelling. Spellers who are confident about their verb spelling skills not only make fewer errors (product analysis), but they also take shorter pauses when preparing to spell the correct inflectional ending of a homophonous verb form (process data). In addition, the effect of Log Lemma
Frequency was facilitatory: pause times became shorter as lemma frequency increased. This effect can indicate that inflected forms with a high lemma frequency are themselves items with a high whole-word frequency (these two frequency measures often being highly correlated as is the case here; $r = .88$). Hence, they are quickly retrieved by the whole-word route, which is then faster than the computational route. Alternatively, it may mean that the stem form is quickly available for verbs with a high-frequency lemma. Fast retrieval of HF stems also speeds up the subsequent computation of the correct inflectional ending, so that this process terminates faster than the retrieval route. In contrast, the main effects of Homophone Ratio and Form were not significant, but did interact with each other. Surprisingly, the observed interaction effect is opposite to our hypothesis. The pause times for the d-forms (PP context) increased as verbs became more d-dominant (i.e., when target form and dominant form coincided). However, the pause times for the t-form were unaffected by Homophone Ratio\textsuperscript{34}. As with the product data analysis, it appears that t-dominant verbs are less susceptible to the Homophone Dominance effect. A post-hoc analysis on the subset of t-dominant verbs indeed confirmed that the effect of Form was not significant for these items ($\chi^2 = 2.78, p > .05$), whereas it was for the subset of d-dominant verbs ($\chi^2 = 9.58, p = .002$).

The finding that the process for spelling the high-frequency d-form (PP context) is inhibited (i.e., longer pause times) for d-dominant verbs is puzzling. Possibly, rule application is responsible for the current pattern of results. In the product data analysis, we concluded that a percentage of correctly spelled (t-)forms must result from rule application. This entails that there must be a compositional process at work capable of suppressing automatic processes that lead to intrusion errors (i.e., a d-bias and Homophone Dominance) and thus paving the way for rule application. A first

\textsuperscript{34} In order to maximize the number of observations, we performed a second analysis in which forms without revisions in the critical area (d4-8) were not excluded. This analysis showed the same significant results. In addition, excluding participants with a perfect score did not alter the interaction effect between Form and Homophone Ratio or the main effect of Log Lemma Frequency.
possibility is that rule application is attempted equally often in all conditions but that the retrieval route more often ‘wins the race’ when a d-form of a d-dominant verb must be spelled. The latter assumption is required in order to account for the product data, i.e., the large percentage of correct d-spellings and incorrect t-spellings for verbs with a high d-dominance. However, under the assumption that the compositional route always takes the same time when it determines the output of the spelling process, one would expect shorter pause times for d-forms of d-dominant verbs (in contrast to the longer times we observed), since high-frequency items that can be directly retrieved from the mental lexicon speed up the spelling process (cf. Section 1.2.1 of Chapter 1). Of course, the time taken up by the compositional route may differ for the PT and PP contexts: producing a present tense form may be faster or slower than processing a past participle, even if the distance to the marker for the inflectional suffix is kept constant (as in our experimental design). If this were true, past participles would take more processing time than the 3rd person present tense, as the processing data show longer pause durations for the d-form (PP context) of d-dominant forms than for the t-form (PT context). However, this interpretation is incompatible with the finding of equal pause durations for the two contexts in the set of t-dominant verbs. The only possibility that seems to remain is that the fast retrieval of a high-frequency form does not help for regularly inflected verb forms when it conflicts with the output of a compositional process. However, this line of reasoning does not seem to offer a solution either. When two processes compete, one would expect elevated pause times when they produce a response conflict (i.e., a t-spelling vs. a d-spelling), whereas the data indicate increased pause durations when they converge on the same response (i.e., the d-spelling of d-dominant verbs). More trivial interpretations (i.e., not related to lexical processing) do not seem plausible either. It is highly unlikely that this counterintuitive result is due to differences in motor processes during typing, since both conditions were closely matched (i.e., the only difference between both word forms being the final letter). In addition, we are wary of an explanation in terms of a Type 1 error, possibly due to the low number of observations (about 50% missing.
values). Firstly, the effect is highly significant \((p < .001)\). Secondly, we also found non-significant trends in the same direction for other digraphs. Since the results for the process data present the same crossover effect as the product data, yet in the opposite direction, we believe that there must be a psychological reality for this effect.

In the literature, one finds two accounts of such an anti-frequency effect, albeit not in the context of spelling research. Anti-frequency effects for regular inflections (i.e., HF forms are produced more slowly) have been observed in speeded production experiments (Clahsen, Hadler, & Weyerts, 2004; Prasada & Pinker, 1990). Pinker (1999, p. 130) posits that a composition and whole-word retrieval route operate simultaneously and interact during the production of HF inflections. According to the authors, competition between both routes is impossible for LF words, since they do not have lexical representations. For HF regular inflected forms, however, the whole-word retrieval route accesses a stored form and hereby actively blocks the composition route, leading to a processing delay. The size of the processing delay depends on the speed with which a person is able to access the HF representation in memory. In the case of quick lexical retrieval, almost no processing delay is expected because the time needed to suppress the composition route for HF regular forms is very fast and therefore comparable to the time needed to complete the composition process for LF forms. However, if lexical retrieval is slow (e.g., with children), the delay associated with the retrieval of the HF form and the subsequent inhibition of the composition route exceeds the time required to compute low-frequency words, which leads to large anti-frequency effects. However, it is unlikely that this interpretation holds for our data. Firstly, the inhibition effect was very significant. Secondly, there is no reason to assume that our participants were “atypical” in the sense that they all exhibited slow lexical access to high-frequency forms in the mental lexicon.

An alternative account of inhibitory frequency effects for HF words has been put forward by Balota, Law, and Zevin (2000) as well as Finkbeiner, Almeida, Janssen, and Caramazza (2006). They propose that responses
becoming available for production (too) quickly (as is the case of HF words) are suspicious and are therefore rejected to avoid an error. Interestingly, this idea is compatible with both our product and process data.

On a proportion of trials, fast access to the dominant homophone will have caused participants to ‘impulsively’ write down the orthographic pattern of this homophone, as their processing system suggested that this was the correct form. In the case of d-dominant verbs, this gave rise to many correct responses when the d-form had to be spelled (PP-context) and to many incorrect responses when the t-form had to be spelled (PT-context), i.e., a normal effect of Homophone Dominance. In other words, the proportion of cases on which participants relied on the output of the whole-word process caused the effect of Homophone Dominance in the product data.

However, the performance on the t-forms of these outspoken d-dominant verbs (around 64%) indicates that participants did not always trust the output of the whole-word access process, but also often relied on the output of a morpheme-processing mechanism. The almost perfect performance when the d-form of these verbs was the correct spelling is compatible with this analysis, as the d-spelling was the output of both the whole-word access process and the morpheme-based process (this spelling being both the HF form and the grammatically correct form).

Participants’ reliance on the output of the morpheme-based mechanism on a sizeable proportion of trials can account for the process data, i.e., the pause time analysis of the non-revised and fully correct responses. More particularly, it can account for the reverse effect of Homophone Dominance. This account hinges on the idea that quickly available responses are suspicious and, hence, rejected, as suggested by Balota et al (2000) and Finkbeiner et al (2006). Obviously, this suspicion is independent of the target form. In other words, it is the same when a d-form or a t-form must be spelled, as it does not depend on the targeted spelling, but on the quick output of the

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35 We will focus on the d-dominant verbs, as the effect of Homophone Dominance was absent for the t-dominant verbs, possibly due to a d-bias (cf. analysis and discussion of the product data).
whole-word access process. Hence, the reverse effect of Homophone Dominance must emerge when the slower morpheme-based process yields its output. At that moment in processing, the notion of a suspicious response can play its crucial role. On the one hand, when the output of the morpheme-based process matches the suspicious output of the whole-word retrieval process, participants are surprised that the initially rejected response eventually turns out to be the correct one after all. On the other hand, when the morpheme-based process yields a different response, participants are reassured that they did well when rejecting the quickly available response. The result is a reverse effect of Homophone Dominance, i.e., the HF form causes an inhibition effect in participants’ response speed when it is the homophone’s correct spelling.

At first sight, this analysis might sound counter-intuitive. One could reason that, once participants have rejected the response of the whole-word retrieval process, they will exclusively rely on the output of the morpheme-based process. This would predict equal response times for the HF d-spelling and the LF t-spelling of very d-dominant verbs, whereas inhibition was observed for the HF form. It follows that participants were not able to fully suppress the suspicious response. Alternatively, one might reason that, as the suspicious response remains available until processing has terminated (i.e., until the morpheme-based process has yielded its output), faster responses will be made when the two processes yield the same response (as is the case for the d-spelling of these d-dominant verbs) than when they yield different responses (as is the case for the t-spelling). The slower responses in the latter situation would be due to a response conflict. Following this line of reasoning, one would expect facilitation on correctly spelled HF forms, i.e., a normal frequency effect. However, the reverse effect was found, rejecting an account in terms of a response conflict.

Hence, the finding of an inhibition effect on the HF correct spellings reveals two ‘negative’ conclusions: (a) participants were unable to completely suppress the quickly available response of the HF form and (b) the notion of a response conflict cannot be the explanatory concept. However, as argued above, an account in which it is assumed that the responses of both processes
remain available and that the first one is tagged as ‘suspicious’ can make perfect sense of the reverse effect of Homophone Dominance in the pause times. The fact that the fast access to the whole-word representation of a HF representation made participants distrust this output and, hence, reject it as a basis for responding, turned the morpheme-decision process into the most trustworthy process. This resulted in a different status for the outputs of the two processes, making the output from the slow (and more deliberate) morpheme-based process ‘reliable’ and the output from the whole-word access process ‘suspicious’. As a result, participants were surprised when the former process confirmed the suspicious response. This caused longer pause times. However, they were not surprised when that process yielded a different response than the suspicious response. Thus, a reverse frequency effect emerged in the processing data.

Our findings of a normal frequency effect in the product data (manifesting itself in the form of an effect of Homophone Dominance) and a reverse frequency effect in the process data (manifesting itself in a reverse effect of Homophone Dominance) are quite compatible. Their explanation does not require changes to the architecture for processing lexical homophones that we have used so far, i.e., fast whole-word retrieval and slow morpheme-based processing are the only two processes that play a role. It only requires the reasonable assumption that when having to type a verb homophone, its HF spelling becomes so quickly available that (a) it cannot be withheld on a proportion of cases (causing the normal effect of Homophone Dominance in the product data) and (b) can be withheld and classified as a suspicious response on another proportion of cases. When the trusted response of the morpheme-based process coincides with the mistrusted response of the whole-word retrieval process (i.e., when the HF form is the correct spelling), participants are temporarily confused. This is reflected in longer pause times than in cases where the mistrusted (i.e., rejected) response is also rejected by the morpheme-based process.
§ 2 THE HOMOPHONE DOMINANCE EFFECT IN PRODUCTION

In sum, the present online spelling-to-dictation experiment is the first in its kind to examine whole-word frequency effects for regularly inflected verb forms embedded in a sentence context. In a first analysis of the product data, we examined whether the error pattern for weak prefix verbs was modulated by the effect of Homophone Dominance. Similarly to what we observed for verbs with a stem-final d in the offline equivalent of the task, more intrusion errors were found when the target form was the low-frequency homophone of a verb pair. This effect was more pronounced for d-dominant verbs, possibly due to a d-bias. The error analysis corroborates the results of previous offline spelling-to-dictation experiments (Bosman, 2005; Sandra et al., 1999). In a second analysis of the process data, we examined whether the pause analysis mirrored the product analysis. While we expected IKIs to be shorter when the targeted form was congruent with the more dominant form of a homophonous verb pair, we found the reverse effect for d-dominant verbs. Contrary to our hypothesis, pause times for d-dominant verbs at Digraph 6 (i.e., the antepenultimate digraph, preceding the critical digraph containing the suffix spelling) were longer for the higher-frequency d-form compared to the lower-frequency t-form. For t-dominant verbs, pause times did not differ between d- and t-forms. We can account for the inhibitory effect on the high-frequency d-form of d-dominant verbs by assuming that an initial hesitation to output the quick response made available by the retrieval process for HF forms had to be overcome when the output of the morpheme-based checking mechanism yielded the same output. This evidently led to longer pause times compared to when the LF homophone was the correct spelling. In contrast, we did observe a facilitatory effect of Log Lemma frequency at the same interval: IKIs became faster as verbs’ lemma frequency increased. This finding can suggest two things: the written production of inflections in the process of typewriting involves a compositional route that accesses a verb’s stem (i.e., shorter pause times for verbs with a high-frequency lemma) that is terminated before that of whole-word retrieval. This would corroborate previous findings by Sahel et al. (2008), who found that the pause times for German compounds are co-determined by stem frequency, with shorter pauses for compounds with a
high-frequency head. Alternatively, the lemma frequency effect is confounded with that of whole-word frequency (i.e., verb forms with a high lemma frequency are often words with a high whole-word frequency) and indicates that these verb forms are quickly retrieved by the faster whole-word route.\footnote{Note that this does not contradict the earlier account in terms of a conflict of suspicious vs. reliable responses. This conflict involves the two homophones of the same verb, which have the same lemma frequency. In contrast, the effect of lemma frequency is situated between verbs and does not involve differences between their HF and LF homophones.}

The pause analysis also showed where the cognitive efforts involved in spelling the correct inflectional morpheme take place, namely at the digraph preceding the suffix. This location of the frequency effects does not come as a surprise. Effects at the intra-word level for suffixed words were reported by Kandel et al. (2012) (see also Weingarten et al., 2004). They suggest that “the suffix is kept active since the beginning of the word or [...] is re-activated at certain locations before the actual production of the suffix itself” (p. 193). This re-activation of the suffix is said to manifest itself particularly at the letter preceding the morpheme boundary (Kandel et al., 2012). The cognitive load subsequently “decreases at the inter-letter interval that separates the root from the suffix” (p. 192). This view fits in with the present results, since the observed frequency effects were found at the digraph preceding the interval containing the inflectional suffix.

In the following experiment, we will examine whether the effect of Homophone Dominance at the sublexical level found in the error pattern of the offline spelling-to-dictation task also transfers to the error pattern and pause behavior in an online spelling-to-dictation task (i.e., the same rationale that we applied to stem-final d and weak prefix verbs).
1.2.3. Past tense verb forms

1.2.3.1. Hypothesis

In this experiment, we examine whether the Homophone Dominance effect at the sublexical level found in an offline spelling-to-dictation task is also present in the product and process data of its online equivalent. We made use of the same set of singular past tense forms whose final phoneme cluster /t@/ is ambiguous between the homophonous orthographic patterns te and tte. Recall that for verbs whose stem ends in -s (e.g., suste, ‘hushed’) the correct pattern is ste, but that there are also verbs whose final past tense cluster is stte (e.g., rustte, ‘rested’). We compared these s verbs to p verbs, which do not involve sublexical homophony (i.e., pte is the only existing orthographic cluster).

Since the offline spelling-to-dictation task showed that errors are more likely for the former verb type (e.g., *sustte for suste), our first aim is to find out whether the occurrence of a sublexical homophonous pattern also modulates the error pattern in an online production task. We expect the error data (i.e., the product data) to show that sublexical intrusions are more likely for verbs with a homophonous orthographic pattern in word-final position (i.e., for s verbs). Our second aim is to examine the difference in pause behavior (online data) between verbs with and without sublexical homophony. We hypothesize pause times to be longer for past tense forms with a homophonous orthographic pattern (i.e., s verbs) compared to verbs without such a competing pattern (i.e., p verbs). Diverging pause times for s and p verbs are taken to be indicative of the choice or uncertainty to spell a single or double t, which we expect for the former but not for the latter verb type.

In addition, we are also interested in examining at which location the cognitive efforts involved in making this choice are situated. Based on other research findings, we expect these efforts involved in selecting the correct orthographic ending of the inflected verb form (te or tte) to lead to increased pause times at the morphosyllabic boundary (Weingarten et al., 2004) or the
boundary preceding it (Kandel et al., 2012; see also Section 1.2.2.3). The former location is supported by keystroke logging studies on the spelling of words containing doublets: the choice whether a single or double consonant will be spelled is made before the first of the two consonants (Nordqvist, Leiwo, & Lyytinen, 2003; Solheim & Uppstad, 2003: both cited in Strömqvist, Holmqvist, Johansson, Karlsson & Wengelin, 2006). In our case, this interval also coincides with the morphosyllabic boundary, i.e., between the stem-final letter s or p and the first suffix letter t (i.e., the first letter of the orthographic sequence te or tte).

1.2.3.2. Method

Stimuli. The same 24 past tense verb forms used in the offline spelling-to-dictation task (see Section 1.1.2.2) were incorporated in the online equivalent. As already mentioned, half of these verb forms had a stem ending in -s (e.g., suste, ‘hushed’) while the other half had a stem ending in -p (e.g., repte, ‘rushed’). They were embedded in sentences consisting of 11 words, with the past tense appearing in fifth position. To exclude the possibility that differences in pause times were due to the surrounding context, we made a sentence pair for each dyad of an s and a p verb. These sentences were matched for the word preceding the critical verb form and for the two words following it (i.e., x-1 until x+2). An example of a matched sentence pair is the following:

```
1 2 3 4 5 6 7 8 9 10 11
p verb Toen hij wakker werd repte hij zich onmiddelijk naar zijn werk.
   ‘When he woke up rushed he himself instantly to his work place’
```

```
1 2 3 4 5 6 7 8 9 10 11
s verb Toen dat bekend werd suste hij zich met een optimistische gedachte.
   ‘When that public became calmed he himself with an optimistic thought’
```

Note also that the sentence structure is similar to that used in the previous experiments, i.e., a structure consisting of a subclause followed by the main clause. In addition, the critical sentences contained an extra spelling difficulty on a word that
was not a verb (e.g., onmiddellijk, ‘immediately’). To further draw attention away from the purpose of the experiment, we included 30 filler sentences with a similar sentence structure containing difficult-to-spell words, none of which was related to the spelling of past tense forms, such as:

Sinds mijn opa **gepensionneerd** is, maakt hij elke dag overheerlijke pannenkoeken.
‘Since my grandpa retired, makes he every day delicious pancakes.’

Recordings of these sentences were made by a female speaker. The sentences were dictated twice: once at a normal speech rate and the second time more slowly and in chunks, but (crucially) without pauses around the verb region (x-1 until x+1).

**Design.** Four experimental versions (1A, 2A, 1B, 2B) were created, consisting of 36 sentences each. As in the offline spelling-to-dictation task, the 24 critical sentences were evenly distributed across the four experimental versions ($n = 6$), to avoid putting focus on past tense forms. In total, each version contained three $s$ verbs (with sublexical homophony) and three $p$ verbs (without such homophony). The six critical sentences in each version were complemented by 30 filler sentences. We created two randomization sequences in which the 36 sentences of each version were evenly distributed across two experimental blocks, divided by a 2-minute pause. The following restrictions applied to the randomization sequences: critical sentences did not initiate or terminate one of the two experimental blocks and were separated by at least one filler sentence.

**Participants & Procedure**

**Participants.** Twenty-five subjects with fluent typing skills, who were students at Antwerp University, participated for course credit (mean age: 21.64; SD = 1.92). None of the participants were non-native speakers of Dutch or had a reading disorder.
**Procedure.** The procedure used was nearly identical to the one described in Section 1.2.2.2. Audio files were placed on the computer instead of on a website, no survey was administered and the experiment only took about 30 minutes to complete. Before the practice trial, we also measured participants’ typing speed. Since we wanted to examine whether pauses were significantly slower for s verbs compared p verbs, we had to exclude the possibility that the difference between the two was due to motor differences\(^37\). While the two letters on each side of the morphosyllabic boundary for s verbs (i.e., s\(_t\)) involve typing with different fingers of the same hand, the letters on each side of the morphosyllabic boundary of p verbs (i.e., p\(_t\)) are typed with two hands. To account for the speed with which both intervals were typed, we asked participants to complete a copy task before the actual experiment. They had to copy two sentences ten times. Each sentence contained both a word ending in -pte and a word ending in -ste. One word was a past tense verb form (e.g., *kruiste*, ‘crossed’) and the other was an adjective (e.g., *gehandicapte*, ‘handicapped’), both word categories being used once for the ste and pte clusters. The verb forms and adjectives were matched on frequency, length, position in the sentence and letter preceding the s/p. The average pause time of each participant for both intervals (i.e., s\(_t\) and p\(_t\)) was later used as explanatory variable in the statistical analysis. These were the two sentences to be copied:

De slang **kruiste** het pad van de **gehandicapte** commissaris.
‘The snake **crossed** the path of the **handicapped** commissioner.’

De vrouw **stripte** die dag voor de **enthusiaste** echtgenoot.
‘The woman **stripped** that day for the **enthusiastic** husband.’

\(^{37}\) It was not necessary to account for differing typing speed across the two conditions in the online spelling-to-dictation task targeting lexical intrusions, since both conditions (i.e., PT and PP context) involved the same verb (e.g., *verzamelt* and *verzameld*). The letters *t* and *d* are typed with the same hand.
1.2.3.3. Results and Discussion

Data processing. Participants’ writing sessions were stored in an idfx-file, which can be used by Inputlog’s token analysis to extract the targeted verb forms (see Section 1.2.2.3). However, due to an unidentified problem, the token analysis did not function properly. Therefore, we extracted the offline (i.e., final product) and online data (i.e., pause times and revision information) for the past tense verb forms on the basis of the General analysis generated by Inputlog (Leijten & Van Waes, 2013; version 5.4.0.4).

In order to deal with differing word lengths, we applied the same alignment procedure described in Section 1.2.2.3. This allowed us to analyze the pause times for digraph positions shared by all verbs. Since the selected past tense forms were very short (between 5 to 8 letters), there were only six shared digraphs. A step-forward procedure was applied for the first two digraphs. Let us take suste as an example. The first digraph (d1) represents the transition from the space preceding the verb form to the first letter of the verb form (SPACE_s) while digraph 2 (d2) represent the transition from the first to the second letter (su). Digraphs 3 to 6 were coded in a backward manner. Digraph 6 represents the transition from the final letter of the word to the space following it (e_SPACE), while digraph 5 represents the IKI between the penultimate and final letter (t_e) and so forth. The alignment procedure is exemplified in Table 6, for the shortest word (i.e., suste) and the longest word (i.e., schrapte).

<table>
<thead>
<tr>
<th></th>
<th>d1</th>
<th>d2</th>
<th>d3</th>
<th>d4</th>
<th>d5</th>
<th>d6</th>
</tr>
</thead>
<tbody>
<tr>
<td>suste</td>
<td>SPACE_s</td>
<td>s_u</td>
<td>u_s</td>
<td>s_t</td>
<td>t_e</td>
<td>e_SPACE</td>
</tr>
<tr>
<td>schrapte</td>
<td>SPACE_s</td>
<td>s_c</td>
<td>a_p</td>
<td>p_t</td>
<td>t_e</td>
<td>e_SPACE</td>
</tr>
</tbody>
</table>

Table 6. Digraph alignment for two past tense forms: one ending in ste and one ending in pte.

Product data

Results. After removing participants that did not make any sublexical intrusion errors (n = 20), we were left with only 27 observations when
§ 2 The Homophone Dominance Effect in Production

summing over the data from 5 participants. Due to this small number of observations, we were unable to statistically analyze the product data. From a descriptive point of view, however, we noticed that in the set of 27 remaining observations, only seven contained a sublexical intrusion, six of which were made on s verbs. A binomial test shows that the probability of observing 6 intrusions on s verbs and 1 intrusion on p verbs to be marginally significant (p = .055). The difference in overall error rate between the online and offline spelling-to-dictation task can probably be traced back to two factors. First of all, only 25 participants took part in this experiment, compared to 94 participants in the offline variant. Secondly, the participants in the online task were on average four years older and, perhaps more importantly, were students at the Linguistics Department of Antwerp University (instead of 6th graders in secondary school). These two factors possibly led to a smaller error percentage in the online production task.

Process data

Results. As for the online spelling-to-dictation task targeting lexical intrusions, revised and incorrect verb forms were removed to avoid invalid comparisons due to missing or alternative digraphs (see Alamargot et al., 2015; Bertram et al., 2015; Gentner et al., 1988). This procedure resulted in 11% missing data points and 134 remaining observations. Verb forms were typed 6 times on average. The recorded pause times serving as dependent variables were accurate at 6ms. Pause times were transformed to approach a normal distribution by means of the following formula: -1000/Pause time. The pause time for each digraph was analyzed separately using a linear mixed effects model (LMM). The control independent variables tested for inclusion were: Word Length, Trial, Switch (i.e., was the digraph typed with one or two hands), log Whole-word Frequency, Log Lemma Frequency and Pause Time for the preceding digraph (see Gentner, 1982, 1983). Specifically for the analysis of Digraph 4, representing the digraph whose letters occurred on both sides of the morphosyllabic boundary, the per-participant average typing speed for the s_t and p_t intervals taken from the copy task was also tested for
The explanatory variable of interest was whether or not a verb exhibits Sublexical Homophony (no vs. yes). After determining the random structure of the model, we followed the same outlier removal approach that was used in the pause analysis of weak prefix verbs (see Baayen, 2008, p. 279). After removing outliers, defined as data points whose absolute standardized residuals exceeded 2.5 standard deviations from zero, we fitted a model with the same predictors to this restricted data set. We will only report these trimmed models in which the effect of Sublexical Homophony proved to be significant. The analyses showed that this effect was restricted to Digraph 4. The random structure of the LMM for Digraph 4 incorporated the maximal random effect structure justified by the design, namely a by-participant random intercept and slope for Sublexical Homophony and a by-item random intercept. The results of the regression model for Digraph 4 are presented in Table 7, while the partial effects for this model are plotted in Figure 7.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( \beta )</th>
<th>( SE(\beta) )</th>
<th>( z )</th>
<th>( \chi^2 )</th>
<th>( p(&gt;\chi^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>5.20</td>
<td>0.09</td>
<td>59.43</td>
<td>135.27</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Average Typing Speed</td>
<td>0.005</td>
<td>0.001</td>
<td>4.52</td>
<td>15.48</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Sublexical Homophony</td>
<td>0.35</td>
<td>0.17</td>
<td>2.09</td>
<td>4.39</td>
<td>0.036</td>
</tr>
</tbody>
</table>

Table 7. Coefficients of a mixed-effects linear regression model predicting the inverted ((-1000/Pause Time)) pause time for Digraph 4 from average Typing Speed and Sublexical Homophony, together with the estimate \( \beta \), standard error, \( z \)-value, \( \chi^2 \)-value and \( p \)-value.
Figure 7. Partial effects plot of effects represented in Table 7.

**Discussion.** Recall that Digraph 4 represents the morphosyllabic boundary, namely the transition between the final letter of the stem (s or p) and the first letter of the past tense te-suffix. The results show that the per-participant average typing speed for the s_t and p_t intervals measured in the copy task significantly predicted the pause times of Digraph 4: as the average typing speed for that interval increased, so did the pause times. In addition, the effect of Sublexical Homophony was also significant: the pause times for s verbs were significantly longer at the morphosyllabic boundary compared to p verbs.
§ 2 The Homophone Dominance Effect in Production

The former finding is relatively easy to understand. Slow typers have on average longer IKIs because their motor skills involved in typing are less automatized. Hence, the effect may mean nothing more than the simple fact that participants who typed slowly in the copy task also needed a longer IKI at the critical Digraph 4. In that case, the effect is purely the reflection of the degree to which motor skills in typing have become automatic. Alternatively, it might also be informative on the time taken by ongoing cognitive processing. When an interval requires slow typers to engage in a cognitively demanding process, i.e., make a decision as to whether the next orthographic sequence is *te* or *tte*, it makes them face the analogue of a dual task paradigm, which causes a temporary overload in working-memory and a resulting long IKI. Fast typers, on the other hand, who have a much better motor control when typing, can allocate more working-memory space to the demanding cognitive process and, hence, spend less time to finish it, which manifests itself as a shorter IKI at the critical Digraph 4. Although both these interpretations are compatible with the data, the former is the simplest one and, hence, the most parsimonious.

The second finding supports our hypothesis that pause times for rule-based spelling forms increase at the morphosyllabic boundary, as a result of a competing homophonous pattern at the sublexical level. If the rule were uniformly applied, pause time should not differ depending on the preceding grapheme (*s* or *p*). However, the results show that pause times are significantly shorter for verbs evoking no confusion for the spelling of the sound sequence [t@] between *te* or *tte* (i.e., *p* verbs) compared to verbs with a homophonous competitor (i.e., *s* verbs).

The finding that pause times are delayed when there is competition for a grapheme cluster at the sublexical level mirrors the findings by Bonin and Méot (2002) in a spelling-to-dictation handwriting task (see also Bonin, Peereman, & Fayol, 2001). They found that onset latencies for monosyllabic nouns were co-determined by phonology-to-orthography (PO) consistency of final units, with longer pause times for inconsistent items. The authors argue that it is highly likely that multiple phoneme-to-grapheme mappings become
available, the relative frequency of which determines the choice for a specific spelling. In a dual-route model of spelling in which both a lexical (e.g., whole-word frequency) and sublexical (e.g., PO consistency) route are involved (Rapp, Epstein, & Tainturier, 2002), the competition between alternative orthographic realizations results in a processing delay compared to the situation where both routes converge (Bonin & Méot, 2002). Such an explanation is entirely in line with our findings. Competition between two different phoneme-to-grapheme conversions (/st@/ > ste or stte) took longer to resolve than a case in which no such competition was present (/pt@/ > pte). Note that the difference in pause times between the two verb types cannot be attributed to word length or lemma/whole-word frequency since they were closely matched. Crucially, the effect can also not be due to cluster frequency in general since the trigram ste (2420.35 occurrences per million) appears 13 times more often word-finally compared to the trigram pte (183.95 occurrences per million)\[^{38}\]. We therefore conclude that the delay in pause times can only result from the ambiguity in the phoneme-to-grapheme conversions of s verbs (e.g., suste) caused by the homophonous stte-pattern found in other past tenses (e.g., rustte). Note that the two homophonous spelling patterns do not coincide with a morpheme but extend across the morpheme boundary.

The results also support our hypothesis in terms of the location where the cognitive efforts involved in spelling the ambiguous cluster are situated. As hypothesized, pause times diverged for verbs with and without sublexical homophony at the morphosyllabic boundary, i.e., at the digraph representing the transition from the final letter of the verb stem to the first letter of the suffix. Here, the choice between the t-spelling and the tt-spelling has to be made. This interval has been shown to be particularly sensitive to effects of lexical access, such as whole-word frequency (Weingarten et al., 2004). Specifically for the spelling of double consonants, keystroke logging studies

\[^{38}\] The bigram frequency of st (27780.49 occurrences per million) is also much higher than that of pt (1851.95 occurrences per million) in the SUBTLEX-NL database (Keuleers et al., 2010).
have demonstrated that the cognitive efforts related to the choice of the double spelling are located before the first of the two consonants (Nordqvist et al., 2003; Solheim & Uppstad, 2003: both cited in Strömqvist, Holmqvist, Johansson, Karlsson & Wengelin, 2006). Recall that the effect of Homophone Dominance for homophonous weak prefix verbs was situated one interval earlier (i.e., at the digraph preceding the morphemic boundary).

In sum, we can conclude that pause times for Dutch past tense inflections, which (in principle) can easily be computed online by means of a rule (i.e., add a te-suffix to the verb stem), are influenced by the presence a homophonous orthographic cluster at the sublexical level. Pause times diverged for s and p verbs at the morphosyllabic boundary, the location where spellers decide whether to write a single or double t. Whereas the correct spelling of the past tense suffix [t@] is always te, pause times for s verbs (correct spelling is ste) were delayed by the existence of a homophonous stte-pattern in phonologically similar words compared to p verbs (correct spelling is pte) for which the alternative ptte-pattern is not attested in other words. This shows that regular inflection is not strictly rule-based: if people applied the rule, pause times should be insensitive to the identity of the preceding grapheme (s or p). Since the speed at which the spelling of the past tense te-suffix was initiated depended on the presence of a sublexical homophonous pattern, we put forward the hypothesis that spellers are sensitive to the statistical co-occurrence of letter strings, whether they constitute morphemic units or not.

In the final section of this chapter, we will examine whether the Homophone Dominance effect on lexical intrusions also manifests itself in a naturalistic context, i.e., in real-life writing situations. Furthermore, we will investigate the role of morphological and phonological neighbors on the preferred inflectional ending.
2. **NATURALISTIC CONTEXT**

2.1. **Hypothesis**

It can be argued that intrusion errors elicited in dictation experiments under time pressure are not representative of ordinary writing situations. The conditions created under such ‘laboratory conditions’ obviously differ in many ways from real-life writing situations. Even so, one might counter such criticisms by pointing out that the higher likelihood to observe intrusions from higher-frequency homophones could not occur if these homophones were not somehow represented in the lexical architecture. Indeed, the errors that a system can make by definition reflect the design features of that system, no matter the circumstances in which these errors are observed. Thus considered, the laboratory conditions created in speeded dictations merely push the system to its limits, as the researcher is in search of a clear stamp of the system’s underlying structure. Yet, one might object, the magnitude of the Homophone Dominance effect is perhaps exaggerated under experimental conditions. In other words, it is possible that in a real-life writing context this effect is a very small one and is perhaps even barely observable. If that were true, the theoretical implications of the effect would be less interesting.

Therefore, we aim to demonstrate that the Homophone Dominance effect is not only a source of errors under experimental conditions, but equally affects the normal spelling process. To that end, we attempted to extend the effect of Homophone Dominance to a large corpus of naturalistic data. Finding the effect in a large sample of texts would provide a stronger empirical basis for the idea that regular verb forms have their own orthographic representations in the mental lexicon. In addition to an effect of whole-word frequency of the verb itself, we will also investigate whether the whole-word frequency of words bearing morphological and/or phonological similarity to that verb (i.e., morphological and phonological neighbors) co-determines which inflectional suffix is spelled. This is based on the hypothesis that the preferred spelling of homophonous verb forms is determined not only by a
verb’s dominant orthographic pattern but also by that of words sharing an identical or similar phonological structure. The rationale for this hypothesis fits our view of the mental lexicon, which has been proposed throughout this work: the structure of the mental lexicon or the lexical access process itself is sensitive to words that are very similar to the target word, i.e., homophones but also morphologically related words and words that are (only) phonologically related (for instance, through a homophonous orthographic sequence straddling the morpheme boundary; cf. sublexical intrusions). Whereas some connectionist architectures are able to capture these similarities in the way words are encoded into the weight structure of its connections, an exemplar-based processing model may capture them by its sensitivity to morphological and phonological relationships during the process of lexical access. Whereas the small number of verb forms that can be used in an experimental context makes it difficult to study the influence of morphological and phonological neighbors, the variety of forms that can be found in a large database makes it possible to include these additional factors in our study.

### 2.2. The ecological validity of the Homophone Dominance effect

While a clear Homophone Dominance effect arose under experimental conditions (Frisson & Sandra, 2002b; Sandra et al., 1999; Sandra & van Abbenyen, 2009), Sandra (2010) conceded that this effect might be an artifact of speeded dictation tasks. He posits that this type of task could also be seen as artificial or devoid of meaning and result from “a superficial process of mapping sounds onto graphemes” (p. 437). It might therefore not be representative of normal writing situations and their underlying mental processes. Because experimental studies furthermore targeted only a preselected and small set of verbs, a complementary analysis of naturalistic corpora is necessary to generalize from experimental to naturalistic writing.
situations. However, note that there is also an important similarity between both contexts. Just like an experimental context, a naturalistic context is time-consuming. Because people also focus on content and formulation during normal writing, not all memory resources are allocated to monitoring spelling issues. Hence, normal writing places a burden on working memory and gives leeway to sources of noise such as the frequency-sensitive retrieval of orthographic representations (assuming that representations for high-frequency verb form homophones indeed exist). In addition, as has been mentioned above, it seems improbable that a system that is artificially put under pressure were to produce errors that shed no light on its internal design and workings, i.e., experimental conditions are meant to be a model of the real writing situation. However, no matter how unlikely it may seem that the effect of Homophone Dominance only turns up in experiments, the test of the pudding is still in the eating, i.e., one can only claim an effect of Homophone Dominance in naturalistic writing if one has actually studied errors in such a context.

To test whether the Homophone Dominance effect was indeed an experimental artifact, Sandra (2010) examined whether the effect was also present in a corpus study based on Google counts. He found that the frequency relation between the two homophones of verbs with a stem-final d indeed modulated the error pattern: more errors were found where the HF homophone invaded the spelling of the LF homophone than the other way around. However, there are a number of issues with the approach taken by Sandra (2010).

Firstly, only the pattern “ik (‘I’) + verb” and “hij (‘he’) + verb” were searched for. This excludes utterances that have intervening items between subject and verb form, all 2\textsuperscript{nd} person and imperative forms, as well as the inverse construction, or third-person constructions that have a noun phrase as a subject rather than a simple pronoun. Consequently, many instances of homophonous verbs (potentially the most ambiguous ones) were left out of the equation.
§ 2 THE HOMOPHONE DOMINANCE EFFECT IN PRODUCTION

Secondly, Sandra (2010) does not take into account the fact that Google counts are problematic for a number of reasons. A first confound is that the pattern that is searched for is not always correctly targeted by looking for this two-word sequence. Due to the removal of punctuation and capitalization in the search process, elements across two different sentences or phrases might incorrectly be grouped together. Moreover, since no part-of-speech tagging is present, Google counts are particularly ambiguous for the wrong spelling of 3rd person singular present tense forms, which is identical to the spelling of the verb’s past participle. If one looks for the incorrect 3rd person singular *hij betekend (‘he meant’), one will also target correct past participles (e.g., Wat hij betekend heeft voor mij...; ‘What he meant has for me...’). A second issue pertains to the fact that Google counts are based on page hits rather than instances. Although page counts are highly correlated with n-grams (Keller & Lapata, 2003), this approach ignores multiple occurrences of a pattern on the same page. A third factor that introduces noise into Google counts is that the large majority of hits when searching for homophonous verbs occur in the context of texts explaining the spelling rules of Dutch verb forms. A quick check shows that among the first ten hits for the spelling pattern ik vind (‘I find’), six pages were about how to apply the rule, containing both correct and incorrect instances. While Sandra (2010) argued for the reliability of Google counts by examining the same group of verbs in two different data sets collected three years apart, Nakov and Hearst (2005) point to the instability of counts for the exact same search, as a result of queries being sent to different machines storing different data and differing in update cycles. Whereas the sequence hij vindt (‘he finds’) resulted in 544,000 hits on a particular day, the number of hits was 529,000 a few days later. This also confirms the observation made by Nakov and Hearst (2005) that Google counts for searches with many hits are not accurate, but rounded. The final and biggest problem, however, resides in the number of duplicates taken up in the Google counts. Many identical texts (e.g., news reports, lyrics, book reports, etc.) appear on

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39 Reported counts result from Google search queries on the 31st of October and 5th of November 2014.
multiple sites (i.e., different URLs). While these pages should be counted as a single hit, they all equally add to the count. For the aforementioned reasons, Google counts are inherently prone to a lot of noise. Therefore, we preferred to compile a carefully annotated corpus that has access to the writer’s identity. We will discuss the characteristics of this corpus in the Method Section (2.4).

2.3. Morphological and phonological neighbors

2.3.1. Evidence in favor of morphological and phonological neighbors

As already mentioned in our hypothesis, we aim to prove that the preferred spelling pattern of regular Dutch verbs is not only determined by Homophone Dominance, but is co-determined by a verb’s morphological and phonological neighbors. In what follows, we will review evidence from both production and perception experiments that supports our hypothesis that orthographic representations of words sharing a similar phonological pattern with the to-be-spelled homophonous verb form (i.e., morphological and/or phonological neighbors) are also activated, next to those of the verb’s exact homophones.

Our hypothesis that morphologically related words are activated during the production of words with an ambiguous orthographic pattern is supported by studies with very young children. Experiments have revealed that language users are aware of morphological relations between words from a very young age onward and can make use of this morphological information during spelling. Treiman, Cassar, and Zukowski (1994) showed that 5- to 8-year-olds’ spelling accuracy of the intervocalic phoneme /d/ in American English, correctly spelled as t, depended on whether it was the final letter of a stem morpheme or not. More correct t-spellings were found when the /d/-phoneme was the final letter of a stem’s spelling in multimorphemic words such as dirty compared to when it was not, as in monomorphemic words such as duty. This
indicated that young spellers made use of their knowledge of the stem’s spelling (*dirt* is spelled with a *t*) to spell the morphologically related word *dirty*. They could not rely on this type of morphological information to reduce error rates in the case of monomorphemic words. Reliance on morphologically related words is especially evident in the case of word-final silent letters, i.e., letters that are not pronounced. Sénechal (2000) showed that 7- and 9-year-olds spelled silent consonants (e.g., *grand*, ‘large’) correctly more often when they were clearly pronounced in a morphologically related word (e.g., *grande*, feminine form) in comparison with words that did not have such support from morphological neighbors (e.g., *jument*, ‘mare’).

Evidence for the activation of morphologically related words is also supported by evidence in visual and auditory perception with adults. Schreuder and Baayen (1997) and Bertram, Baayen, and Schreuder (2000) performed a series of lexical decision tasks in Dutch and found a facilitatory family size effect on lexical decision latencies for monomorphemic words, as well as derivations and inflections. Family size refers to the number of derivations/compounds in which the target word appears as a constituent, i.e., its morphological family. In other words, the larger this morphological family, the faster participants responded. In contrast to the *number* of words in a morphological family, the summed *frequencies* of all its members did not affect reaction times to derived or monomorphemic words (Bertram, Baayen, et al., 2000; Schreuder & Baayen, 1997). Crucially, semantic transparency turned out to be a prerequisite for the family size effect (i.e., the effect increased when semantically opaque derivations and compounds were not counted), suggesting that it is a not a pre-lexical effect but originates in the central lexicon itself. For monomorphemic and inflected target words, however, reaction times were co-determined by the summed frequencies of the inflectional variants of the target (Bertram, Schreuder, et al., 2000; Schreuder & Baayen, 1997). Bertram, Baayen, et al. (2000) argue that family size (i.e., a type count) is the only predictor outside the inflectional domain, whereas both family size and stem frequency (i.e., a token count) are key determinants of RTs to inflected forms. All studies on family size converge on the same idea:
these effects arise “due to activation spreading between semantically transparent morphologically related words stored in the central lexicon” (Bertram, Baayen, et al., 2000, p. 401).

Meunier and Segui (1999) refined the family size effect: they observed that auditory lexical decisions times were longer for derived words with many higher frequency family members than for those with only few such members. The authors argue that this finding strongly suggests that it is the word’s position within the morphological family in terms of its frequency (i.e., does the target word have many or few morphologically related words of a higher frequency with which it competes?) that determines the speed at which the word is processed rather than the sheer number of family members (family size). Altogether, the studies discussed above strongly support the claim that morphological relatives influence both production and perception.

We hypothesize that activation is not restricted to morphological neighbors but also spreads to phonological neighbors. The question whether phonologically related words affect the processing of novel inflected word forms has played a key role in a central debate in psycholinguistics, contrasting the relative importance of rules and storage. An important model in this respect is the dual-route model developed by Pinker (1999). It posits that the formation of regularly inflected forms is strictly rule-based, whereas irregular forms are (partly) similarity-based and therefore imply retrieval of stored full-forms. The English past tense has proven to be the testing ground for this issue. Prasada and Pinker (1993) found support for his hypothesis in an experiment that required participants to provide the past tense of nonce verbs. They used an irregular form more often when the nonce forms had a strong phonological similarity with existing irregular English verbs (e.g., *skring > *skrung, analogous to string > strung, sting > stung, …) (Prasada & Pinker, 1993). In contrast, the preference for the regular ed-suffix did not depend on the nonce verbs’ similarity to existing regular verbs. However, this apparent discrepancy between regular and irregular forms has been criticized by Eddington (2000), who found that a single-route instance-based model that makes use of a phonology-based similarity algorithm is able to capture the
data for both regular and irregular forms.

The finding that *regular* English past tense inflection is at least partly driven by analogy to phonologically similar words was extended to regular plural inflection by Kemp and Bryant (2003). The authors showed that both 5- to 9-year-olds and adults relied on orthographic patterns of phonologically similar words when spelling the English regular plural /z/-ending (see also Pacton et al., 2001). Rather than making use of a deterministic morpheme-based spelling rule (i.e., add -s to plurals), the /z/-ending was more often correctly realized as s after a consonant (e.g., *fibs*) than after a long vowel (e.g., *bees*). The authors interpreted this finding as evidence for competition from an alternative orthographic pattern after a long vowel (e.g., *-ze*) in phonologically similar items such as non-plurals (e.g., *breeze*), occasionally giving rise to errors like *beeze*. Such a competing pattern is absent when the plural morpheme follows a consonant, leading to an enhanced spelling performance.

Evidence for the activation of phonologically similar words also comes from studies on the production of Dutch regular past tense forms. Again, this domain is governed by a straightforward rule: a voiceless stem-final phoneme is followed by the te-suffix whereas a voiced phoneme is followed by the de-suffix. Notwithstanding this clear rule, Ernestus and Baayen (2004) found that the pattern of intrusion errors (i.e., making the wrong suffix choice) was determined by a verb’s similarity to phonological neighbors. Participants were provided with the infinitival form of an existing verb through headphones, after which they had to give the verb’s past tense form and, hence, the correct inflectional suffix (e.g., *-te* or *-de*). Erroneous substitutions of the te-suffix by the de-suffix or vice versa (e.g., *krabte* instead of *krabde*, ‘scratched’) were more likely if a verb’s phonological neighborhood favored the non-standard form (e.g., *trappe* ‘kicked’, *repte* ‘rushed’, …).

Finally, a Google corpus study confirmed that the error pattern on regular Dutch past tenses was determined by competition between the orthographic pattern of a target verb form and that of its phonological neighbors (Sandra, 2010). As mentioned in the above paragraph, the past
tense formation in Dutch involves a very simple rule: add a te-suffix to the verb stem if the stem’s final phoneme is voiceless, otherwise add the de-suffix. However, this rule was overridden by high-frequency competing orthographic patterns in phonological neighbors. Since there are more (and more frequent) verbs whose stem ends in -cht than in -ch, the tte-ending is more frequent after the ch cluster than the homophonous competing te-ending (i.e., forms like lachte, ‘laughed’ occur less often than forms like wachtte, ‘waited’). In contrast, this tte-ending is the least frequent orthographic pattern after the s cluster (i.e., forms like suste, ‘hushed’ occur more often than forms like rustte, ‘rested’). The frequency relation between these two conflicting orthographic patterns in the set of thus defined phonological neighbors determined the error pattern: past tenses for st verbs, like rustte, were more often misspelled (*ruste) compared to past tenses for cht verbs, such as zwichtte (*zwichte), due to a stronger competition from the ste-pattern than from the chte-pattern.40

The effects of morphological and phonological neighbors fit well into a memory-based learning account of word production, in which similar words in the mental lexicon influence the decision-making process, rather than explicitly taught rules. This memory-based learning rationale has been applied to a variety of psycholinguistic phenomena. Daelemans (2002) was able to quite accurately predict the correct plural ending of German nouns, some of which are regular while others are irregular. Moreover, B. Vandekerckhove, Sandra, and Daelemans (2009) and B. Vandekerckhove, Sandra, and Daelemans (2013) showed that thematic fit and Dutch prenominal adjective order can be successfully modeled with such an exemplar-based approach (both being probabilistic phenomena, showing strong trends but no stringent rules). In addition, Keuleers et al. (2007) demonstrated that the formation of the Dutch plural as well as the English past tense (Keuleers, 2008) does not require a dual mechanism that takes into account both a default rule for regular forms and a similarity-based component for irregular ones. Rather, a

40 Obviously, this study is prone to the same criticism on the use of Google counts as the one described earlier.
single analogy-driven mechanism is able to simulate experimental findings. More closely related to the present research, Daelemans and van den Bosch (2007) showed that an exemplar-based model could simulate homophone intrusions in Dutch. Their study included homophones involving different lexemes such as *mei-mij* ([mK]; ‘May’-'me’) but also homophonous verbs, as used in the present research. Five context words on both the left and right side of the homophone were taken into account, together with their part-of-speech information. Based on this information, the exemplar-based model was able to simulate that low-frequency homophones were more often replaced by their high-frequency counterpart rather than vice versa. We used the same memory-based rationale to determine whether morphological and/or phonological neighbors influence the written production of Dutch homophonous verbs.

### 2.3.2. Morphological and phonological neighbors in the current study

In the present study, we refer to morphological neighbors as verbs sharing a phonologically identical stem with the homophonous verb. For instance, *vermeld(t)* (‘mention(s)’) and *meld(t)* (‘report(s)’) share the stem [mElt]. The more dominant orthographic form among the morphological neighbors *vermeld-vermeldt* might influence which orthographic form (d-ending or dt-ending) of the homophonous target pair *meld-meldt* is the preferred spelling. We set out from the hypothesis that the whole-word frequency distribution for a verb’s morphological neighbors operates independently of the whole-word frequency effect at the level of the target verb form itself. If this proves to be true, it strongly suggests that the orthographic representations of morphologically related words are also activated during the written production of homophonous inflected verb forms in Dutch. However, this idea also hints at the possibility that the spelling process is not only affected by morphological neighbors but by all neighbors sharing a homophonous orthographic sequence, i.e., by its phonological neighbors.

Therefore, we also examined whether phonological neighbors (in this
case rhyme neighbors) co-determine which inflectional ending is preferred. The spelling choice for the homophonous verb pair *meld-meldt* ([mElt]) might not only be influenced by the frequency distribution between *meld* and *meldt* itself and this distribution among its morphological neighbors *vermeld* and *vermeldt*, but also by that among its rhyme neighbors, such as *scheld-scheldt* ([sxElt]; ‘curse(s)’). We operationalized phonological neighbors as words whose stem rhymes with that of the verb. Because they share the final orthographic pattern with the homophonous verb forms, they are the most likely candidates among phonological neighbors to affect the spelling of the inflectional ending. The key role we assign to rhyme neighbors is in line with research by Ernestus and Baayen (2004) in Dutch, who showed that phonological neighbors, defined in terms of their final rhyme, influenced the choice between the allomorphic past tense suffixes *-te* and *-de*, leading to occasional intrusion errors (e.g., *krabte* instead of *krabde*, ‘scratched’ under the influence of *trapte*, ‘kicked’), exactly as verbs with rhyming stems affected the choice between the regular ed-suffix and the irregular form for past tenses of pseudo-verbs verbs in English (Nunes, Bryant, & Bindman, 1997). Rhyme neighbors also play a special role in word naming: Peereman and Content (1997) showed that in French, the facilitatory effect of orthographic neighborhood size on monosyllabic word naming is actually dependent upon phonographic rhyme neighbors, differing from the target word by not only the first letter, but also by the first phoneme. Similarly, Ziegler and Perry (1998) demonstrated that the facilitatory effect of neighborhood density on reaction times in a lexical decision task was due to the fact that most neighbors in English are body neighbors (i.e., words with an identical orthographic rhyme). Specifically for Dutch, Ziegler and Goswami (2005) showed that phonological neighbors of monosyllabic words are also predominantly rhyme neighbors (but see Loncke, Martensen, van Heuven, & Sandra, 2009 for Dutch nonword reading). Based on this evidence, we hypothesize that Dutch spellers partly rely on the dominant orthographic pattern of rhyme neighbors when choosing between the two alternative spellings of homophonous verb forms in Dutch.

In short, we hypothesize three independent information sources for the
spelling of the inflectional ending of a homophonous regular verb form in Dutch: (a) the relationship between the whole-word frequencies of the two verb homophones, (b) the relationship among the whole-word frequencies of the verb form’s morphological neighbors (defined as stem-sharing words) and (c) the relationship among the whole-word frequencies of the verb form’s phonological neighbors (defined as rhyme-sharing words). We will focus on two verb types that were also used in the dictation tasks discussed earlier in this chapter: stem-final d verbs (d-homophones vs. dt-homophones) and weak prefix verbs (t-homophones vs. d-homophones).

2.4. Method

2.4.1. The corpus

To test the ecological validity of the Homophone Dominance effect, as well as the influence of morphological and/or phonological neighbors on the preferred spelling of homophonous Dutch verbs, we examined a corpus of carefully annotated fragments taken from a spontaneous writing situation. The corpus was collected from the social networking site Netlog, which allowed its somewhat 100 million users to interact with each other through the use of a personal profile. The content of a profile ranged from simple messages and blogs to pictures, videos, events or even playlists. This corpus consisted of a total of 1,537,283 Dutch (mostly Flemish) posts made up of 18,712,627 tokens.

As many text fragments are part of a (chat) conversation, the majority of the language extracts used in this corpus are bound by time restrictions to

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41 We would like to thank Netlog (Massive Media) for supplying us with the data and Bram Vandekerckhove for his contribution to this section.
42 The token count includes words, emoticons and punctuation marks. Meta-information regarding authors’ age, gender and location is also available (for more information, see De Decker, 2014; Peersman, Daelemans, & Van Vaerenbergh, 2011). Pre-processing steps such as identifying and extracting the last post of an interaction and obtaining metadata as well as tokenization were performed in line with the procedures described in Peersman et al. (2011).
ensure efficient turn-taking. The maxims of chatspeak require chatters to be quick and keep their messages short (R. Vandekerckhove & Nobels, 2010, p. 658). The chat medium therefore imposes a considerable time pressure on chatters and puts a heavy burden on their working memory, creating optimal conditions for observing homophone intrusions according to previous experimental findings. Several studies (Fayol et al., 1994; Sandra et al., 1999, 2004) have shown that when task demands imposed time restrictions (e.g., in speeded dictation or dual tasks), the performance of the working memory was negatively affected. Together with the informal setting of a social network site, this time pressure results in fluent writing output that is rarely checked for spelling errors (De Decker, 2014, p. 17; Murray, 1990, pp. 43-44). If the conclusions drawn from the experiments reported by Fayol et al. (1994), Sandra et al. (1999) and Sandra et al. (2004) are correct, the Netlog corpus provides the ideal context for examining whether stored orthographic representations can override rule application in a naturalistic writing context.

This informal setting, however, also results in disregard for the rules that govern standard language usage, both at the level of linguistic choices and at the level of spelling words and word forms. Consequently, the language used on Netlog is inherently prone to spelling variation (Androutsopoulos, 2011, p. 154; De Decker, 2014, p. 14). Therefore, we limited our search to the two standard forms of a homophonous verb pair, yielding 34,095 relevant fragments. A computerized analysis that is able to cope with the ambiguities arising from spelling variation (i.e., normalization of fragments) as well as to correctly detect the grammatical structure of a fragment in order to determine the appropriate verb inflection, was not yet available when collecting the data (but see Kestemont et al., 2012).

Instead, fragments were evenly divided among nine independent annotators, who provided us with the inflectional category of each verb

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43 We also allowed for verb forms with clitic pronouns such as k (“I”) or t (“it”) (e.g., kmeld) to be selected. A verb was taken up in the search when it was present in both the d-form and (d)t-form in SUBTLEX-NL (Keuleers et al., 2010) as well as CELEX (Baayen et al., 1995), two frequency counts for Dutch.
homophone (e.g., 1\textsuperscript{st} person singular). They were split into groups of three and each group rated 200 shared fragments to compute inter-rater reliability. The average Fleiss’ kappa score was 0.95 (Geertzen, 2012). This high agreement score justifies the reliability of the participants’ ratings. After removal of duplicates and irrelevant/unannotated fragments, 33,320 data points were left.\footnote{The annotators were all students at Antwerp University. There were eight possible ratings for the inflectional category: 1\textsuperscript{st} person singular, 2\textsuperscript{nd} person singular non-inverted, 2\textsuperscript{nd} person singular inverted, 3\textsuperscript{rd} person singular, past participle and imperative. If the form was not a verb form (e.g., but a noun), it was labeled as “irrelevant” (e.g., \textit{het kleed}; ‘the dress’). Unannotated fragments (marked as “unknown”) refer to fragments that could not be rated, due to ambiguous or missing grammatical information. The latter two sets of fragments were removed from the data set.} For each data point, we had information on both the targeted (i.e., correct) and actual (i.e., written) inflectional ending. In the next section, we will describe the operationalization of the independent variables used to predict this written inflectional ending.

\section*{2.4.2. Operationalization of variables}

\subsection*{2.4.2.1. Dependent variable}

In the offline experiments reported so far, our dependent variable was whether or not the participant made an intrusion error. However, this corpus analysis is not equivalent to an experimental and well-balanced design in which the number of observations for every condition is pre-determined. In contrast, we are dependent upon participants’ spontaneous writing output. This, for instance, leads to only one observation on a homophone pair for a large number of verbs (i.e., both homophones were not targeted), thus only filling half of the design of the experiments previously reported. Analyses of these experiments sought to find an interaction effect between the Homophone Ratio measure and the correct spelling pattern (based on the grammatical subject or context). For the current analysis, this would translate into three two-way interactions: one for each Ratio measure in interaction with the Form
variable. The three Ratio measures are: (a) Homophone Ratio or the relationship between the two whole-word frequencies of the homophones, (b) Morphological Neighbor Dominance or the relationship among the whole-word frequencies of the target’s morphological neighbors and (c) Phonological Neighbor Dominance or the relationship among the whole-word frequencies of the target’s phonological neighbors. The Form variable was an implementation of the spelling rule, which deterministically selects the spelling of the inflectional suffix on the basis of grammatical information. Given the unbalanced nature of the current data, convergence issues made it virtually impossible to detect such interactions. Therefore, we opted to predict which inflectional ending (i.e., d, dt or t) was chosen on the basis of four main effects: Form, Homophone Ratio, Morphological Neighbor Ratio and Phonological Neighbor Ratio, which we will discuss in more depth in the next section. Note that both approaches are conceptually equivalent: we try to predict the spelling pattern on the basis of the dominant orthographic pattern.

2.4.2.2. Independent variables

To predict which inflectional ending is chosen, we followed an exemplar-based learning approach. We made use of the Tilburg Memory-Based Learner (TiMBL; Daelemans, Zavrel, van der Sloot, & van den Bosch, 2010) and its implementation of IB1 (see Daelemans & van den Bosch, 2005). Recall that exemplar-based learning does not resort in any way to abstract rules but relies on an analogical process to generate predictions. An exemplar-based model computes the output on the basis of the similarity (on a number of dimensions) of its input to the items it has stored in its knowledge base. Words in the knowledge base that are equally similar to the input (based on these dimensions) cluster together in so-called neighborhoods. It is possible to specify which neighborhood(s) can influence the decision-making process, ranging from inclusion of the closest neighborhood only (k=1) to inclusion of even items in the furthest neighborhoods. The predicted outcome is
determined by the most frequent output class within the set of neighbors (e.g., the inflectional spelling \(d\) for the target verb form \(ik\ \text{meld}, \ ‘I\ report’\)).

For the present purpose, the knowledge base contained all words with a final [t]-sound appearing in the SUBTLEX-NL database (Keuleers et al., 2010). Phonological information was taken from CELEX (Baayen et al., 1995). The decision to store words in the database that are pronounced with a final [t] was based on the fact that the problem involved the spelling of the final [t]-sound for verb homophones. This can be spelled as either \(d\) or \(dt\) for stem-final \(d\) verbs and as either \(d\) or \(t\) for weak prefix verbs. In contrast to the standard procedure in memory-based learning, the knowledge base also contained the to-be-predicted items, since spelling errors on verb homophones have been shown to arise through retrieval of already known forms (Largy et al., 1996; Sandra et al., 1999). To account for the crucial frequency effects, each word appeared in the knowledge base as many times as it appeared in the SUBTLEX-NL database (Keuleers, Brysbaert & New, 2010). This way, the more frequent ending or output class receives a larger weight. Note that no cut-off point for frequency was used such that even low-frequency words played a role.

Next to verb forms, the knowledge base also included other parts of speech. Homophonous nouns and adjectives have been shown to have an impact on the Homophone Dominance effect. Sandra and van Abbenyen (2009) observed more \(d\)-intrusions (e.g., \(hij\ \text{kleedt} > hij\ *kleed\; ‘he\ *dress’) on verb forms with a homophonous noun/adjective whose final letter is \(d\) (e.g., \(het\ \text{kleed}; \ ‘the\ dress’) compared to matched homophonous verbs without such a non-verbal homophone. Homophone intrusions across parts of speech were also found in French (Largy et al., 1996). The authors observed that plural verb forms (e.g., \(filtre(nt); \ ‘filter’) were prone to intrusions from their plural noun homophone (e.g., \(filtres\) when this noun had a higher frequency. In English, Hare et al. (2001) found that participants preferred regular past tense forms (e.g., \(allowed\)) in a dictation task when their frequency was higher compared than that of its non-verbal homophone (e.g., \(aloud\)). Based on the finding that homophones activate all corresponding orthographic representations
regardless of their lexical category (and that this activation process is apparently frequency-sensitive), we ignored part-of-speech information when determining the similarity of a word in the database to a homophonous verb form. Rather, TiMBL computes this similarity on the basis of a number of dimensions referring to a verb's morphological and phonological structure.

In order to group morphologically related words (i.e., morphological neighbors) together, we provided each word with its phonetically transcribed verbal stem. This first dimension represents the smallest rightmost meaningful part (e.g., [mElt] for meld, vermeld, gemeld, ...). By incorporating this type of information, morphological similarity between words with the same verbal stem is able to affect the predicted inflectional ending.

In order to compute phonological similarity between words, the phonological attributes of the items in the knowledge base were characterized in terms of an onset-nucleus-coda structure for each syllable (e.g., vermeld: v, @, r, m, E, lt). For each word, seven syllable positions were encoded, using the ‘=’ sign for an empty slot in the syllable (possibly all slots for a given syllable position). Syllables were encoded in a backward fashion, starting with the word’s final syllable at syllable position 7.

In sum, the knowledge base contains items that are determined by a fixed set of characteristics, namely their verbal stem and their phonological attributes. Since our purpose was to simulate which inflectional ending was chosen, each item also contained an outcome class, namely the orthographic spelling pattern of the [t]-sound for that word (i.e., d, dt or t).45

As already mentioned, TiMBL predicts an inflectional ending based on the most frequent output class among its set of neighbors. However, it also

---

45 A example of an item (e.g., vermeld) stored in the knowledge base is the following:

<table>
<thead>
<tr>
<th>verbal stem</th>
<th>S1</th>
<th>S2</th>
<th>S3</th>
<th>S4</th>
<th>S5</th>
<th>S6</th>
<th>S7</th>
<th>output class</th>
</tr>
</thead>
<tbody>
<tr>
<td>mElt</td>
<td>ONC</td>
<td>ONC</td>
<td>ONC</td>
<td>ONC</td>
<td>ONC</td>
<td>ONC</td>
<td>ONC</td>
<td>ONC</td>
</tr>
<tr>
<td></td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
<td>=</td>
</tr>
</tbody>
</table>
returns the class distribution, namely how many neighbors support each output class (either d, t or dt). Whereas a classic computational approach is mostly interested in the accuracy of an exemplar-based system, the goal of the present research is to mimic human behavior (i.e., which intrusion errors are most probable). For a specific verb, an exemplar-based approach always predicts the outcome of the output class with the highest frequency, whether the probability distribution is 0.51 vs. 0.49 or 0.99 vs. 0.01. However, it is obvious that intrusion errors of the higher-frequency homophone are more probable in the latter situation than in the former. Since we want to examine whether the frequency relation between the homophonous endings of a verb and that of its neighbors affects which inflectional ending is chosen, we are more interested in the probabilities assigned to each output class, rather than the predicted class itself.

We performed three different simulations to obtain these class distributions. In a first simulation (a), the neighborhood (N) includes only verbs’ exact homophonous forms. In a second simulation (b), the neighborhood is expanded to verbs’ morphological neighbors, grouped together on the basis of their shared stem. A final simulation (c) returned the class distribution when the neighborhood was extended to the phonological rhyme neighbors of a verb’s stem. Taking the verb melden as an example, we get the following neighborhoods (N) and class distributions:

(a) N: meld ‘report’, meldt ‘reports’> d: 733 - dt: 394
earlier’ share their stem [mElt] with the two verb homophones >
d: 742 - dt: 4946
(c) N: the verbal stem [mElt] rhymes with, for instance, the stem
[stElt] as in herstelt ‘recovers’ or [bElt] as in gebeld ‘called’ > d:
71266 - dt: 1202

To take these three fine-grained frequency relations between the
orthographic endings into account, we used the class distribution returned by
TiMBL for each type of frequency relation, turned it into a Ratio measure and
introduced the latter as a predictor in a generalized linear mixed effects Model
(GLMM). An additional reason why we preferred the mixed effects analysis to
the output class assigned by TiMBL is that such an analysis can also take
random effects into account. The preference for an inflectional ending might
for instance differ from item to item.

We will compare the fit of several models by systematically adding the
four crucial variables, which are: Form, Homophone Ratio, Morphological
Neighbor Ratio and Phonological Neighbor Ratio. The first predictor, labeled
Form, is a categorical variable that embodies the rule for inflection (i.e., is the
correct spelling a d-form or (d)t-form?). The second predictor, labeled
Homophone Ratio, represents the frequency relation between the two
homophonous forms of a verb, obtained from simulation (a). This variable was
operationalized by means of the following formula:

\[
\text{Homophone Ratio} = \log_{10} \left( \frac{\text{Frequency } d \text{ form}}{\text{Frequency } dt \text{ form}} \right)^{47}
\]

46 Note that the class distribution for morphological neighbors returned by TiMBL also
included frequency counts of the exact homophones (a). To obtain the unique
contribution of morphological neighbors, the class distribution for exact homophones
(a) was deducted from that of the morphological neighbors (b) (e.g., for the d-
outcome: 1475-733 = 742). The same procedure was applied for the phonological
neighbors.
Note that this continuous frequency measure is identical to the one used in the previous experiments of this dissertation and indicates whether a verb is more frequent in its (d)t-form (< 0) or d-form (> 0). The larger the absolute value, the more pronounced the frequency relation. We expect that as Homophone Ratio increases (i.e., as verbs become more d-dominant), the probability of a d-ending will also increase. If the frequency relation between two homophones explains additional variance in the data, this would extend the Homophone Dominance effect to a naturalistic context.

The third predictor, Morphological Neighbor Ratio, embodies the frequency relation among the homophonous endings of a verb’s morphological neighbors, obtained from simulation (b). It was calculated analogously to the measure of Homophone Ratio:

\[
\text{Morphological Neighbor Ratio} = \log_{10}\left(\frac{\text{Frequency } d \text{ form Morphological Neighbors}}{\text{Frequency } d(t) \text{ form Morphological Neighbors}}\right)
\]

As Morphological Neighbor Ratio increases, the d-ending becomes the more frequent one among a verb’s morphological neighbors. Therefore, we expect more d-endings as this measure increases. Finding an additional effect of Morphological Neighbor Ratio would show that not only the frequency relation between a verb’s exact homophones influences which inflectional ending is chosen, but also the frequency relation among its morphological neighbors (e.g., vermeld-vermeldt for meld-meldt).

For the final predictor, Phonological Neighbor Ratio, we used the frequency distribution between the two alternative spelling patterns obtained from simulation (c), as determined on the basis of a verb’s phonological rhyme. This distribution was used to calculate a ratio value along the lines of the preceding formulas:

---

47 Importantly, the frequency counts for the d- and (d)t-forms were +1-smoothed. This was done to avoid division by zero (zero in denominator) or taking the logarithm of zero (zero in numerator).
Again, a positive value for *Phonological Neighbor Ratio* indicates that the d-ending is more dominant among a verb’s phonological neighbors. We hypothesize that the pattern of errors will reveal a preference for this d-ending compared to the (d)t-ending, as *Phonological Neighbor Ratio* increases. This final measure allows us to answer the question whether the phonological pattern shared by verbs and their rhyme neighbors activates their orthographic pattern and thus affects spelling performance. In other words, does the frequency distribution of *scheld-scheldt* ([sxElt]) also influence which inflectional ending is preferred for the verb homophones *meld-meldt* ([mElt])?

### 2.5. Results and Discussion

The three outcome variables (*d*, *t*, and *dt*) were analyzed as two binomial contrasts (i.e., *d* vs. *dt*, *d* vs. *t*), one for each verb type.\(^48\) Whereas stem-final d verbs (e.g., *melden*) have *d* and *dt* as possible orthographic realizations of the [t]-sound, weak prefix verbs can have either a d- or t-ending (*d* coded as 0; *(d)t* coded as 1). We fitted a generalized linear mixed effects model (GLMM) via the lme4 package (Bates et al., 2014) and the R statistical software package (R Core Team, 2014).

After inspection of the data, we found that most participants only contributed one observation to the data set (i.e., unique observations). This was true for both stem-final d verbs (70% of the participants contributing unique observations) and weak prefix verbs (78% of the participants contributing unique observations). Because there are not enough observations for each participant to reliably estimate per-participant random effects, this

\(^{48}\) Combining *t* and *dt* into one category would result in ambiguous analyses, such as a *t*-neighbor supporting a *dt*-form.
results in convergence problems. To avoid this issue, we downsampled participants by randomly selecting one observation per participant. This led to 40% data loss for stem-final d verbs (13,550 remaining observations) and 29% for weak prefix verbs (7,431 remaining observations). The random structure of the reported models was maximal (Barr et al., 2013; Jaeger, 2008), including random intercepts for item and lemma and a by-lemma random slope for the Form variable.

To examine which explanatory variable affected the choice for an inflectional ending, we ran four different models, adding each variable in a stepwise manner to the model with only random effects (Form > Homophone Ratio > Morphological Neighbor Ratio > Phonological Neighbor Ratio). The least complex model includes only the variable Form, whereas the most complex one includes all four variables. Since the model comprising the Form variable and the three ratio variables yielded similar effects for the variables already comprised in the simpler models, the regression tables and partial effects plots depicted below only show the results of the most complex GLMM containing all four independent variables (Table 8 and Figure 8 for stem-final d verbs; Table 9 and Figure 9 for weak prefix verbs).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>β</th>
<th>SE(β)</th>
<th>z</th>
<th>χ²</th>
<th>p(&gt; χ²)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.88</td>
<td>0.20</td>
<td>-9.59</td>
<td>67.42</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Form</td>
<td>-2.33</td>
<td>0.28</td>
<td>-8.45</td>
<td>94.07</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>-0.46</td>
<td>0.18</td>
<td>-2.59</td>
<td>5.98</td>
<td>.015</td>
</tr>
<tr>
<td>Morphological Neighbor Ratio</td>
<td>0.007</td>
<td>0.13</td>
<td>0.06</td>
<td>0.003</td>
<td>.956</td>
</tr>
<tr>
<td>Phonological Neighbor Ratio</td>
<td>0.003</td>
<td>0.13</td>
<td>0.03</td>
<td>0.0006</td>
<td>.980</td>
</tr>
</tbody>
</table>

Table 8. Coefficients of a mixed logit model predicting the probability of a dt-spelling for stem-final d verbs on the basis of Form, Homophone Ratio, Morphological Neighbor Ratio and Phonological Neighbor Ratio together with the estimate β, standard error, z-value, χ²-value and p-value. The χ²- and p-value represent the values obtained from likelihood ratio tests comparing the most complex model (with all four variables) to a model without the variable under scrutiny.
Figure 8. Partial effects plot of effects represented in Table 8.
### Table 9

Coefficients of a mixed logit model predicting the probability of a t-spelling for weak prefix verbs on the basis of Form, Homophone Ratio, Morphological Neighbor Ratio and Phonological Neighbor Ratio together with the estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value. The $\chi^2$- and $p$-value represent the values obtained from likelihood ratio tests comparing the most complex model (with all four variables) to a model without the variable under scrutiny.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$z$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-0.17</td>
<td>0.08</td>
<td>-2.07</td>
<td>4.17</td>
<td>.041</td>
</tr>
<tr>
<td>Form</td>
<td>-1.63</td>
<td>0.13</td>
<td>-12.34</td>
<td>126.14</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>-0.60</td>
<td>0.11</td>
<td>-5.57</td>
<td>30.40</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Morphological Neighbor Ratio</td>
<td>-0.22</td>
<td>0.09</td>
<td>-2.38</td>
<td>5.72</td>
<td>.017</td>
</tr>
<tr>
<td>Phonological Neighbor Ratio</td>
<td>-0.18</td>
<td>0.06</td>
<td>-3.07</td>
<td>10.04</td>
<td>.002</td>
</tr>
</tbody>
</table>

Figure 9. Partial effects plot of effects represented in Table 9.
Discussion. The Form variable was found to significantly predict which inflectional ending was chosen for both verb types. If the d-form is the grammatically correct target form, the probability of a (d)t-ending decreases significantly. However, it is crucial to note that the correctly predicted outcomes on the basis of the inflectional rule coincide with those predicted by Homophone Ratio in a large number of cases. Obviously, the higher-frequency homophone is most often the grammatically correct homophone. Independently of this Form variable, the Homophone Ratio variable also significantly predicted which inflectional ending was chosen for both verb types. As verbs become more frequent in the d-form, this d-form is preferred to the competing but lower-frequency (d)t-form. The effect of Morphological Neighbor Ratio was significant for weak prefix verbs, but not for stem-final d verbs. For weak prefix verbs, the effect of Morphological Neighbor Ratio mimics that of Homophone Ratio: spellers prefer the d-ending as Morphological Neighbor Ratio increases, namely as this d-ending becomes the more frequent ending among a verb’s morphological neighbors. Analogous to the effect of Morphological Neighbor Ratio, the effect of Phonological Neighbor Ratio was also restricted to weak prefix verbs. As the d-form becomes more dominant among the phonological neighbors of a weak prefix verb, spellers are more likely to write down this high-frequency d-form.

In this section, we examined whether the preferred spelling of Dutch homophonous verbs is not only determined by the morpheme-based spelling rule, but also by the whole-word frequency of these verbs’ homophones (i.e., the Homophone Dominance effect) and that of their morphological and phonological neighbors. We showed that the Homophone Dominance effect found under experimental conditions (Sandra et al., 1999) is also present in a large-scale corpus of naturalistic data. This is true for the two verb types that were studied in these experiments (i.e., stem-final d verbs and weak prefix verbs). Furthermore, this study extends the findings of a Google corpus study on stem-final d verbs (Sandra, 2010) to a carefully annotated corpus that targets both stem-final d verbs and weak prefix verbs. In addition, we showed
that morphological and phonological neighbors co-determine which inflectional ending is written down, although this effect was restricted to weak prefix verbs.

Following a memory-based learning approach, we simulated which neighborhoods (i.e., sets of equally similar words) influence the spelling of inflectional endings for Dutch regular verb forms, without resorting to explicitly taught rules. For each of the three neighborhoods under scrutiny (i.e., homophonous, morphological and phonological neighborhoods), we used the probabilities assigned to each possible spelling outcome (i.e., $d$ vs. $dt$, $d$ vs. $t$) to calculate a ratio metric, which was then used as a predictor for the chosen inflectional ending.

Firstly, we examined whether the frequency relation between a verb’s homophonous forms determines which orthographic realization (i.e., $d$ or $(d)t$) of the ambiguous $[t]$-sound is more likely to be written down. Dictation tasks (e.g., Sandra et al., 1999) showed that the error risk increased when the correct inflected form is of lower frequency compared to the competing one. In this study, we examined whether this Homophone Dominance effect is also present in ordinary writing situations, namely in a large-scale corpus collected from a social networking site. We found that, despite high-speed writing conditions, chatters are still able to apply the rule in a considerable number of cases (about 70%) but regularly fall prone to the ‘pressure’ of the dominant homophone. We showed that, as verbs become more $d$-dominant (i.e., more frequent in their $d$-form), this $d$-form is more likely to be the preferred spelling, leading to homophone intrusions when the alternative $(d)t$-form is the correct spelling. As verbs became more $(d)t$-dominant, however, we observed a preference for the $(d)t$-ending. Importantly, this effect was observed independently of the effect of Form, which captures all spellings that are predicted by the spelling rule, including the correct spellings of the dominant homophones (thus reducing the power to detect an effect of

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49 But bear in mind that a considerable subset of the rule-based spellings would also be predicted by the factor Homophone Ratio, i.e., in more than half of the cases (as the dominant pattern obviously occurs in more than 50% of all homophonous forms).
Homophone Dominance). This leads to the conclusion that the Homophone Dominance effect is not just an experimental artifact, but is also representative of normal writing situations. The persistence of intrusion errors strongly suggests that the spelling of regularly inflected verb forms in Dutch does not exclusively obey a combinatory system. Rather, the fact that the pattern of intrusions errors is governed by Homophone Dominance under experimental conditions and in a naturalistic context suggests that regular verb forms are stored as full forms in the mental lexicon (at least HF homophonous ones). When writers want to spell a regular homophonic verb form, the shared phonological structure of the homophonic verb forms activates the two corresponding orthographic representations. Because the higher-frequency orthographic representation receives a larger amount of activation and inhibits production of the lower-frequency alternative (reasoning along the lines of an interactive-activation model), this leads to occasional intrusion errors.

Secondly, we studied whether the frequency distribution of inflectional endings in the set of words exhibiting morphological similarity to a verb has an effect beyond that of its exact homophones (i.e., Morphological Neighbor Ratio). The analysis showed that only weak prefix verbs were affected by this measure: the spelling choice for one of the two homophonous forms (e.g., bestelt/besteld) is also influenced by the dominant orthographic pattern among words sharing the verbal stem (e.g., [stElt] as in herstelt/hersteld). We will postpone our discussion why this effect was not found for stem-final d verbs and focus on the weak prefix verbs here. For these verbs, the effect of Morphological Neighbor Dominance mimics that of Homophone Dominance: as the d-form becomes the more frequent ending among a verb’s morphological neighbors, this d-form is preferred over the lower-frequency (d)t-form and vice versa if the t-form is the more frequent ending. We take this finding as evidence for the idea that Dutch homophonic verbs forms activate the orthographic representations of morphologically related (complex) words through their shared verbal stem. These morphological neighbors are consequently able to affect the preferred spelling of the ambiguous inflectional ending of weak prefix verbs. This conclusion is supported by the observation
that even young children rely on information from morphologically related words during spelling (Sénéchal, 2000; Treiman et al., 1994) and the observation that morphologically related words affect visual word recognition. Bertram, Baayen, et al. (2000) found that the larger a word’s morphological family (i.e., its family size), the faster lexical decision times were across a range of Dutch derivational and inflectional suffixes. Our finding that Morphological Neighbor Ratio had an effect on the spelling of a verb homophone confirms the hypothesis put forward by Bertram, Baayen, et al. (2000) that formally and semantically transparent complex words can activate their base, from which activation spreads to morphologically related items stored in the mental lexicon. Whereas Baayen and co-workers did not find an effect of the token frequency of the morphological family members\(^{50}\), our dominance metric was a token-based measure. Possibly, token frequency is more important in spelling than in word recognition. At any rate, in speeded writing (which consumes a considerable amount of working-memory resources), spellers do not deterministically apply a morpheme-based spelling rule for Dutch homophonous verbs. Rather, when they are writing under time pressure, they also tend to resort to a fallback strategy and rely on the most frequent orthographic ending (a) of the word itself but also (b) of words sharing a verbal stem, at least in the case of weak prefix verbs.

Finally, we tested whether the most frequent orthographic pattern among words bearing phonological similarity to a homophonous verb form co-determines which inflectional ending is favored. Because of the ambiguous nature of these verbs’ inflectional ending (for spelling purposes), the orthographic representations of words with similar phonological structures might provide support during the decision-making process. For the present purpose, these phonological neighbors refer to words whose verbal stem rhymes with that of the to-be-spelled verb (e.g., the stem of the phonological neighbor gebeld, ‘called’, i.e., [bElt] rhymes with that of the stem of bestelt/d, namely [stElt]). The special status of rhyme neighbors has been confirmed in a

\(^{50}\) Recall that Bertram, Schreuder, et al. (2000) found an effect of token frequency of inflectional variants on complex Dutch word forms.
number of studies in production (Ernestus & Baayen, 2004; Nunes et al., 1997) and perception (Peereman & Content, 1997; Ziegler & Goswami, 2005; Ziegler & Perry, 1998). For weak prefix verbs, our analysis indeed showed that Dutch spellers exhibited a preference for the d-ending as this became the most frequent orthographic ending among a verb’s phonological neighbors. We will again postpone the discussion why this effect was not found for stem-final d verbs and first focus on the finding for weak prefix verbs. This effect of Phonological Neighbor Dominance indicates that activation did not only spread via the verbal stem to morphological neighbors, but also to phonological neighbors. Evidence supporting the claim that phonologically related words affect lexical processing in production tasks comes from the production of regular past tense forms (Eddington, 2000) and regular plural forms in English (Kemp & Bryant, 2003), two other word types in the domain of inflectional morphology. This was also found to be true for the production of regular Dutch past tense forms (Ernestus & Baayen, 2004; Sandra, 2010), where more errors were found when the erroneous form was supported by a verb’s phonological neighborhood. For instance, the verb stem *krab* (‘scratch’) yielded the incorrect past tense *krabte* instead of the correct form *krabde* (required by the voiced stem-final obstruent /b/). Because voiced obstruents are devoiced in final position (i.e., [krAp]), a stem-final [p] activates phonological neighbors like *trap* (/trAp/; ‘kick’), taking the past tense te-suffix (trappe, ‘kicked) and thus form the basis for a wrong analogy (*krabte ≈ trappe*).

Unlike weak prefix verbs, stem-final d verbs did not exhibit effects of morphological or phonological neighbors. There are a number of possible explanations for this discrepancy. Firstly, the number of weak prefix verbs (294) in the data set is almost twice as large as that of stem-final d verbs (148), i.e., there was more statistical power to detect an effect in the set of weak prefix verbs. In addition, much of the variance for stem-final d verbs had already been explained by the other two significant predictors, namely Form (i.e., the spelling rule) and Homophone Ratio, when entering the Morphological Neighbor Ratio measure (and, hence, Phonological Neighbor...
Ratio measure, which was entered as the last factor). For stem-final d verbs, the dominant pattern among homophones, morphological and phonological neighbors was the same in 56% of the cases (type count), while this is only true for 30% of weak prefix verbs. Because the neighborhood ratio measures vary less independently for stem-final d verbs, it is highly plausible that the statistical analysis was unable to pick up on the fine-grained differences between the measures.

Secondly, we propose that an explanation in terms of a ceiling effect is further supported by the assumption that a simplification strategy (i.e., a d-bias) was at work for stem-final d verbs. This is evident from the following two confusion matrices depicting the correct spelling forms (endings) versus the chosen ones, respectively for stem-final d verbs and weak prefix verbs:51

<table>
<thead>
<tr>
<th>Correct ending</th>
<th>Written ending</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>DT</td>
</tr>
<tr>
<td>12119</td>
<td>1180</td>
</tr>
<tr>
<td>5575</td>
<td>4032</td>
</tr>
</tbody>
</table>

Table 10. Confusion matrix (correct vs. written endings) for stem-final d verbs.

<table>
<thead>
<tr>
<th>Correct ending</th>
<th>Written ending</th>
</tr>
</thead>
<tbody>
<tr>
<td>D</td>
<td>T</td>
</tr>
<tr>
<td>3689</td>
<td>1500</td>
</tr>
<tr>
<td>1862</td>
<td>3362</td>
</tr>
</tbody>
</table>

Table 11. Confusion matrix (correct vs. written endings) for weak prefix verbs.

From these two tables, we conclude that the number of correctly spelled forms (stem-final d verbs: 71%; weak prefix verbs: 68%) exceeds that of incorrectly

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51 Note that the numbers in these two tables represent the total data set before participant downsampling. However, it is clear that they embody the same trends as in the statistical analyses.
spelled forms for both verbs types. Collapsing across the two rows in each table – correct vs. incorrect – this difference is significant in a chi-square test (stem-final d verbs: $\chi^2 = 3,854.22; p < .001$; weak prefix verbs: $\chi^2 = 1,306.9; p < .001$). Together with the significant result for the Form variable in the statistical analysis, this suggest that spellers do apply the rule in a large number of cases. In addition, the interaction effect in the two sets of data is significant (stem-final d verbs: $\chi^2=4,005.99; p < .001$; weak prefix verbs: $\chi^2 =1,314.31; p < .001$). For stem-final d verbs we see that, when the target orthographic form ends with *dt*, people only wrote this form less than half of the time (42%). In contrast, when the d-form was the correct form, only 9% was an intrusion error (i.e., a dt-form). This signals a general tendency for stem-final d verbs towards simplification, namely a bias towards the least complex form (i.e., the stem d-form). This bias is supported by the significant effect for the intercept in the statistical analysis. For weak prefix forms, the interaction indicates more intrusions of the d-form when the t-form was the target (36%) compared to the opposite pattern (29%). Although there is also a d-bias for weak prefix verbs (see also, Sandra et al., 1999), it is considerably smaller than the same bias in stem-final d verbs. It is this very strong d-bias in the set of stem-final d verbs that requires our attention to account for the absence of neighborhood dominance effects.

From the statistical analysis we know that simplification is not the only factor at play, but that Homophone Ratio is also significant. Therefore, it is essential to check whether this bias is a genuine effect and not a hidden effect of Homophone Ratio. Indeed, as there was no way to (experimentally) control the distribution of d-dominant and dt-dominant verbs across the two types of expected endings, the large number of d-intrusions (58%) in comparison with the small number of dt-intrusions (9%) might be the result of an over-representation of d-dominant verbs in the condition 'dt expected' and an under-representation of dt-dominant verbs in the condition 'd expected'.

52 D-intrusions were 1.24 times (i.e., 36/29) more frequent than t-intrusions for weak prefix verbs, whereas d-intrusions were 6.44 times more frequent (i.e., 58/9) than dt-intrusions for stem-final d verbs.
When classifying each verb form according to its dominance type, however, it appears that there are 61% (721/1180) d-dominant verbs in the condition 'dt expected', whereas there are also 61% (3389/5575)\textsuperscript{53} dt-dominant verbs in the condition 'd expected'. The probability of finding a spelling error when errors are solely due to Homophone Dominance should, in other words, be the same when a $d$ is expected as when a $dt$ is expected. However, the data show that it is in fact more than 6 times smaller. This clearly indicates that there is a d-bias (reflecting a tendency to simplify) besides the effect of Homophone Dominance. This tendency towards simplification was also found by Clifton, Cutler, McQueen, and van Ooijen (1999) in English. They observed that spellers preferred a monomorphemic homophone (e.g., \textit{baste}) even when the inflected form had a higher frequency (e.g., \textit{based}). Specifically for Dutch homophonous verbs, this d-bias was also observed in the Google corpus analyzed by Sandra (2010) and in a dictation study performed by Frisson and Sandra (2002a). The majority of the errors were d-intrusions showing that (a) d-forms are less prone to intrusions or (b) dt-forms are spelled incorrectly more often than expected on the basis of their Homophone Ratio. Taken together, these results indeed strongly suggest that, besides intrusion errors resulting from Homophone Dominance, another mechanism is generating errors for stem-final d verbs, namely a simplification strategy. While a HF d-form (in combination with a d-bias) easily overrides the correct dt-spelling, the salience of the HF dt-form must be very strong to overcome the bias towards a d-spelling and lead to an effect of Homophone Dominance. From a speller’s point of view, a preference for the stem d-form comes naturally since it appears in each inflectional variant of the verb (\textit{meld, meldt, melden, gemeld, meldend, ...}). Furthermore, the omission of suffixes serves the purpose of fast writing and should not come as a surprise in the light of the particular communication medium, namely chat conversations. It is all the more surprising, then, that in such a writing situation the effect of

\textsuperscript{53} The denominator of each ratio represents the total number of verb forms in the spelling condition, whereas the nominator represents the number of d-dominant or dt-dominant verb forms in this set.
Homophone Dominance still survives (knowing, furthermore, that is also partially ‘absorbed’ by the Form variable), attesting to the pervasiveness of this effect.

Summing up, there are three factors at play for stem-final d verbs, namely rule application, the Homophone Dominance effect, but also a general d-bias. This d-bias might cancel out the effects of these verbs’ morphological and phonological neighbors. This is all the more probable because these neighbors predominantly support the d-spelling (in respectively 89% and 100% of all cases). In contrast, the size of the d-bias is much smaller for weak prefix verbs, and their morphological and phonological neighbors also show less preference for this d-ending (both 63%). These two factors favor the probability of finding an effect of morphological and phonological neighbors for weak prefix verbs, but work against the probability of finding such an effect for stem-final d verbs.

A final possible explanation for the absence of morphological and phonological neighbor effects for stem-final d verbs might be that neighbor effects are not token but type effects. This has been stressed by Schreuder and Baayen (1997) and Bertram, Baayen, et al. (2000). Therefore, we conducted an analysis in which we substituted the Morphological and Phonological Neighbor Ratio by two analogous measures based on type counts. The results showed that the probability of writing a d-spelling did not depend on the frequency relation between the number of d- and (d)t-neighbors ($ps > .05$). Since this was true for both verb types, we conclude that the number of neighbors supporting a d-form in relation to a (d)t-form does not have an impact on the preferred spelling.

As a final remark, we would like to point out that the analysis of a spontaneous writing situation presents a distinctive advantage over laboratory studies. The informal setting together with the limited amount of time and attention devoted to spelling issues presents the ideal context to uncover the automatic processes underlying lexical processing. However, studying homophone intrusions in a naturalistic context also introduced a number of limitations. Since participants produced text without any restrictions, we had
no control over the chosen set of verbs and their characteristics. Skewed distributions potentially led to diverging conclusions for stem-final d vs. weak prefix verbs (i.e., the discrepancy between the neighborhood effects for the two verb types). In addition, we had to downsample participants to avoid convergence problems in the statistical analysis because the large majority of participants only contributed one observation to the data set. In addition, the difficulty of the syntactic structures in which the verb forms are embedded cannot be controlled for. Consequently, naturalistic data are prone to noise from a number of uncontrolled variables in contrast to well-designed laboratory studies.

We conclude that the effect of Homophone Dominance found in experimental contexts also determines the pattern of intrusion errors outside the laboratory, namely in a large-scale corpus from a social networking site consisting predominantly of chat messages. This is an important finding, indicating that the effect of Homophone Dominance, which we elicited under artificial conditions of time pressure (online and offline spelling-to-dictation tasks), also manifests itself in real-life situations where one is writing under time pressure and has limited attentional resources available. In addition, the preferred spelling pattern for weak prefix verbs was co-determined by the dominant pattern among their morphological and phonological neighbors. The absence of these effects for stem-final d verbs does not mean that neighbors have no effect on the spelling of these verb forms, as this null effect can be traced to the operation of other factors (e.g., a strong d-bias). The neighbor effects provide further evidence for the activation of full forms during the production of homophonous regular verb forms in Dutch as well as for the idea of interconnectivity in the mental lexicon on the basis of morphological and phonological relatedness (see also, Bertram, Baayen, et al., 2000; Ernestus & Baayen, 2004; Schreuder & Baayen, 1997).
3. Conclusion of Chapter 2

In Chapter 2, we aimed to extend the findings of previous spelling experiments in two ways (see Figure 10 at the end of this section for an overview). Our first objective was to replicate the Homophone Dominance effect found in spelling experiments with both stem-final d verbs and weak prefix verbs and (additionally) to generalize the effect to a naturalistic context. Whereas the Homophone Dominance effect has been taken as evidence for the storage of whole-word representations for regularly inflected verb forms, a rule-based but frequency-sensitive model is also capable of explaining the results. Our second objective was therefore to elicit errors involving the illegal combination of a non-stem and a suffix, which are impossible from a rule perspective (e.g., *sustte for suste, ‘hushed’). In addition, a rule-based account is also unable to explain why the pattern of sublexical errors should be determined by Homophone Dominance (i.e., is dependent on the existence of a sublexical homophonous cluster). To answer these questions, we performed three types of experiments.

In order to replicate the Homophone Dominance effect found in previous dictation tasks, we performed an offline spelling-to-dictation task. For this experiment, we asked participants to write down sentences containing either the 1st or 3rd person singular forms of stem-final d verbs. In accordance with our hypothesis, the results showed that intrusions most often involved substitutions of the LF form by the HF homophone. As verbs become more dt-dominant (i.e., dt-form becomes the most frequent homophone), more dt-intrusions were found in the 1st person (e.g., ik *rijdt; ‘I *drives’) compared to d-intrusions in the 3rd person. The reverse pattern of results was found for d-dominant verbs: d-intrusions in the 3rd person (e.g., hij *meld; ‘he *report’) were more likely than dt-intrusions in the 1st person. However, the difference between d- and dt-intrusions was less pronounced for d-dominant verbs. We suggested that this is possibly due to the conflicting morphosyntactic information of the 1st person singular subject and the words separating it from the verb form, which often favored a 3rd person interpretation. This led to a
general preference for the third-person dt-form, which can only be counteracted by verbs that have a very strong dominance toward the d-form.

In the same offline spelling-to-dictation task, we examined whether verbs involving homophony at the sublexical level are prone to frequency-induced intrusion errors too. To provide an answer to this question, we compared past tense verb forms with a competing orthographic pattern at the sublexical level (s verbs; e.g., suste, ‘hushed’) to verb forms without such a homophonous competitor (p verbs; e.g., repte, ‘rushed’). The error pattern confirmed our hypothesis: more sublexical intrusions were found for verbs whose final grapheme is homophonous with another cluster (e.g., *sustte analogous to rustte) compared to verbs without such competition (e.g., *reptte).

In order to generalize the Homophone Dominance effect to weak prefix verbs, we examined the error pattern and pause behavior of this second type of homophonous verbs in an online spelling-to-dictation task. This task required participants to type sentences on a computer, instead of writing them down by hand on a piece of paper. The error pattern mimicked the results of stem-final d verbs in the offline spelling-to-dictation experiment: fewer errors were found for the high-frequency homophone of a verb pair. The probability of a correct d-spelling increased as the d-form became the most frequent form of a verb (i.e., d-dominant verbs), while it decreased when the dt-form became the most frequent form of a verb (i.e., dt-dominant verbs). The reverse pattern of results was found when the dt-form was the targeted form. The effect was more clearly observed for d-dominant verbs, possibly due to a d-bias. The analysis of the pause behavior, however, did not confirm our hypothesis: pauses were not shorter when the targeted form and the most frequent form coincided. While the pause times for the d- and t-form did not diverge for t-dominant verbs, we found an inhibitory effect of Homophone Dominance for d-dominant verbs. As verbs became more d-dominant, pause times increased when the HF d-form had to be written compared to when the LF t-form was targeted. Moreover, the inhibitory effect of whole-word frequency was observed at the interval preceding the inflectional suffix, suggesting that the cognitive efforts involved
in spelling the inflectional suffix of weak prefix verbs (i.e., possibly indicating re-access of the suffix; see Kandel et al., 2012) occur at this position. However, the explanation offered by Balota et al. (2000) and Finkbeiner et al. (2006) regarding inhibitory frequency effects allows us to reconcile the seemingly contradictory results of the product and process data (i.e., an expected and a reverse effect of Homophone Dominance). In line with our hypothesis that HF homophones are accessed most quickly, the product data revealed that intrusion errors were more likely when the LF homophone was targeted. This shows that participants were unable to suppress the HF but incorrect homophone on a number of occasions. In contrast, the fact that this HF homophone became available so quickly made participants skeptical about the output of the retrieval route on another number of occasions, which caused them to reject this outcome as a response and label it as 'suspicious'. As a result, the slower morpheme-based process came into play to verify whether this suspicious response was really the correct one, with two possible outcomes. Either the outcome of the morpheme-based process conflicted with the fast response, confirming the suspicious status of this HF homophone (i.e., its spelling was rejected as an incorrect spelling and the homophonous suffix spelling was chosen) or the morpheme-based process indicated that the suspicious response (suggesting an incorrect spelling) was the targeted and correct form after all. In the latter case (i.e., the HF form was targeted), the temporary confusion resulting from the fact that the trusted response coincided with the suspicious response was responsible for elevated pause times compared to when the LF homophone was the correct spelling. In contrast, we did find a facilitatory effect for lemma frequency: shorter pause times were observed for verbs with a high lemma frequency. We take this as evidence for access to a verb’s stem and the involvement of a compositional route during the written production of weak prefix verbs. Yet, due to the typically strong correlation between lemma frequency and the frequency of the inflected forms, we cannot reject the possibility that the lemma effect reflects full-form retrieval of the inflected forms.
Analogous to our analysis of weak prefix verbs, we examined whether the pause behavior for regular past tenses was also affected by the effect of Homophone Dominance at the sublexical level in an online spelling-to-dictation task. Past tense forms for which the [t]-sound is not ambiguous between a single or double t (i.e., p verbs) had significantly shorter pause times at the morphosyllabic interval compared to verbs with a homophonous competitor (i.e., s verbs). Such a delay for s verbs is the result of a temporary confusion between the correct ste-pattern and the existence of a competing homophonous stte-pattern in phonologically similar words (e.g., "rustte", ‘rested’). The effect manifested itself at the morphosyllabic boundary, which is the location at which spellers need to decide whether the /t/-phoneme is spelled as a single or double t.

The two experiments reported with regard to sublexical intrusions show that during the written production of Dutch past tense inflections, whose spelling is strictly rule-based (i.e., add -te to the verb stem), spellers display a sensitivity to the co-occurrence of letter strings, whether they coincide with a morpheme or not. A rule-based account is unable to explain these errors. Firstly, sublexical intrusions involve the illegal combination of a non-stem (e.g., *sust) and the past tense te-suffix. Secondly, such an account cannot explain why the risk of a sublexical intrusion is dependent on the presence of a competing homophonous orthographic pattern, nor why pause times differ depending on the preceding grapheme (s or p). The results do support a view in which letter strings, whether matching a morphemic unit or not, are stored based on their co-occurrence in written language.

To exclude the possibility that the Homophone Dominance effect is an experimental artifact, a third and final experiment at the production level consisted of analyzing homophone intrusions in a large-scale naturalistic corpus. The results confirmed our hypothesis for both stem-final d verbs and weak prefix verbs: even in an ordinary writing situation, the Homophone Dominance effect is operative. As the d-form becomes the most frequent homophone, it is preferred to the competing but lower-frequency (d)t-form, while the latter is preferred for (d)t-dominant verbs. Whenever writers
experience time pressure – either in the context of an experiment or in a real-life writing situation – the spelling of regularly inflected homophonous verb forms is plagued by errors due to the effect of Homophone Dominance.

This experiment also allowed us to examine whether morphological and/or phonological neighbors co-determine which inflectional ending is preferred. The results showed that Dutch spellers partly relied on the dominant orthographic pattern among morphological and phonological neighbors when choosing between the two alternative spellings of weak prefix verbs: as the d-form became the more frequent orthographic ending among these neighbors, this d-form was more often preferred. The opposite was true when the t-form was the most frequent pattern. Note that these two effects arose independently of the morpheme-based spelling rule and the effect of Homophone Dominance. Taken together, these findings suggest that the whole-word representations of homophonous Dutch verb forms are activated during production, together with those of morphologically and phonologically related words (for weak prefix verbs).

In conclusion, Chapter 2 has shown that Dutch spellers often run into the trap set up by our cognitive infrastructure when spelling regular homophonous verb forms. They often make intrusion errors resulting from the quick activation of high-frequency words (lexical intrusions) or orthographic patterns (sublexical intrusions), despite the transparent nature of the spelling rules that govern them. The question remains, however, whether this cognitive infrastructure creates a double trap across modalities. We hypothesize that the effect of Homophone Dominance at the lexical and sublexical level does not only govern spelling, but also underlies perception. Chapter 3 will therefore examine whether high-frequency homophonous forms or patterns are also (a) processed more quickly and/or (b) overlooked more often as an error in a series of perception experiments.
§ 2 The Homophone Dominance effect in production

<table>
<thead>
<tr>
<th>STEM-FINAL D VERBS</th>
<th>OFFLINE STD</th>
<th>ONLINE STD: PRODUCT</th>
<th>ONLINE STD: PROCESS</th>
<th>CORPUS</th>
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<td>HD</td>
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<td>✓</td>
<td>?</td>
<td>✓</td>
</tr>
<tr>
<td>LEMMA</td>
<td>×</td>
<td>×</td>
<td>?</td>
<td>✓</td>
</tr>
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</table>

<table>
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<tr>
<th>WEAK PREFIX VERBS</th>
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<th>CORPUS</th>
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</thead>
<tbody>
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<td>✓</td>
<td>✓</td>
<td>?</td>
<td>✓</td>
</tr>
<tr>
<td>LEMMA</td>
<td>×</td>
<td>×</td>
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<tr>
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</tr>
<tr>
<td>LEMMA</td>
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<td></td>
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</tr>
</tbody>
</table>

Figure 10. Overview of the results from Chapter 2. ×: no significant effect; ✓: significant effect conform the hypothesis; (✓): marginally significant effect; ?: significant effect contrary to the hypothesis; hatched: not available; HD = Homophone Dominance effect; Lemma = Log Lemma Frequency effec
CHAPTER 3

THE HOMOPHONE DOMINANCE EFFECT IN PERCEPTION

1. PRODUCTION VS. PERCEPTION

In Chapter 2, we demonstrated that the pattern of homophone intrusions on regularly inflected verb forms in the spelling domain is governed by Homophone Dominance. However, the question remains why these errors persist in carefully re-read texts. We hypothesize that the mental lexicon creates a double trap: during production, it activates frequent homophonous full forms and orthographic patterns, leading to occasional (sublexical) homophone intrusions when the alternative form is targeted. During perception, intrusions involving this frequently occurring homophone or homophonous pattern might also be processed more quickly and, due to the ensuing feeling of familiarity, be overlooked as an error more often compared to the low-frequency one. This hypothesis, however, is not as straightforward as might appear at first sight. Since production and perception are sensitive to different factors (e.g., Gollan et al., 2011), these two modalities are not necessarily each other’s mirror image. This necessitates a direct comparison of the results in production and perception so as to fully understand the persistence of homophone intrusion errors.

There are good reasons to expect discrepancies since lexical access is achieved differently for the two modalities. In production, the process of lexical access is meaning-driven: the correct lexical representation has to be selected from a set of semantically related words (Gollan et al., 2011; Levelt, Roelofs, & Meyer, 1999). In perception, however, the process is form-driven: phonological and/or orthographic representations are activated when they (partially) match the visual or acoustic stimulus. Lexical access is achieved when all form-related, but irrelevant words are inhibited.
A series of experimental findings contrasting performance in spelling and reading provide evidence in favor of distinct processing mechanisms. Firstly, evidence has accumulated that reading does not necessarily improve spelling abilities. Spelling performance of beginning spellers/readers on new words did not consistently depend on reading exposure (i.e., the number of times these words were read) (Bosman & de Groot, 1991, 1992). The same pattern of results was found with adults: spelling performance for pseudowords only increased after exposure to eight reading trials, but not after one, two, three or four trials (Gompel, Tromp, de Vries, & Bosman, 1990). A second strong argument in favor of two separate processing mechanisms comes from the dissociation between reading and spelling impairments in people suffering from brain damage (Hanley & Kay, 1992) or patients diagnosed with dyslexia (Weekes & Coltheart, 1996). Further evidence for distinguishing lexical access mechanisms in production and perception concerns the role of orthographic neighbors: while these have been shown to speed up production, they have yielded both facilitatory and inhibitory effects in perception (see Andrews, 1997 for an overview). Likewise, discrepancies between reading and spelling performance have been observed by Largy (2001). He found that young participants (i.e., 2nd and 3rd year of primary school) were more successful in detecting and correcting erroneous nominal and verbal agreements than in producing correct ones (e.g., *la table* vs. *les tables* ‘the table vs. the tables’; *la bague brille* vs. *les bagues brillent* ‘the ring sparkles vs. the rings sparkle’). Because language users are generally less practiced in spelling, higher cognitive efforts are entailed in spelling than reading, leading to an enhanced performance level for the latter (Largy, 2001).

With respect to whole-word frequency effects for regularly inflected word forms, both similarities and discrepancies have been observed between the two modalities. Fewer errors were made on HF regular forms, both in written production (Kapatsinski, 2010; Largy et al., 1996; Pacton & Fayol, 2003) and in speech production (Stemberger & MacWhinney, 1986). Similarly, shorter processing times were found for HF inflections than for LF inflections in perception tasks like visual lexical decision (Burani et al., 1984;
Colé et al., 1989; Katz et al., 1990; Sereno & Jongman, 1997; Taft, 1979) and auditory lexical decision (Baayen, McQueen, Dijkstra, & Schreuder, 2003). This suggests that production and perception share common lexical representations and processes.

However, dissimilarities between the two modalities with regard to frequency effects have also been established by Gollan et al. (2011). The authors contrasted the results of a picture naming experiment with those of a visual lexical decision task and eyetracking experiment: while frequency effects were present in both modalities, the size of the effects depended on the semantic constraints of the sentence. Without a constraining context, production revealed larger frequency effects than reading, while the reverse pattern was found with a constraining context. The authors conclude that although both modalities are frequency-sensitive, lexical access in speech production is characterized mainly by semantic constraints while comprehension is primarily frequency-driven.

The influence of orthographic frequency has also been studied across both modalities. Analogies between spelling and reading have been observed by Ernestus and Mak (2005). Ernestus and Baayen (2004) found that participants made more errors in the production of Dutch past tenses (i.e., substituting the te-suffix by the de-suffix or vice versa) when the phonological neighborhood provided strong support for that allomorphic variant. For instance, the stem of the past tense *krabde* is pronounced with a [p] (i.e., [krAp]; ‘scratch’) due to word-final devoicing of voiced obstruents like /b/. Under the influence of past tenses with a stem-final [p]-sound such as *stapte* (‘stepped’ [stApt@]), *krabde* was sometimes misspelled as *krabte*. In a self-paced reading task, the same type of errors were also processed more quickly when supported by the item’s phonological neighborhood (Ernestus & Mak, 2005).

However, a study by Ernestus and Sandra (in preparation) makes it clear that orthographic frequency effects found in spelling are not directly transferable to perception. The authors contrasted the role of morphology and orthographic frequency in the spelling and reading of regular Dutch
inflections. They studied past participles used as inflected adjectives (e.g., *gewiede tuin, ‘the weeded garden’). During production, writers often spelled these inflections incorrectly (e.g., *gewiedde) with a double t or d, in analogy with the spelling of these verbs’ regular past tenses. The latter end in tte or dde (e.g., wiedde, ‘weeded’) and are quasi-homophonous with their past participle (with the exception of the prefix). Such errors occurred more often when the orthographic frequency of the correct word-final pattern was low (i.e., for vowel-vowel items; e.g., gewiede) than when it was high (i.e., for vowel-consonant items having neighbors in the verbal paradigm sharing that pattern; e.g., geteste ‘tested’ < miste ‘missed’, suste ‘hushed’, ...). In other words, the spelling performance on these inflections was determined by the presence of a high-frequency homophonous orthographic pattern in phonologically similar words. In contrast, morphological structure did not affect the error pattern: adjectives that did not preserve the orthographic pattern of the stem in the inflected form (e.g., omgeprate ‘persuaded’; stem is omgepraat) were not spelled incorrectly more often than those that did (e.g., gewiede; stem is gewied). In a self-paced reading experiment, however, the role of morphological structure became more important. Participants were presented with both the correct spelling and the incorrect spelling (e.g., omgeprate and *omgepraatte). Reading times to adjectival past participles spelled correctly were affected by whole-word frequency only when these verbs preserved the orthographic pattern of the stem in their correct spelling (e.g., gewiede, geteste). In contrast, RTs to incorrect spellings became shorter as whole-word frequency increased, but only for verbs whose incorrect spelling preserved the stem’s spelling (e.g., *omgepraatte < omgepraat). Crucially, their correct spellings did not exhibit a frequency effect. Conversely, readers were not sensitive to the frequency of the orthographic patterns: reading times did not increase as the orthographic frequency of the final pattern decreased (e.g., LF: gewiede/omgeprate vs. HF: geteste). The authors concluded that while spellers prefer patterns containing high-frequency orthographic sequences, readers prefer spellings preserving a word’s morphological structure (i.e., an intact spelling of the stem). In other words, morphological structure plays a
bigger role in word recognition than in production, while orthographic frequency is more important in the latter.

The asymmetries between production and perception described above indicate that the effect of Homophone Dominance we observed in spelling (Chapter 2) cannot simply be generalized to perception without presenting sound empirical evidence for such a claim.

We predict a different pattern of results for lexical and sublexical intrusions. At the LEXICAL level, rule application in the production of homophonous verb forms is a conscious and, hence, time-consuming process, since it is not fully automated. This lack of automaticity is due to (a) the low occurrence frequency of homophonous verb forms, which creates few ‘training’ conditions on the spelling of inaudible inflectional suffixes (i.e., most verb forms are non-homophonous) and (b) the large amount of attentional resources required for the morphosyntactic analysis. During such an analysis, working memory has to determine the correct inflectional suffix, depending on the grammatical properties of another word in the sentence. The time-consuming nature of such a conscious computational process gives leeway to a second (and fast) process besides rule application, namely frequency-sensitive full-form retrieval. In Chapter 2, we have shown that this leads to intrusions on the LF homophone (rather than on the HF one) for the two verb types exhibiting lexical homophony in Dutch verbal paradigms, namely stem-final d verbs (type melden, ‘report’) and weak prefix verbs (type bestellen, ‘order’).

In this chapter, we examine whether such a full-form retrieval mechanism is also responsible for not noticing these errors during perception. We will distinguish single word recognition (i.e., reading isolated words) from word recognition in a minimal context and a sentence context. Importantly, single word recognition experiments with homophonous verb forms license the use of these forms as spelling errors in experiments with a grammatical context. Indeed, it seems a straightforward rationale (a) to first demonstrate that whole-word orthographic representations for regularly inflected word forms are activated in single word recognition (as is the case in spelling) and
(b) to next move on to experiments on visual lexical processing where these same forms are embedded in minimal and larger syntactic contexts.

When isolated words are presented, homophone intrusion errors can obviously not occur, as both homophone spellings are correct word forms. In addition, word recognition outside a grammatical context can be accomplished by relying on a fast and automatic decomposition route, since both homophones are morphologically correct. Note that decomposition does not exclude the possibility of whole-word frequency effects, as this may be a mandatory process before whole-word access takes place (Taft & Forster, 1975). Alternatively, a decomposition route and a whole-word route might compete according to the ‘winner takes all’ principle, leading to so-called statistical facilitation (see Baayen et al., 1997; Schreuder & Baayen, 1995). Therefore, studying the recognition of regular verb forms in isolation is a necessary step to establish frequency effects of the whole-word forms.

When homophonous verb forms are embedded in a minimal context (e.g., immediately preceded by the subject; *ik meld, ‘I report’), a morphological analysis identifying the suffix has to be complemented by a syntactic one. During this syntactic analysis, the contextual appropriateness of that suffix is determined (i.e., the correctness of the homophonous form is checked), which is the reverse process of the one used in production. While this check can be performed relatively easy when the marker and the verb form are adjacent (i.e., as in a minimal context), a sentence context in which they are separated by intervening words renders such a conscious checking mechanism time- and resource-consuming. Stated otherwise, the probability that such a check (based on the output of morphological decomposition) is terminated decreases as the distance between the marker and verb form increases (Sandra et al., 1999). Under such conditions, whole-word retrieval is more likely to become the fastest processing route, with high-frequency intrusions being processed more fluently and, hence, noticed less often (i.e., the Homophone Dominance effect).

To summarize, we expect the Homophone Dominance effect to manifest itself more clearly when working memory resources are depleted by a
time-consuming morphosyntactic analysis, which is more effortful in a sentence context than in a minimal context. Since such a checking mechanism is even superfluous in single word recognition, we hypothesize that experiments targeting isolated words are least likely to yield an effect of Homophone Dominance. Note that these three conditions do not differ in the likelihood of morphological decomposition, which is believed to be a blind prelexical process, but in their mobilization of a post-decomposition morphosyntactic check.

At the sublexical level, a morphological analysis suffices to detect a spelling error, both during single word recognition and sentence reading. Contrary to lexical intrusions, where the intruder is a form that appears in the verb’s inflectional paradigm, sublexical intrusions of the type *sustte do not constitute existing word forms. Rather, they are morphologically incorrect: after stripping off the te-suffix or de-suffix in incorrectly spelled Dutch past tenses, the remaining letter string does not constitute a verb stem (e.g., *sustte > non-verb stem *sust + -te). Therefore, sublexical intrusions are more likely to be noticed than lexical intrusions. If readers always rely on such a morphological analysis, sublexical intrusions should (a) always incur a processing delay relative to the correct spelling and (b) always be detected as an error, regardless of the orthographic frequency of the inflected form. We hypothesize that this is not (always) the case. Rather than always relying on a process of morphological decomposition, readers are (simultaneously) sensitive to the co-occurrence frequency of letter patterns, even those straddling the morphemic boundary in an inflected word form (e.g., ste in a word like sus-te, ‘hush-ed’). If such sublexical patterns occur with a sufficiently high frequency, the incorrectly spelled (yet homophonous) past tense form should be accepted as a possible form, despite the fact that the word form is morphologically illegal. It is hypothesized that sublexical intrusions that are made most often in production, namely those involving the substitution of a sublexical orthographic string by a competing homophonous pattern, are also processed more quickly and/or left undetected most often during perception.
We will test the hypothesis that Homophone Dominance also creates this double trap across modalities at the sublexical level.

In what follows, we will examine whether Homophone Dominance modulates the reaction times and/or error rates in a series of perception experiments for stem-final d verbs, weak prefix verbs (lexical homophones) and past tense verbs (sublexical homophones). We investigate whether spelling errors involving a frequently occurring homophone or homophonous pattern are processed more quickly and/or overlooked more often than intrusions involving the LF homophone or a non-existent homophonous pattern. We explore this hypothesis by examining (a) online processing measures (i.e., reaction times and error rates) (b) and offline processing measures (i.e., error detection rates). The online processing measures were studied in a series of word recognition tasks in which homophonous verb forms were visually presented in isolation (lexical decision task; Section 2), embedded in a minimal context (spelling decision task and phonological decision task; Section 3) or in a sentence context (eyetracking task, self-paced reading task and maze task; Section 0). Offline processing was targeted in a proofreading task where intrusions were also embedded in a sentence context (also Section 4).

### 2. Single Word Recognition

As already indicated in Chapter 1 (Section 2.1), numerous studies have found evidence for the idea that morphologically complex words are processed via their morphemic units. Recall that a popular research technique consists of varying a word’s stem frequency, while keeping whole-word frequency and other factors constant. The rationale behind this technique is that an effect of stem frequency on reaction times and/or errors is indicative of morpheme-based lexical access. Using this manipulation, lexical decision tasks have revealed that regularly inflected word forms and derivations with a high-frequency stem are processed more quickly than those with a low-frequency stem (Burani et al., 1984; Colé et al., 1989; Taft, 1979). The issue of stem-based
Lexical access has also been investigated by means of the masked priming paradigm. This technique is used to examine whether words sharing a morphological relationship (e.g., derivation-stem) prime each other, independently of their semantic and/or orthographic similarity and the morphological status of the prime (e.g., pseudo-morpheme or real morpheme). This was found to be the case in, for instance, English (Rastle et al., 2000; Rastle et al., 2004), Spanish (Sánchez-Casas et al., 2003), French (Longtin et al., 2003), Hebrew (Boudela & Marslen-Wilson, 2005) and Dutch (Diependaele et al., 2005). These results have been taken as evidence in favor of a process of blind morphological decomposition that strips off any possible affix from the presented letter string and provides lexical access through the stem representation (Longtin et al., 2003).

However, this conclusion has been questioned by Giraudo and Grainger (2000), who found that the size of the morphological priming effect was determined by the (derivational) prime's whole-word frequency, but not by its stem frequency. This suggests that morphemic representations are only activated after whole-word representations have been accessed. In their supralexical model, morphological relations affect word recognition only in later processing stages. In experiments using the frequency manipulation technique, whole-word representations have also been found to affect visual word recognition of regular derivations and inflections. When keeping stem frequency constant but varying whole-word frequency, researchers showed that high-frequency regular derivations/inflections were processed more quickly than those with a lower frequency (Burani et al., 1984; Colé et al., 1989; Katz et al., 1990; Sereno & Jongman, 1997; Taft, 1979).

More recently, strong evidence has been put forward that both whole-word and morphemic representations are units for lexical access. In a dual-route model, such as the Parallel Dual-route model (Baayen et al., 1997; Schreuder & Baayen, 1995), a direct whole-word retrieval route and a decomposition route operate simultaneously. The speed at which both routes terminate (determining which one ‘wins’ the race) is affected by a number of factors, such as frequency, word formation type, suffix productivity and affixal
homonymy (Bertram, Schreuder, et al., 2000). For instance, depending on the syntactic function of the regular but homonymous Dutch te-suffix, whole-word or stem frequency effects were observed in a lexical decision task (Bertram, Schreuder, et al., 2000). When it was used as the past tense suffix (e.g., suste, ‘hushed’), which is its most frequent usage, only stem frequency effects were found. In contrast, whole-word frequency effects were observed when it was used as the less frequent and unproductive derivational suffix (e.g., diepte, ‘depth’). A similar dissociation was found for the regular suffix -en, which can be used either as a marker of plural nouns (e.g., flessen, ‘bottles’) or, more frequently, as a marker of both the infinitive (which is homographic with the plural present tense) and the plural of verb forms in the past tense (e.g., liepen, ‘ran’). In a lexical decision task, the RTs for plural nouns were affected by whole-word frequency (Baayen et al., 1997), whereas those for plural past tenses of irregular verbs were not. These findings suggest that a decomposition and whole-word route are both initiated during recognition of morphologically complex words. Which of the two is the fastest route is co-determined by the status of the suffix. When it is homonymic (e.g., the Dutch en-suffix has two syntactic functions), recognition via the parsing route is slowed down for the least frequent usage because of the subcategorization conflict between its two functions (i.e., the semantic integration of the stem and the most frequent usage of the suffix is unsuccessful). Consequently, the whole-word route is the fastest processing route, leading to whole-word frequency effects. Conversely, lexical access is achieved more quickly through the decomposition route for the more frequent interpretation of the suffix, leading to stem frequency effects (see Bertram, Laine, et al., 2000 for a similar conclusion in Finnish).

Based on these findings, one would expect that morphological decomposition plays a major role in the visual recognition of regularly inflected Dutch verb forms, including homophones verb forms. The suffix -t, for instance, is highly productive and only has one syntactic function (i.e., marker of the 2nd/3rd person singular present tense). As both homophones are

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54 Recall that RTs to singular (i.e., monomorphemic) nouns were affected by their stem frequency and not by their whole-word frequency.
morphologically correct in isolated word recognition (Section 2), the morphological decomposition process is likely to affect processing (possibly operating in parallel with a whole-word retrieval process). However, the processing of inflected verb forms in a (minimal or sentence) context (examined in Sections 3 and 4) not only involves morphological decomposition but also the syntactic licensing of the inflectional suffix, i.e., checking the appropriateness of that suffix in the grammatical context. Whereas this process is relatively easy when the inflectional suffix is audible (the reader being able to rely on phonological recoding), it is more time-consuming for homophonous verb forms, whose suffix is inaudible. It is this time-consuming component of the reading process that is expected to create an advantage for the whole-word route. When the syntactic licensing process does not terminate before the whole-word route can access a representation in the mental lexicon, the latter will affect the reading process. This will cause homophone intrusions to go unnoticed: the decomposition route will be too slow for error detection, whereas the whole-word route will provide access to the lexical representation of the error and, hence, generate a feeling of familiarity. As a result, the spelling error will be accepted more quickly for intrusions featuring the high-frequency form in comparison with intrusions involving the low-frequency form. In other words, an effect of Homophone Dominance is predicted in reading spelling errors on verb homophones. In this section, we examine whether the Homophone Dominance effect manifests itself for stem-final d and weak prefix verbs in an isolated lexical decision task (LDT), which will be described in more detail below.

### 2.1. Lexical decision task: stem-final d verbs

#### 2.1.1. Hypothesis

The first perception experiment involves a lexical decision task (henceforth LDT) in which participants have to decide whether a visually presented letter string is an existing Dutch word (form) or not. This experiment enables us to
answer two main questions. Firstly, we examine whether the whole-word frequency relation between the d- and dt-form determines the speed with which stem-final d verb forms are processed and/or the number of errors made on them. We predict the d-form to be processed more quickly and/or accurately than the dt-form of the same verb as verbs become more d-dominant and vice versa as verbs become more dt-dominant (i.e., an interaction between Form and Homophone Ratio). Note that isolated verb homophones are not spelling errors (i.e., no homophone intrusions), as there is no syntactic context that requires the use of a particular suffix. Earlier, we argued that reliance on the whole-word route in the processing of (misspelled) verb homophones is likely due to the presence of such a context that requires readers to verify whether the inflectional ending of the verb form matches the morphosyntactic properties of the marker (e.g., the subject). Because the latter process is not only conscious, but also time-consuming, it is likely that the whole-word route terminates before the checking process (subsequent to morphological decomposition) is completed. In the present experiment, however, verb homophones were presented without a grammatical context, rendering a checking mechanism superfluous and, therefore, making effects of the whole-word route less likely. Still, even if morphological decomposition played a major role in the processing of the homophonous verb forms in isolation, this would not rule out effects of their whole-word frequency (i.e., they do not mutually exclude each other). Indeed, whole-word representations may be linked to the representations of their morphemes. In line with such a view, Taft (1979) demonstrated that the stem frequency of regularly inflected forms determined lexical decision times when their whole-word frequency was held constant but also found the reverse: their whole-word frequency affected response latencies when their stem frequency was held constant. If an effect of Homophone Dominance is found in the present experiment, this will not only confirm the existence of full-form representations for regular present tense forms of stem-final d verbs (at least, homophonous ones), but also indicate that these representations are accessed in the course of visual word recognition (as they are in spelling, Chapter 2). Moreover, it would
demonstrate that this access is so fast that it does not depend on the slow checking process subsequent to morphological decomposition.

Secondly, this experiment can also provide an answer to the question whether whole-word frequency affects the processing of regularly inflected homophonous and non-homophonous Dutch verbs in the same way. We will directly compare the processing of inflected forms of stem-final d verbs and of verbs that do not have two homophonous forms within their inflectional paradigm (henceforth non-homophonous verbs). We set out from the hypothesis that a stronger effect of whole-word frequency will be found for homophonous verb forms than for non-homophonous ones. The reason is that the orthographic pattern of a non-homophonous form can be recognized either through access to the orthographic lexicon or through access to the phonological lexicon (i.e., non-homophonous verbs exhibit one-to-one phoneme-to-grapheme mappings). In contrast, the unique identification of a homophonous verb form requires access to the orthographic lexicon, as its phonological representation is compatible with two spelling patterns. Hence, an effect of whole-word frequency is more likely to emerge for homophonous verb forms. The absence of a whole-word frequency effect for non-homophonous Dutch verb forms was already observed in a series of lexical decision tasks reported by Bertram, Schreuder, et al. (2000) and Baayen et al. (1997). In sum, we expect whole-word frequency to be a stronger predictor of lexical decision times for homophonous than for non-homophonous verbs (i.e., an interaction effect between Word Type and Log Whole-word frequency).

2.1.2. Method

Stimuli and Design
Stimuli. Each experimental version consisted of 140 words (yes-responses) and 140 non-words (no-responses). The word category consisted of three groups: homophonous verb forms \(n = 28\), non-homophonous verb forms \(n = 56\) and noun fillers \(n = 56\). The first group was made up of stem-final d
verbs, containing 14 d-dominant and 14 dt-dominant verbs. This includes the verbs used in the experiments of Chapter 2 ('basic set') and 4 additional verbs ('extended set'; see Table 1 in Appendix for their characteristics). They were presented in either the 1st person d-form (e.g., *meld*) or the 3rd person dt-form (e.g., *meldt*, see Design). A second group consisted of non-homophonous and regularly inflected verb forms. Analogous to the stem-final d verbs, half were 1st person forms, while the other half were 3rd person forms (e.g., *meld* > *hUIL* ‘cry’; *meldt* > *keert* ‘turns’; see Table 4 in the Appendix for their characteristics). They were matched with the homophonous verb forms for Log Whole-word Frequency \( t = 0.23, p = .82 \), Log Lemma Frequency \( t = 0.49, p = .63 \) and Length \( t = 0.07, p = .94 \)\(^{55}\). Note that each experimental version contained twice \( n = 56 \) as many non-homophonous verb forms as homophonous verb forms \( n = 28 \). This was done to draw attention away from the critical verbs and to mimic the fact that non-homophonous verbs appear more often in texts than homophonous verbs (see Section 1.2 of Chapter 1). A final group consisted of 56 noun fillers (e.g., *beer* ‘bear’). For each word, we created an orthographically and phonotactically legal non-word, obtained by changing one letter of an existing Dutch word of the same length and grammatical category (verb or noun) and in the same grammatical person (for verbs, e.g., 1st person).

**Design.** Each of the four experimental versions contained 280 items (i.e., 140 words and 140 non-words). In list A, half of the critical stem-final d verbs \( n = 14 \) were presented in their d-form and the other half in their dt-form. Verbs that were presented in their d-form in list A appeared in their dt-form in list B and vice versa. These critical items were accompanied by 56 non-homophonous verb forms (i.e., matched to the homophones in lists A and B), as well as 56 noun fillers and 140 non-words. The items were evenly distributed across four blocks of 70 items, each containing one fourth of the

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\(^{55}\) Since each verb form had a non-homophonous match, both for its whole-word and its lemma frequency, there were 112 non-homophonous matched forms (i.e., 28 verbs x 2 inflected forms x 2 matches).
items of an item type. To control for fatigue or habituation effects, these two lists were pseudo-randomized twice (R1/R2), taking into account the following restrictions: (a) a maximum of four yes- or no-responses could occur in sequence and (b) stem-final d items were separated from each other by at least one item from another item type. This gave rise to the following four experimental versions: AR1, AR2, BR1, BR2. In addition, five extra words and five extra non-words were selected to function as practice items. These were identical across all versions.

**Participants and Procedure**

*Participants.* Twenty-eight native speakers of Dutch (mean age = 22.11, SD = 2.99), who were students at Antwerp University, participated in the experiment. All had normal or corrected to-normal vision and had not been diagnosed with any reading disorder. They had not previously taken part in an experiment on homophone intrusions.

*Procedure.* The experiment was run on an OptiPlex 380 connected to a Dell-monitor (60-50Hz) and a Wingman Precision USB, measuring the reaction times (RTs) and error rates (ERs). Participants sat in front of the monitor at a distance of about 60 cm. A fixation cross appeared in the center of the computer screen for 500ms, followed by a letter string at the same position. This letter string was presented in uppercase and disappeared either after making a response or after 3,000ms when no response was made. The stimuli were presented in the Courier New font with a size of 14 points. Stimulus presentation was controlled by the DMDX software program (Forster & Forster, 2003). The letters were printed in white on a black background.

Participants were tested individually in a soundproof booth. They were given written instructions about the task, informing them to respond as fast as possible whether the presented letter string was an existing Dutch word or not, while making as few errors as possible. A yes-response was made by pushing the ‘word’-button with their preferred hand, while a no-response was made by pushing the ‘non-word’-button with the other hand. If the instructions were
understood, the experimenter started the experiment, which consisted of a practice block (10 items) and four experimental blocks (70 items each). Between each block, the sentence “Attention: the next block will start” appeared on the screen. Participants could freely choose when to press the ‘start’-button and initiate the next block. It took approximately 20 minutes to complete the experiment.

2.1.3. Results and Discussion

In a first analysis (a) we examined whether the Homophone Dominance effect modulated RTs and ERs for the inflected forms of stem-final d verbs. In a second analysis (b) we investigated whether the effect of whole-word frequency differed between homophonous and non-homophonous verb forms, again both for RTs and ERs.

(a) The Homophone Dominance effect

RT analysis. Incorrect responses were removed from the data set (n = 42). The RTs of the remaining 742 observations were transformed by means of the formula \(-1000/RT\) to reduce the positive skew in the distribution. These inverted reaction times (RTi) were analyzed by means of a linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The control variables tested for inclusion were: Trial, Word Length, Log Lemma Frequency and (inverted) PreviousRT. The manipulated variables were Form (d-form vs. dt-form) and Homophone Ratio. The interaction between these two variables, representative of the Homophone Dominance effect, was the effect of interest. Importantly, there was a strong correlation \((r = -.47)\) between Log Lemma Frequency and Word Length. To reduce the collinearity of the model, we followed the approach taken by Milin, Filipović Đurđević, and Moscoso del Prado Martín (2009)\(^{56}\) and orthogonalized Word Length and Log

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\(^{56}\) The same procedure was used in all subsequent analyses in which there were highly correlated measures.
Lemma Frequency. We regressed Word Length against Log Lemma Frequency and used the residuals of this regression as a fixed predictor representing Word Length in our model. Thus, there was no shared variance between the two measures. The random structure of the model consisted of a by-participant random intercept, a by-lemma random intercept, as well as a by-participant random slope for Form. In a following step, we removed outliers, defined as data points whose absolute standardized residuals exceeded 2.5 standard deviations from zero (Baayen, 2008, p. 279). After removing these outliers \((n = 13)\), we fitted a model with the same predictors (i.e., significant control variables and theoretically relevant variables) to the remaining subset of the data. Table 12 represents the results of this regression analysis, while the partial effects of this model are plotted in Figure 11.

<table>
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<tr>
<td>Trial</td>
<td>-0.001</td>
<td>0.0003</td>
<td>-4.03</td>
<td>13.52</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Word Length</td>
<td>0.04</td>
<td>0.01</td>
<td>3.73</td>
<td>11.08</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.15</td>
<td>0.04</td>
<td>3.51</td>
<td>32.56</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>-0.12</td>
<td>0.03</td>
<td>-3.91</td>
<td>12.11</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Form</td>
<td>-0.05</td>
<td>0.03</td>
<td>-1.37</td>
<td>1.86</td>
<td>.173</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>-0.02</td>
<td>0.03</td>
<td>-0.58</td>
<td>0.33</td>
<td>.567</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>0.16</td>
<td>0.04</td>
<td>4.30</td>
<td>18.20</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Table 12. Coefficients of a mixed-effects linear regression model predicting inverted reaction times from Trial, Word Length, (inverted) PreviousRT, Log Lemma Frequency, Form, Homophone Ratio and their interaction, together with the estimate \(β\), standard error, \(t\)-value, \(χ^2\)-value and \(p\)-value
Figure 11. Partial effects plot of effects represented in Table 12. As the value for Homophone Ratio increases on the x-axis, the d-form becomes the more dominant homophone of the verb pair, with negative values representing dt-dominant verbs and positive values representing d-dominant verbs.
ER analysis. All 874 observations were analyzed using a generalized linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The dependent variable represents the correctness of the response. This binomially distributed variable was coded in the following way: an error was marked as 0, whereas a correct response was marked as 1. The same control variables as in the RT analysis were tested for inclusion and the theoretically important variables also remained the same (i.e., Form, Homophone Ratio and their interaction). The final model contained a by-participant random intercept and a by-item random intercept. The results from the regression analysis are depicted in Table 13, while the partial effects of this model are plotted in Figure 12.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$z$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.61</td>
<td>0.37</td>
<td>9.82</td>
<td>74.07</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>1.00</td>
<td>0.51</td>
<td>1.96</td>
<td>16.46</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Form</td>
<td>1.04</td>
<td>0.49</td>
<td>2.14</td>
<td>4.65</td>
<td>.031</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>0.61</td>
<td>0.34</td>
<td>1.80</td>
<td>3.48</td>
<td>.062</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>-1.26</td>
<td>0.66</td>
<td>-1.90</td>
<td>3.64</td>
<td>.056</td>
</tr>
</tbody>
</table>

Table 13. Coefficients of a mixed logit model predicting the probability of a correct response from (inverted) PreviousRT, Form, Homophone Ratio and their interaction, together with the estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.
b) Whole-word frequency effects for homophonous vs. non-homophonous verbs

*RT analysis.* After removal of incorrect responses \((n = 142)\), there were 2,112 observations left\(^57\). Again, these RTs were inverse-transformed \((-1000/RT)\) and analyzed by means of a linear mixed effects model (see Section 1.1.1.3 of

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\(^57\) Upon closer inspection, it turned out that seven weak prefix verbs were accidentally selected as part of the control group. They were consequently excluded from the analysis. This did not affect the matching for Whole-Word Frequency \((t = 0.14, p = .89)\), Log Lemma Frequency \((t = 0.44, p = .66)\) or Word Length \((t = 0.49, p = .63)\).
Chapter 2 for the full statistical procedure). Likelihood ratio tests determined whether it was necessary to take up the following control variables: Trial, Word Length, (inverted) PreviousRT, Grammatical Person (1st vs. 3rd person) and Log Lemma Frequency. The variables under examination were: Log Whole-Word Frequency, Word Type (Homophonous vs. Non-homophonous verb) and the interaction between both. Since both Word Length and Log Whole-word Frequency were highly correlated with Log Lemma Frequency (respectively $r = -0.48$ and $0.93$), we regressed both variables against Log Lemma Frequency and used the residuals of these regressions as fixed predictors in the LMM. Because our aim was to demonstrate the effect of whole-word frequency, we applied the most stringent test, by regressing whole-word frequency against lemma frequency instead of the other way around. The random structure of the model consisted of a by-item random intercept, a by-lemma random intercept and a by-participant random intercept. In addition, the model also included a by-participant random slope for log Whole-word Frequency. After removal of potentially harmful outliers (absolute standardized residuals > 2.5 standard deviations; $n = 35$), we fitted a model with the same predictors to this subset of the data. The results of the regression analysis are presented in Table 14. Figure 13 visualizes the partial effects of the independent variables reported in Table 14.

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58 Note that in this analysis we are not making use of the Homophone Ratio measure but of Whole-word Frequency. In previous analyses, the former measure was preferred because of a high correlation between Log Lemma Frequency and Whole-word Frequency. However, for non-homophonous verbs, such a ratio obviously does not exist. Therefore, this analysis compares the effect of Log Whole-Word Frequency (i.e., its residuals) on homophonous and non-homophonous verbs.

59 The final number of observations after all removal procedures was 1960.
### Table 14

Coefficients of a mixed-effects linear regression model predicting inverted reaction times from Trial, Log Lemma Frequency, Word Length, (inverted) PreviousRT, Word Type, Log Whole-word Frequency and the interaction between Word Type and Log Whole-word Frequency, together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.58</td>
<td>0.03</td>
<td>-46.28</td>
<td>124.76</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial</td>
<td>-0.0005</td>
<td>0.0002</td>
<td>-3.22</td>
<td>10.00</td>
<td>.002</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>-0.13</td>
<td>0.02</td>
<td>7.49</td>
<td>45.19</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Word Length</td>
<td>0.03</td>
<td>0.007</td>
<td>4.27</td>
<td>16.52</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.12</td>
<td>0.02</td>
<td>4.84</td>
<td>105.97</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Word Type</td>
<td>-0.05</td>
<td>0.03</td>
<td>-1.58</td>
<td>2.46</td>
<td>.117</td>
</tr>
<tr>
<td>Log Whole-word Frequency</td>
<td>-0.07</td>
<td>0.03</td>
<td>-1.89</td>
<td>3.49</td>
<td>.062</td>
</tr>
<tr>
<td>Word Type x Log Whole-word</td>
<td>0.13</td>
<td>0.06</td>
<td>2.30</td>
<td>5.11</td>
<td>.024</td>
</tr>
</tbody>
</table>
Figure 13. Partial effects plot of effects represented in Table 14.

**ER analysis.** We analyzed all 2,254 observations by means of a generalized linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full
statistical procedure). The dependent variable was binomially distributed and reflects the correctness of the response (correct = 1; incorrect = 0). Control variables tested for inclusion were the same as in the RT analysis, as were the theoretically important variables (i.e., Word Type, Log Whole-word Frequency and their interaction)\textsuperscript{60}. The random structure of the model consisted of a by-item random intercept. Table 15 summarizes the results of the analysis and Figure 14 visualizes the partial effects.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>z</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.23</td>
<td>0.16</td>
<td>20.14</td>
<td>299.59</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Word Length</td>
<td>0.27</td>
<td>0.07</td>
<td>4.00</td>
<td>16.25</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Word Type</td>
<td>-0.22</td>
<td>0.27</td>
<td>-0.82</td>
<td>0.68</td>
<td>.410</td>
</tr>
<tr>
<td>Log Whole-word Frequency</td>
<td>0.62</td>
<td>0.14</td>
<td>4.40</td>
<td>19.09</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Word Type x Log Whole-word Frequency</td>
<td>-0.03</td>
<td>0.27</td>
<td>-0.12</td>
<td>0.02</td>
<td>.902</td>
</tr>
</tbody>
</table>

Table 15. Coefficients of a mixed logit model predicting the probability of a correct response from Word Length, Word Type, Log Whole-word Frequency, and the interaction between Word Type and Log Whole-Word Frequency together with the estimate $\beta$, standard error, z-value, $\chi^2$-value and $p$-value.

\textsuperscript{60} Note that we used the true values for the variables Word Length and Log Whole-word Frequency instead of their residuals since the control variable Log Lemma Frequency, with which they highly correlate, was not significant in the ER analysis.
Figure 14. Partial effects plot of effects represented in Table 15.

Discussion. In the RT analysis for homophonous verb forms, the control variables Trial, Word Length, PreviousRT and Log Lemma Frequency had a significant effect. For the variable Trial, we found that responses became faster as the experiment progressed. Word Length, however, had a negative effect: RTs increased as the length of the letter string increased. For previous RTs, we observed that the RTs on the critical verbs increased as RTs on the preceding trial increased. The final control variable Log Lemma Frequency had a facilitatory effect: RTs decreased as verbs’ lemma frequency increased. The main effects of Form and Homophone Ratio, however, were not significant.
Crucially, the interaction between these two variables (i.e., the Homophone Dominance effect) was highly significant. As verbs became more d-dominant, RTs for d-forms decreased, whereas they increased for dt-forms.

Similar trends were found in the error analysis. PreviousRT was the only control variable that had a significant effect: more correct responses were made as the RT on the previous trial increased. This time, the main effects of Form and Homophone Dominance were significant. Fewer errors were made on dt-forms. Error rates also decreased as verbs’ d-dominance increased. The interaction effect between both variables was marginally significant: whereas Homophone Ratio did not affect the number of errors made on dt-forms, it did affect the number of errors on d-forms. As verbs became more d-dominant (i.e., when the d-form became the most frequent homophonous form), d-forms were less often rejected as non-words.

Since the Homophone Dominance effect was significant for RTs and marginally significant for ERs, this suggests that whole-word representations for homophonous forms of stem-final d verbs are accessed during visual word recognition, at least in a lexical decision task. This is all the more surprising, given the fact that these regularly inflected verb forms were presented in isolation. This means that there was no need for a conscious and time-consuming morpheme-based error detection mechanism (involving a morphosyntactic analysis) that might trigger reliance on a fast whole-word retrieval process. As whole-word frequency effects still surfaced in a LDT that provides the ideal situation for a purely decompositionally driven mechanism to manifest itself, this suggests that whole-word retrieval is not dependent on a time-consuming checking mechanism. The finding that the HF homophone was processed faster in comparison with its LF counterpart provides us with a first indication that Homophone Dominance is a key determinant in both the production and perception of homophonous forms of stem-final d verbs. It also strongly suggests that comparable effects will be found for weak prefix verbs, the other verb type with homophonous forms in its inflectional paradigm (these will be examined in Section 2.2).
In the comparison between homophones and non-homophones, the significant control variables in the RT analysis were Trial, Word Length, Log Lemma Frequency and Previous RT (see above for their interpretation). The main effect of Word Type was not significant: this indicates that RTs did not differ between homophones and non-homophones. In contrast, Log Whole-word Frequency (i.e., its residuals) yielded a significant facilitatory effect. Crucially, this main effect was modulated by an interaction effect with Word Type. Figure 13 clarifies this interaction and shows that the facilitatory effect of whole-word frequency on RTs is larger for homophones than for non-homophones. The ER analysis partly corroborated these findings. It showed an effect of Word Length (i.e., longer words elicit more correct responses). In addition, the main effect of Word Type was not significant, whereas that of Log Whole-word Frequency was: the more frequent verb forms were, the less likely they were to be rejected as non-words. This was true for both verb types (i.e., no interaction effect with Word Type).

The results of the analysis allow us to draw an important conclusion: the effect of whole-word frequency is more pronounced for homophones. Although the error rates on non-homophones are apparently affected by this factor, the effect for homophones is much more robust, manifesting itself in both the RT and the ER analysis. This suggests that, in isolated visual word recognition, whole-word representations for regular verb inflections are more likely to be accessed for Dutch verbs that have two homophones within their verbal paradigm. This observation can be linked to the one made by Bertram, Laine, et al. (2000) and Bertram, Schreuder, et al. (2000), who found that affixal homophony triggers whole-word storage for Dutch and Finnish regularly inflected word forms. They found that when an affix serves more than a single semantic or syntactic function, inflected forms with such an ambiguous affix are more likely to be processed via the whole-word route (at least, when the suffix represents the

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61 Separate RT analyses of the two verb subsets (homophones vs. non-homophones) showed that Log Whole-Word Frequency was only significant for homophones.

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lower-frequency usage of the inflectional morpheme). Similarly, we found that whole-word retrieval is operative for verb forms involving an ambiguous mapping between orthography and phonology. In the case of homophonous verb forms, a single phonological representation is mapped onto two orthographic representations, which makes it necessary to access to the orthographic lexicon. For non-homophonous verb forms, however, visual word recognition seems to be driven predominantly by morphological decomposition, given the absence of a whole-word frequency effect in the RT data. This corroborates earlier findings by Bertram, Schreuder, et al. (2000) and Baayen et al. (1997) in a set of lexical decision tasks. They did not find a whole-word frequency effect for Dutch verb forms with the regular and productive past tense suffix \textit{-te} and the verb plural suffix \textit{-en}. The reason for the absence of a whole-word frequency effect on the RTs for non-homophonous verb forms might be that their phonological representation is unambiguous (i.e., linked to a single orthographic). This means that phonological recoding of the letter string (possibly subsequent to a process of morphological decomposition) suffices to decide that the word form exists (i.e., access to the orthographic lexicon is not necessary to make a lexical decision). Crucially, these findings do not exclude the existence of whole-word orthographic representations for non-homophonous forms (see Taft, 1979 for whole-word frequency effects for regular verbs in English), but merely show that these are less likely to be accessed under the conditions of the present LDT.

2.2. **Lexical decision task: weak prefix verbs**\textsuperscript{62}

2.2.1. **Hypothesis**

In this experiment, we aim to extend the Homophone Dominance effect obtained in a LDT with stem-final \textit{d} verbs (see Section 2.1) to the second type

\textsuperscript{62} This section is the result of a collaboration with Astrid Schoenmaeckers in the context of her master's thesis.
of homophonous Dutch verbs, namely weak prefix verbs (i.e., d-homophone vs. t-homophones). In Chapter 2, we found that spellers are more likely to write down the HF homophone of such a verb, leading to intrusion errors when the LF form is targeted. We hypothesized that retrieval of this HF homophone would also speed up processing during visual word recognition. More particularly, as verbs become more d-dominant, d-forms should be processed more quickly, while t-forms should exhibit longer RTs (i.e., an interaction between Form & Homophone Ratio). The error rates might also reveal a preference for the HF form, which should then be rejected as a non-word less often than the LF form. Recall that observing an effect of Homophone Dominance in a LDT argues in favor of whole-word retrieval, even though whole-word representations for regularly inflected forms are logically superfluous. Observing an effect of Homophone Dominance would be particularly strong evidence in favor of such a claim as this experiment creates the ideal situation for relying solely on the decomposition route. Indeed, inflected forms outside a grammatical context do not mobilize the error checking mechanism that is used in sentence reading, a process that slows down the decomposition route relative to the whole-word retrieval route.

### 2.2.2. Method

**Stimuli and Design**

**Stimuli.** Each experimental list consisted of 96 words (yes-responses) and 96 non-words (no-responses). The former comprised four subtypes. A first subtype was made up of 24 critical weak prefix verbs: 12 d-dominant ones and 12 t-dominant ones. These verbs are identical to those used in Chapter 2 and will be used throughout the experiments in this chapter (see Table 3 in Appendix for their characteristics). Half were presented in their present tense t-form and half in their past participle d-form (see Design). A second group consisted of verbs with two near-homophones in their inflectional paradigm. Half were presented in their 2\(^{nd}/3^{rd}\) person present tense t-form, which is partly homophonous with their past participle d-form that was presented in
the other half (e.g., luistert-geluisterd; [ILst@rt]-[x@ILst@rt]; ‘listens’-‘listened’). This second subtype functioned as a filler group and was complemented by a third and fourth filler group consisting of 24 1st person singular forms of non-homophonous verbs (e.g., neem, ‘take’) and 24 past tense forms ending in -te (e.g., suste). These three filler groups were used to draw participants’ attention away from the critical weak prefix verbs. For each word, we created an equivalent non-word that was orthographically and phonotactically legal and obtained by changing one letter of an existing word. These 96 non-words consisted of 24 forms with a be-/ver-prefix (i.e., weak prefixes) and the suffix -t or -d (e.g., *beschaligt > beschadigt ‘harms’), 12 non-words derived from present tense t-forms (e.g., *speegt > speelt ‘plays’), 12 non-words derived from past participle d-forms (e.g., *gespeegd > gespeeld ‘played’), 12 non-words derived from present tense stem forms (e.g., *geem > neem ‘take’) and 24 non-words derived from past tense forms (e.g., *kruste > kraste ‘scratched’). These non-words were used to avoid that participants could make a yes-response on the basis of the presence of a particular prefix or suffix.

**Design.** The four experimental versions were made up of 192 items each (i.e., 96 words and 96 non-words). The 24 critical weak prefix verbs were counterbalanced across lists A and B: half (n = 12) were presented in their d-form and half in their t-form in list A, and vice versa in list B. These 24 items were supplemented with 24 near-homophonous verbs (half presented in their t-form and half in their d-form), 24 1st person non-homophonous verb forms, 24 past tense forms as well as 96 non-words. Items were evenly distributed across three experimental blocks, consisting of 64 items each. The experimental lists were pseudo-randomized (R1/R2) using the same criteria as described in Section 2.1.2. This yielded four experimental versions: AR1, AR2, BR1, BR2. The three experimental blocks were preceded by a practice session consisting of ten items.
Participants and Procedure

Participants. Twenty-eight participants (mean age = 21.11; SD = 2.66) took part in the experiment. They had normal or corrected-to-normal vision and no record of a reading disorder. They were students at Antwerp University participating for course credit, but had not previously taken part in an experiment on homophone intrusions.

Procedure. The procedure used in this experiment was identical to the one described in Section 2.1.2.

2.2.3. Results and Discussion

Results. RT analysis. First of all, incorrect responses (n = 34) were removed from the data set. The RTs of the remaining 638 observations were log-transformed to approach the normal distribution. We fitted a linear mixed effects model (LMM) to the log-transformed RTs (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The control variables tested for inclusion were: log-transformed PreviousRT, Trial, Word Length and Log Lemma Frequency. The theoretically important predictors were Homophone Ratio, Form (d-form vs. t-form) and, most importantly, their interaction (i.e., representing the Homophone Dominance effect). The maximal random structure as justified by the design included a by-lemma random intercept, a by-lemma random slope for Form, a by-participant random intercept as well as a by-participant random slope for Form, Homophone Ratio and their interaction. Data points whose absolute standardized residuals exceeded 2.5 standard deviations from zero (n = 16) were considered as outliers and were removed from the data. Next, we fitted a model with the same fixed and random structure to the remaining data points. Table 16 presents the results of the regression analysis, the partial effects of which are plotted in Figure 15.
Table 16. Coefficients of a linear mixed effects model predicting the log-transformed RTs from PreviousRT, Word Length, Form, Homophone Ratio, and the interaction between Form and Homophone Ratio with the estimate \( \beta \), standard error, \( t \)-value, \( \chi^2 \)-value and \( p \)-value.

![Graphs showing partial effects plot of effects represented in Table 16. As the value for Homophone Ratio increases on the x-axis, the d-form becomes the more dominant homophone of the verb pair, with negative values representing t-dominant verbs and positive values representing d-dominant verbs.](image-url)
ER analysis. We fitted a generalized linear mixed effects model to all 742 data points (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The dependent variable was binomially distributed (correct = 1; incorrect = 0). Control variables tested for inclusion were identical to those in the RT analysis, as were the theoretically important variables (i.e., Form, Homophone Dominance, and their interaction). The random structure of the model consisted of a by-item and a by-participant random intercept. Table 17 summarizes the results of the GLMM and Figure 16 visualizes its partial effects.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( \beta )</th>
<th>( SE(\beta) )</th>
<th>( z )</th>
<th>( \chi^2 )</th>
<th>( p(&gt;\chi^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>4.17</td>
<td>0.54</td>
<td>7.80</td>
<td>59.83</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>0.10</td>
<td>0.51</td>
<td>0.20</td>
<td>0.04</td>
<td>.841</td>
</tr>
<tr>
<td>Form</td>
<td>-0.81</td>
<td>0.33</td>
<td>-2.45</td>
<td>7.00</td>
<td>.008</td>
</tr>
<tr>
<td>Homophone Ratio x Form</td>
<td>-0.64</td>
<td>0.51</td>
<td>-1.24</td>
<td>1.58</td>
<td>.210</td>
</tr>
</tbody>
</table>

Table 17. Coefficients of a mixed logit model predicting the probability of a correct response from Homophone Ratio, Form and their interaction, together with the estimate \( \beta \), standard error, \( z \)-value, \( \chi^2 \)-value and \( p \)-value.
Figure 16. Partial effects plot of effects represented in Table 17

Discussion. The RT analysis showed that two control variables were significant: RTs increased as PreviousRT and Word Length increased. In addition, the main effect of Form was significant, with faster RTs for past participle d-forms than for present tense t-forms. In addition, the main effect of Homophone Ratio was significant: as verbs became more d-dominant, reaction times increased. Crucially, the theoretically important interaction between Homophone Ratio and Form was not significant. As verbs became more d-dominant, their RTs did not significantly decrease for the HF d-form and did not increase for the LF t-form. The interaction effect between Form...
and Homophone Ratio was also absent in the ER analysis, although Form was again significant as a main effect (i.e., fewer errors were made on d-forms).

The results disconfirmed our hypothesis: Homophone Dominance did not affect the speed with which homophonous forms of weak prefix verbs were processed, nor how many errors were made on them. While the final partial effect plot suggests that there is an effect of Homophone Dominance for verbs that are strongly d-dominant (right side of the plot), a separate analysis on the subset of d-dominant verbs did not reveal an interaction effect between Form and Homophone Ratio, neither for RTs nor for ERs (ps > .05). Since the HF homophone did not cause a processing advantage, neither for d-dominant nor for t-dominant verbs, this strongly suggests that whole-word representations are not accessed for weak prefix verbs during isolated visual word recognition.

One might want to dismiss the current experiment because neither the effect of Homophone Dominance, nor that of Log Lemma Frequency was found. This could suggest that the experiment did not tap into frequency effects at all, even though frequency effects typically appear in a lexical decision task. Log Lemma Frequency was not taken up as control variable because it exceeded the .05 α-level when tested for inclusion by means of likelihood ratio tests. More specifically, it had a p-value of .09. However, having shown that the theoretically relevant interaction effect between Form and Homophone Ratio was not significant, it is justified to leave this interaction effect out of the equation and fit a new model that includes only the significant main effects from both the theoretically relevant (Form and Homophone Ratio) as well as all control variables (including Log Lemma Frequency). The RT analysis showed that the effect of Log Lemma Frequency was indeed facilitatory ($\beta = -0.07, SE(\beta) = 0.03, z = -2.18, \chi^2 = 4.37, p(> \chi^2) = .037$): reaction times decreased as verb forms’ lemma frequency increased.

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63 The final model included the following (significant) fixed predictors: PreviousRT, Word Length, Log Lemma Frequency and Form. The random structure consisted of a by-participant random intercept and random slope for Form as well as Log Lemma Frequency. In addition, it also included a by-lemma random intercept and slope for Form.
The significant effect of lemma frequency implies that the task is valid when it comes to targeting frequency effects.

The absence of an interaction effect for weak prefix verbs stands in sharp contrast with the highly significant effect of Homophone Dominance found for stem-final d verbs in the LDT (cf. previous experiment). This rules out the possibility that this experimental task is unable to pick up whole-word frequency effects for inflected verb forms. The dissociation between the two verb types might then have resulted from differences in the frequency ratios of the selected verbs. If larger ratio values were used in the set of stem-final d verbs, this would have made it more likely to detect an effect of Homophone Dominance for this verb type than for weak prefix verbs. However, a t-test showed that the two verb sets were matched in terms of their Homophone Ratio ($t = 1.05, p = .3$). We conclude that the discrepancy between the results for both verb types is not due to a more pronounced frequency ratio for stem-final d verbs.

The absence of an interaction effect is also at odds with our findings in Chapter 2, where we showed that spellers prefer the HF homophone of a weak prefix verb during production, both in an online spelling-to-dictation task and a corpus study. In contrast to the findings for stem-final d verbs, the results obtained in the present perception experiment (i.e., isolated visual word recognition) do not mirror the results obtained in the production experiments. This discrepancy might be due to the presence of a sentence context in the latter experiments. There are two reasons why a sentence context might be more likely to induce effects of whole-word frequency. First, such a context requires that the correctness of the suffix letter (the output of a process of morphological decomposition) is checked by retrieving the word controlling the spelling of the verb form (e.g., the subject or the auxiliary verb). This checking process is time-consuming and may not be terminated when the whole-word representation of the higher-frequency homophone quickly becomes available, giving rise to an effect of Homophone Dominance. This was likely the case in the online spelling-to-dictation experiment, where the marker and verb form were separated by a number of other words, a factor
that has been shown to affect the number of homophone intrusions (Sandra et al., 1999, 2004). In contrast, when words are presented outside a sentence context (as in this lexical decision task), there is obviously no check on the correctness of the suffix spelling. As responses can be made by making use of the decomposition route only, it might outperform the whole-word retrieval route such that the Homophone Dominance effect is absent. However, this argument should equally apply to stem-final d verbs. Yet, these verbs gave rise to a clear effect of Homophone Dominance in the lexical decision task. Hence, the argument cannot account for the dissociation between the two verb types.

There is, however, a second reason why the absence of a sentence context might make it difficult to detect effects of whole-word frequency for weak prefix verbs. While a lexical decision task in which the homophones are presented in isolation may seem the best way to measure effects of whole-word frequency, a particular property of weak prefix verbs may have triggered other frequency effects as well. The presence of a weak prefix might have biased readers to interpret the verb form as a past participle. There are several indications that this may indeed have been the case. Firstly, a corpus count performed by Frisson and Sandra (2002a) reveals a strong association between the prefixes be-/ver- (the ones used in the present experiment) and the suffix letter -d (past participle suffix). In other words, when a verb form contains the prefix be- or ver-, there is a high probability that the suffix will be -d (Bosman, 2005; Sandra et al., 1999). Secondly, participants in the lexical decision experiment had a clear preference for the d-form of weak prefix verbs, suggesting that they were indeed biased to process these verb forms as past participles. They made significantly fewer errors on the d-form and correct responses on this form were significantly faster than correct responses on the t-form (i.e., significant main effect of Form in both the RT and ER analyses). Recall that this d-bias was also present in the production experiment and corpus study of Chapter 2, which emphasizes its importance in the processing of these forms. Obviously, a d-bias will make it more difficult to detect effects of whole-word frequency. It is crucial to note that the d-bias in the lexical decision task was not caused by a stronger frequency ratio for d-dominant
verbs. While the frequency ratio is on average larger for d-dominant verbs (0.66) compared to t-dominant verbs (0.46), a t-test showed that this difference was not significant ($t = 1.63, p = .12$). \textsuperscript{64} If a d-bias affects lexical decision latencies to the homophones of weak prefix verbs, the absence of a significant effect of Homophone Dominance in a single word recognition task does not necessarily mean that these verb forms have no whole-word representations. The bias may have obliterated the effect of such representations. Possibly, an effect of Homophone Dominance will emerge when the forms are presented in a syntactic context (as in the production experiments). This will be investigated in the experiments below.

### 3. Word Recognition in a Minimal Context

#### 3.1. Spelling decision task

##### 3.1.1. Stem-final d verbs

##### 3.1.1.1. Hypothesis

The lexical decision experiment confirmed that whole-word representations of HF homophones can be accessed to speed up processing during perception, at least for stem-final d verbs. In the context of such an experiment, all verb forms are obviously correctly spelled (as there is no syntactic context). Since our main goal is to explain why texts of Dutch language users are plagued by homophone intrusions, a more natural approach would be to study the perception of both correctly and incorrectly spelled verb forms in a syntactic context. One way of accomplishing this goal is to present verb forms in such a context and ask participants to decide whether they are spelled correctly or not. Although we found that the HF homophone of stem-final d verbs was retrieved in isolated visual word recognition (i.e., lexical decision), this

\textsuperscript{64} Moreover, the d-homophones and t-homophones were also matched on Log Whole-word Frequency ($t = 0.48; p = 0.63$)
observation by no means guarantees that readers rely on whole-word representations when having to decide whether the verb form is spelled correctly in a grammatical context. The introduction of a spelling check on the suffix letter by definition requires morphological decomposition. If this decomposition process and the subsequent spelling check are finished before the verb form’s whole-word representation becomes available, no effect of Homophone Dominance will be found. If, however, whole-word retrieval is the fastest route, an effect of Homophone Dominance will emerge.

To answer this question, we devised the current spelling decision task (SDT) in which we embedded stem-final d verb forms in a minimal grammatical context, i.e., the verb form was immediately preceded by a personal pronoun. We elicited grammaticality judgments on both correctly spelled (yes-response; e.g., *hij meldt) and incorrectly spelled (no-response; e.g., *hij *meld) verb forms. Crucially, the phonology of such two-word combinations (both the correct and incorrect ones) is perfectly acceptable. Given that the marker and verb form were adjacent, this manipulation offered a very stringent test of the Homophone Dominance effect. In spelling experiments, an adjacent condition has been shown to yield fewer intrusions in comparison to a condition where subject and verb form are separated by several other words (Sandra et al., 1999). To check whether the verb form is spelled with the correct suffix letter, the participant’s working memory needs to identify the marker representing the required morphosyntactic information. This retrieval process is more effortful in the case of a distant marker than in the case of an adjacent one, making access to the whole-word representation of the higher-frequency form more likely in the former case. Because of the immediate presence of the marker in the present experiment, it creates the optimal condition to quickly complete the required morphosyntactic analysis and check whether the correct spelling rule has been applied, without accessing the verb form’s whole-word representation. If participants could indeed uniformly apply the spelling rule, there would be no difference in RTs/ERs between the HF and LF homophones, neither for the correct forms, nor for the incorrect ones. However, if participants retrieve the whole-word
representation of the HF homophone, we predict a different pattern of results. For correctly spelled verb forms, we expect HF homophones to be processed more quickly and with fewer errors compared to their LF counterpart (i.e., an interaction between Homophone Ratio and Form). Although a HF form could not help participants decide whether a verb form is spelled correctly or not, its familiarity would bias them to make a yes-response, leading to faster responses and fewer errors when that spelling is correct. For incorrectly spelled verb forms, the presence of a HF form would also create a yes-bias. However, since incorrect spellings require a no-response, this would result in a response conflict. If so, we expect a delay in RTs and/or an increase in errors for homophone intrusions corresponding to the HF homophone, while those corresponding to the LF homophone should be rejected more easily. In other words, if the task allows the HF homophone to access its whole-word representation (which exists, cf. the effect of Homophone Dominance in the lexical decision task) before the spelling check is finished, we predict that a HF homophone will be accepted more easily as a correct spelling pattern and will be more difficult to reject as an error, compared to the LF homophone. In statistical terms, we expect the interaction effect between Homophone Ratio and Form to interact with Spelling (i.e., a three-way interaction between Homophone Ratio, Form and Spelling).

3.1.1.2. Method

Stimuli and Design

Stimuli. Each experimental version consisted of 216 two-word combinations, half of which were spelled correctly (yes-response) and half of which were spelled incorrectly (no-response). The first word of the two-word combination was either the personal pronoun *ik* or *hij* ('I/he') or the article *de* ('the'), while the second word was either a verb or a noun. These items can be subdivided into 5 main categories. A first group consisted of 24 critical stem-final d verbs ('basic set', see Table 1 in Appendix), half of which were d-dominant and half of which were dt-dominant. Half were spelled correctly (e.g., *ik meld/hij*
meldt, ‘I report/he reports’) while the other half were spelled incorrectly (e.g., *meldt/hij *meld). This entails that d- and dt-spellings required both a yes-response and a no-response, so that participants could not make a correct response by relying on the final letter pattern only. A second group was made up of 24 critical ‘sublexical’ verbs (i.e., past tenses, half of which contained a word-final letter pattern that was homophonous at the sublexical level). These were identical to those used in the production chapter (see Table 2 in Appendix for their characteristics). Half of these past tense verbs were p verbs (no homophonous letter cluster) and the other half were s verbs (with a homophonous letter cluster). Again, half were spelled correctly (e.g., *hij sustte/ik repte, ‘he hushed/I rushed’), while the other half were spelled incorrectly (with a double instead of a single t; e.g., *hij *sustte/ik *reptte). These past tense verb forms will be analyzed separately in Section 3.1.2.3. The two critical groups were supplemented with three fillers categories. A first filler group comprised 24 present tense t-forms whose stem ended in a voiced consonant (correct spelling: *hij vult ‘fills’; incorrect, but homophonous spelling: *hij *vuldt or *hij *vuld). A second filler group was composed of 36 past tense forms whose stem ended in -rt, -cht, -nt, -ch or -f (e.g., correct spelling: *hij plantte; ‘he planted’; incorrect spelling: *hij *plante). Thus, the correct spelling of past tense verbs could contain a single t or a double t, making it impossible for participants to rely on the final letter pattern to make a correct response. Finally, a third filler group consisted of 108 noun fillers for which it was possible to create a homophonous, but incorrect spelling pattern (e.g., de trein > de *trijn; ‘the train’).

Design. Each experimental version contained 216 items. Lists A and B represent the counterbalancing for the personal pronouns ik/hij (‘I’, ‘he’). In list A, half of the verb forms were preceded by the 1st person personal pronoun ik, while the other half were preceded by the 3rd person personal pronoun hij and this was reversed for list B. Note that this counterbalancing was only relevant for verb forms (i.e., nouns are always preceded by the article de). Lists L1 and L2 represent the spelling correctness of both verbs and nouns. Half of
the verbs and nouns in list L1 were spelled correctly and half incorrectly. Those spelled correctly/incorrectly in list L1 were spelled incorrectly/correctly in list L2. The correct and incorrect (homophonous) spellings of a verb form never appeared in the same list. In other words, Personal Pronoun (1st vs. 3rd person) and Sublexical Homophony (no vs. yes) were orthogonally combined with Spelling (correct vs. incorrect). Items were evenly distributed across six blocks of 36 items each, with an equal number of items from each item type in each block. To control for fatigue or habituation effects, these four versions were pseudo-randomized (R1/R2), with the same restrictions as explained in Section 2.1.2. In total, there were eight experimental versions (i.e., AL1R1, AL1R2, BL1R1, BL1R2, AL2R1, AL2R2, BL2R1 and BL2R2). Furthermore, twelve practice items preceded each version.

**Participants and Procedure**

*Participants.* Thirty-two subjects, students at Antwerp University, (mean age = 20.38; SD = 1.41) participated for course credit. They had normal or corrected-to-normal vision and had not yet taken part in an experiment on homophone intrusions, nor did they have any record of a reading disorder.

*Procedure.* The procedure used in this experiment is nearly identical to the one described in Section 2.1.2. The difference concerns the written instructions: participants were asked to decide as quickly as possible and with as few errors as possible whether the two-word combination was correctly spelled according to the Dutch spelling rules. Hence, the question was not whether the form existed in the language, but whether it was correctly spelled in the minimal syntactic context.

**3.1.1.3. Results and Discussion**

*Results.* Two participants whose error rate was higher than 25% for stem-final d verbs were excluded from the analysis.
RT analysis. After removing all incorrect responses on the stem-final d verb forms \(n = 87\), the remaining 633 observations were log-transformed and fitted with a linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). Likelihood ratio tests determined which of the following control variables were necessary to take up: Trial, Length (of the two-word combination), Log Lemma Frequency and log-transformed PreviousRT. Because Log Lemma Frequency and Length were highly correlated \(r = -.47\), we regressed Length against Log Lemma Frequency. The residuals of this regression analysis were used as fixed predictor representing Length. The theoretically relevant variables were: Spelling (correct vs. incorrect), Form (d-form vs. dt-form) and Homophone Ratio. We were particularly interested in the three-way interaction between these variables. The maximal random structure as justified by the data consisted of a by-lemma random intercept, a by-participant random intercept and by-participant random slopes for Spelling and Form. Next, we removed observations whose absolute standardized residuals exceeded 2.5 standard deviations \(n = 11\) and fitted a model with the same fixed predictors and random structure to the remaining data points. The results of this final model are reported in Table 18, while its partial effects are represented in Figure 17.
§ 3 The Homophone Dominance Effect in Perception

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>0.04</td>
<td>181.97</td>
<td>211.42</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial</td>
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<td>0.0002</td>
<td>-4.72</td>
<td>21.50</td>
<td>&lt; .001</td>
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<tr>
<td>Length</td>
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<td>0.007</td>
<td>3.45</td>
<td>9.49</td>
<td>.002</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
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<td>0.02</td>
<td>-4.75</td>
<td>15.31</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.12</td>
<td>0.03</td>
<td>4.07</td>
<td>51.04</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Spelling</td>
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<td>0.03</td>
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<td>1.55</td>
<td>.213</td>
</tr>
<tr>
<td>Form</td>
<td>-0.06</td>
<td>0.03</td>
<td>-2.14</td>
<td>4.27</td>
<td>.039</td>
</tr>
<tr>
<td>Homophone Ratio</td>
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<td>0.02</td>
<td>-1.44</td>
<td>1.95</td>
<td>.162</td>
</tr>
<tr>
<td>Spelling x Form</td>
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<td>0.04</td>
<td>-1.41</td>
<td>1.97</td>
<td>.160</td>
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<td>Spelling x Homophone Ratio</td>
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<td>0.03</td>
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<td>0.72</td>
<td>.395</td>
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<tr>
<td>Form x Homophone Ratio</td>
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<td>0.03</td>
<td>2.07</td>
<td>4.26</td>
<td>.039</td>
</tr>
<tr>
<td>Spelling x Form x Homophone Ratio</td>
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<td>0.06</td>
<td>-4.80</td>
<td>22.36</td>
<td>&lt; .001</td>
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</table>

Table 18. Coefficients of a linear mixed effects model predicting log-transformed RTs from Trial, Length, Log Lemma Frequency, PreviousRT, Spelling, Form, Homophone Ratio and all two-way and three-way interactions between the latter three variables with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.
ER analysis. A generalized linear mixed effects model (GLMM; see Section 1.1.1.3 of Chapter 2 for the full statistical procedure) was fitted to all 720 observations. The correctness of the response functioned as the binomially distributed dependent variable (correct = 1; incorrect = 0). Control variables tested for inclusion were the same as in the RT analysis, as were the theoretically important variables. The maximal random structure justified by the data consisted of a by-lemma random intercept. The results from the
GLMM are represented in Table 19 and partial effects are visualized in Figure 18.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$z$</th>
<th>$\chi^2$</th>
<th>$p(&gt; \chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>14.44</td>
<td>57.70</td>
<td>&lt; .001</td>
</tr>
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<td>-2.68</td>
<td>6.12</td>
<td>.013</td>
</tr>
<tr>
<td>Spelling</td>
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<td>0.25</td>
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<td>.496</td>
</tr>
<tr>
<td>Form</td>
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<td>1.49</td>
<td>2.21</td>
<td>.137</td>
</tr>
<tr>
<td>Homophone Ratio</td>
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<td>-0.17</td>
<td>0.03</td>
<td>.863</td>
</tr>
<tr>
<td>Spelling x Form</td>
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<td>0.51</td>
<td>0.44</td>
<td>0.19</td>
<td>.660</td>
</tr>
<tr>
<td>Spelling x Homophone Ratio</td>
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<td>-2.75</td>
<td>7.73</td>
<td>.005</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
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<td>0.33</td>
<td>1.88</td>
<td>3.57</td>
<td>.059</td>
</tr>
<tr>
<td>Spelling x Form x Homophone Ratio</td>
<td>1.16</td>
<td>0.67</td>
<td>1.74</td>
<td>3.05</td>
<td>.081</td>
</tr>
</tbody>
</table>

Table 19. Coefficients of a mixed logit model predicting the probability of a correct response from Length, Spelling, Form, Homophone Ratio and the two- and three-way interactions between the latter three variables, together with the estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.
§ 3 The Homophone Dominance effect in perception

Figure 18. Partial effects plot of effects represented in Table 19.

**Discussion.** For the RT analysis, the significant control variables were: Trial, Length, Log Lemma Frequency and PreviousRT. Reaction times decreased as the experiment progressed (i.e., effect of Trial) and as verb forms’ lemma became more frequent (i.e., effect of Log Lemma Frequency). In contrast, RTs increased as previous RTs and the length of the letter string increased. The main effects of Spelling and Homophone Ratio were not significant, whereas that of Form was: dt-forms were processed more quickly compared to d-forms. The only significant two-way interaction was that between Form and Homophone Ratio. However, this was modulated by a significant three-way
interaction effect between Spelling, Form and Homophone Ratio. The two final plots of Figure 17 allow us to interpret this effect. For d-forms (penultimate plot), we observe the following pattern: as Homophone Ratio increased (i.e., as verbs became more d-dominant), RTs for the HF d-form decreased when they were correctly spelled (yes-response), but increased when they were incorrectly spelled (no-response). For dt-forms (final plot), we observed the reverse pattern: as Homophone Ratio increased (i.e., dt-forms became the less frequent homophone), reaction times on correctly spelled dt-forms increased, whereas they decreased for incorrectly spelled dt-forms.

In the ER analysis, the control variable Length was significant, with fewer errors for shorter letter strings. As with the RT analysis, the main effects of Spelling and Homophone Ratio were not significant, while that of Form was: fewer errors were made on dt-forms. Both the two-way interaction between Form and Homophone Ratio and the three-way interaction with Spelling were marginally significant. Figure 18 visualizes which trends are visible for d-forms (penultimate plot) and dt-forms (final plot). As Homophone Ratio increased, more correct responses for d-forms were found for correctly spelled verb forms (yes-responses), while the error rate increased for incorrectly spelled forms (no-responses). For d-forms, this signals that the HF form is easily accepted when spelled correctly, but is difficult to reject as an incorrect spelling. For dt-forms, however, the pattern of results for the errors does not entirely fit our hypothesis. Homophone Ratio did not affect the ERs of incorrectly spelled dt-forms, indicating that the pattern “ik + dt-form” is swiftly rejected as an error, for both d- and dt-dominant verbs. For correctly spelled dt-forms, however, fewer errors were made as verbs became more d-dominant (i.e., as the dt-form became the less frequent homophone), whereas the hypothesis predicts more such errors with increasing d-dominance. Note, however, that the interaction effect in the error analysis did not reach the significance threshold.

The current experiment supports our hypothesis: the Homophone Dominance effect persists in a spelling decision task with a minimal grammatical context. When participants were asked to judge whether two-
word combinations (i.e., personal pronoun + verb form) were correctly spelled in Dutch, reaction times revealed that the HF homophone was accessed during processing. The results of the present experiment mimic those of the lexical decision task. We observed shorter reaction times for the HF homophone in comparison with the LF homophone when having to respond to a correct spelling (yes-response), but a delay in reaction times when having to dismiss the HF homophone as an incorrect spelling (no-response). This delay is the result of a response conflict: the familiarity of the HF homophone whose whole-word representation became available very quickly suggests a yes-response. However, this initial bias had to be overcome to give a correct no-response. In contrast, the LF homophone was accepted more slowly as a correct spelling, but was also rejected more quickly as an incorrect spelling.

The observation that participants relied on whole-word retrieval is surprising given the close proximity of a personal pronoun. Since RTs differed between the HF and LF homophones, the present results challenge the idea that the immediate presence of the pronoun makes it possible to accomplish morphological decomposition and a subsequent spelling check before the verb form’s whole-word representation becomes available (at least, in the case of a HF homophone). Clearly, the deliberate checking process in a minimal syntactic context is too time-consuming to outperform the retrieval of the verb form’s whole-word representation.

Note that our explanation in terms of a response conflict in the current SDT does not contradict the conflict that gave rise to a reverse effect of Homophone Dominance for weak prefix verbs in the process data of the online spelling-to-dictation task (STDT). Recall that we found an inhibitory effect in the pause times for HF forms, especially those of d-dominant verbs (as a d-bias reduced the effect of Homophone Dominance for t-dominant verbs). In the former task (SDT), the response conflict arises for incorrect HF verb forms. As the whole-word retrieval route quickly activates this HF form, the familiarity of this homophone spelling initially suggests a yes-response (i.e., the spelling is correct). However, when the slower morphosyntactic checking process yields an output that indicates a no-response (i.e., the spelling is in
fact incorrect), participants are confronted with a response conflict and have to suppress the initial yes-response. This response correction inevitably causes a delay in the RTs. However, the conflict in the STDT is of a different nature. Since homophonous verb forms are notorious in a dictation task (i.e., spellers know that their spelling requires careful consideration), participants attempted not to spell too quickly and preferred to wait for the output of the conscious morpheme-based process (an attempt that often failed, yielding the familiar effect of Homophone Dominance in the error analysis, i.e., the product data). Hence, they were suspicious of a response that became available very quickly (i.e., a HF form) and, in a sense, labeled it as ‘unreliable’. When the output of the whole-word retrieval process was confirmed by the output of the more trustworthy morphosyntactic process, i.e., whose output was labeled as ‘reliable’, two conflicting labels were connected to a single spelling form (i.e., the suspicious HF response turned out to coincide with the to-be-given response). This labeling conflict needed to be undone, leading to a processing delay. This labeling conflict did not occur when LF words had to be spelled, as the output of the whole-word process (the HF spelling) was connected to the ‘unreliable’-label, whereas the output of the morpheme-based process (the LF spelling) was connected to the ‘reliable’-label. Hence, pause times were longer when participants produced the correct spelling of HF forms compared to LF forms, i.e., a reverse effect of Homophone Dominance emerged. In other words, the conflict in the SDT is a true response conflict that results from the opposite outputs of the two processes for the visually presented incorrect spelling of the verb’s HF homophone (i.e., a yes- and no-response), whereas the conflict in the STDT is a labeling conflict caused by the same output of two processes when producing the correct spelling of the verb’s HF homophone (i.e., a “suspicious”-label and a “reliable”-label).

In sum, the present findings corroborate the hypothesis that whole-word representations of (HF) homophones verb forms are retrieved during visual word recognition. Whole-word retrieval of the HF homophone makes it easy to accept it as a correct spelling, but difficult to reject it as an incorrect spelling, whereas the reverse is true for the LF homophone. This finding
strongly suggests that the persistence of homophone intrusions on stem-final d verb forms is partly due to readers’ familiarity with the orthographic pattern of the HF homophone. This familiarity creates a bias to accept it as a correct spelling pattern such that readers sometimes fail to see that it is a spelling error.

### 3.1.2. Past tense verb forms

#### 3.1.2.1. Hypothesis

Our hypothesis for the visual processing of homophone intrusion errors at the sublexical level builds on a series of experiments that have found evidence in favor of the activation of orthographic and phonological neighbors in visual word recognition. While most lexical decision studies observed a facilitatory effect of orthographic neighborhood size (i.e., faster RTs for words with many neighbors) (Andrews, 1989, 1992; Forster & Shen, 1996; Sears et al., 1995), null effects (Coltheart et al., 1977) and inhibitory effects have also been reported (Grainger, 1990; Huntsman & Lima, 1996; Perea & Pollatsek, 1998), especially in French and Spanish (Carreiras et al., 1997; Grainger & Jacobs, 1996; Grainger et al., 1989, 1992). Ziegler and Perry (1998) showed that this discrepancy results from the different characteristics of these neighbors across languages. While most orthographic neighbors are rhyme neighbors in English and Dutch, this is not the case in French or Spanish (Ziegler & Goswami, 2005; Ziegler & Perry, 1998). Yates (2005) indeed confirmed the importance of phonological neighbors: English words with many phonological neighbors were recognized faster in a lexical decision task. Moreover, Grainger et al. (2005) found that orthographic and phonological neighbors interact: RTs to French words were affected by the consistency between co-activated orthographic and phonological representations (i.e., so-called cross-code consistency). Words with consistent sound-to-spelling mappings (e.g., *wit*) were processed more quickly than words with inconsistent ones (e.g., *type* > *hype, wipe*, ...). Taken together, these results indicate that a word’s recognition
can be facilitated by orthographically similar words that are also phonological neighbors.

Our hypothesis also builds on the results obtained for past tenses in Chapter 2. In an offline spelling-to-dictation task (Section 1.1.2), sublexical intrusions occurred more often for verb forms with a homophonous orthographic pattern at the sublexical level compared to verb forms without such homophony. More particularly, significantly more intrusions occurred for $s$ verbs (e.g., *sustte instead of suste analogous to rustte, the stte cluster being homophonous with the correct ste cluster in suste) than for $p$ verbs (e.g., *reptte instead of repte; there are no words ending in ptte). These $s$ verbs (i.e., with an ambiguous spelling) also received longer IKIs at the morphosyllabic boundary than $p$ verbs (i.e., with a uniform spelling) in an online spelling-to-dictation task (Section 1.2.3). These results of the production experiments indicate that past tense verb forms are not spelled by means of a strictly rule-based mechanism and are subject to interference from the homophonous (non-morphemic) letter cluster.

The current experiment aimed to find out whether the visual lexical processing of past tense verb forms in a minimal syntactic context is also affected by the presence of a homophonous orthographic pattern in phonological neighbors. Therefore, we used the same set of $p$ and $s$ verbs from the production experiments in a spelling decision task, in which we asked participants to decide whether a two-word combination (e.g., hij *sustte) was correctly spelled, i.e., the same task that we used for stem-final d verbs (see Section 3.1.1). Lexical and sublexical intrusions, however, differ in an important respect: there is no need for a morphosyntactic analysis to decide whether a past tense form is spelled correctly. For past tense forms, morphological decomposition (i.e., stem and suffix identification) suffices. Whereas decomposition results in a legal stem-suffix combination for a correct spelling of $s$ and $p$ verb forms (suste < sus + te), this is not the case for an incorrect spelling. For instance, incorrect *sustte falls apart into sust and te, whereas the morpheme spellings are sus and te. If these past tense verb forms are automatically decomposed and spelling decisions are solely made on the
basis of subsequent access (or a failure of such access) to morphemic representations, RTs and/or ERs should not depend on the frequency of the sublexical cluster. Rather, a misspelling should lead to a comparable processing difficulty for both verb types, as a parsing route would attempt to access the mental lexicon via a non-stem in both cases (e.g., *sust-te/rept-te*). However, if our hypothesis is true, RTs/ERs should differ for past tenses whose word-final orthographic pattern has a homophonous competitor (s verbs) compared to verbs without such sublexical homophony (p verbs). For s verbs, the single ste-pattern is correct but experiences competition from the double stte-pattern, which is the correct spelling in phonologically similar verbs, more particularly verbs whose stem ends in st (e.g., *rustte*). In contrast, thus defined phonological neighbors do not exist for p verbs (e.g., *repte*): as there are no verb stems ending in pt, the final letter string of p verbs (i.e., *pte*) does not have a homophonous competitor (i.e., ptte) in any past tense form, nor is it attested in any other Dutch word. Consequently, the single pte-pattern is always correct, whereas the double ptte-pattern is always incorrect. Therefore, we expect the competition between the two orthographic patterns to result in a response delay for s verbs compared to p verbs. More specifically, we expect longer RTs and more errors for s verbs in both the correct and incorrect spelling conditions compared to p verbs (i.e., a main effect of Sublexical Homophony).

### 3.1.2.2. Method

**Stimuli and Design**

See Section 3.1.1.2.

**Participants and Procedure**

See Section 3.1.1.2.
3.1.2.3. Results and Discussion

**Results.** We removed six participants whose error rate exceeded 25% for the critical past tense forms.

**RT analysis.** After removing all incorrect responses \( (n = 60) \), the remaining 564 observations were log-transformed and fitted with a linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). Likelihood ratio tests determined whether the following control variables were taken up in the final model: Personal Pronoun \( (ik \ 'I' \ vs. \ hij \ 'he') \), Trial, Length (of the two-word combination), Log Lemma Frequency, Log Whole-word Frequency and log-transformed PreviousRT. The manipulated variables were: Spelling (correct vs. incorrect) and Sublexical Homophony (no vs. yes). Due to their high correlation \( (r = .5) \), we regressed Length against Spelling and used the residuals of this regression as a fixed predictor representing Length to reduce collinearity in the model. The full random structure supported by the design was incorporated into the model, consisting of a by-lemma random intercept, a by-lemma random slope for Spelling, a by-participant random intercept and by-participant random slopes for Spelling as well as Sublexical Homophony. After removing outliers (i.e., data points whose absolute standardized residuals > 2.5 standard deviations from zero; \( n = 5 \)), we fitted a model with the same predictors and random structure to the remaining data points. The results of the final model are presented in Table 20, while partial effects are plotted in Figure 19.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( \beta )</th>
<th>( SE(\beta) )</th>
<th>( t )</th>
<th>( \chi^2 )</th>
<th>( p(&gt;\chi^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>0.04</td>
<td>189.47</td>
<td>187.07</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Length</td>
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<td>0.02</td>
<td>2.05</td>
<td>4.17</td>
<td>.041</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.14</td>
<td>0.04</td>
<td>3.38</td>
<td>43.20</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Spelling</td>
<td>0.09</td>
<td>0.04</td>
<td>2.20</td>
<td>4.40</td>
<td>.036</td>
</tr>
<tr>
<td>Sublexical Homophony</td>
<td>0.13</td>
<td>0.03</td>
<td>4.60</td>
<td>17.39</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Table 20. Coefficients of a linear mixed effects model predicting the log-transformed RTs from Length, PreviousRT, Spelling and Sublexical Homophony with the estimate \( \beta \), standard error, \( t \)-value, \( \chi^2 \)-value and \( p \)-value.
Figure 19. Partial effects plot of effects represented in Table 20.

**ER analysis.** We fitted all 624 observations with a generalized linear mixed effects model (GLMM; see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The dependent variable was binomially distributed and represents the correctness of the response (correct = 1; incorrect = 0). Control and theoretically relevant variables were identical to those in the RT analysis. The maximal random structure justified by the data was made up of a by-participant random intercept and by-participant random slope for Spelling. The results of the final GLMM model can be found Table 21. Figure 20 visualizes the partial effects of this model.
§ 3 The Homophone Dominance Effect in Perception

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$z$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>2.81</td>
<td>0.25</td>
<td>11.24</td>
<td>61.64</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>-0.41</td>
<td>0.18</td>
<td>-2.21</td>
<td>4.99</td>
<td>.026</td>
</tr>
<tr>
<td>Spelling</td>
<td>-0.31</td>
<td>0.49</td>
<td>-0.62</td>
<td>0.39</td>
<td>.540</td>
</tr>
<tr>
<td>Sublexical Homophony</td>
<td>-1.49</td>
<td>0.34</td>
<td>-4.34</td>
<td>22.61</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Table 21. Coefficients of a mixed logit model predicting the probability of a correct response from Log Lemma Frequency, Spelling and Sublexical Homophony together with the estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.

Figure 20. Partial effects plot of effects represented in Table 21.

Discussion. The RT analysis yielded significant effects for the control variables Length and PreviousRT: longer reaction times were observed as previous RTs
and the length of the letter string increased. In addition, Spelling had a significant effect: reaction times were longer for verbs with an incorrect spelling (i.e., no-responses) compared to those with a correct spelling (i.e., yes-responses). Note that at this point, it remains unclear whether this delay is really the result of an incorrect spelling or the result of the differences in the motor execution of yes- and no-responses (preferred vs. non-preferred hand). This possibility is tested below in a phonological decision task, where both spellings receive a yes-response (see Section 3.2.3). In addition, the effect of Sublexical Homophony was highly significant: RTs were longer for verbs with a competing sublexical homophonous cluster (i.e., s verbs) compared to those without sublexical homophony (i.e., p verbs). The ER analysis partly corroborated these findings. The only significant control variable was Log Lemma Frequency: as verbs’ lemma became more frequent, more errors were made. The main effect of Spelling, contrary to what was the case in the RT analysis, was not significant: the error rate was equal for both correct and incorrect spellings. Finally, the effect of Sublexical Homophony was again significant for ERs: more errors were made on s verbs, experiencing competition from a homophonous cluster, than on p verbs. The fact that Spelling had no effect on the error rates indicates that it was as easy to detect a spelling error as to find out that the verb form’s spelling was correct. This suggests the operation of a morpheme-decomposition process, whose output can be directly used to make the spelling decision. However, the fact that more errors were made on s verbs than on p verbs suggests that such a decision was not only based on morphological decomposition, but also on the presence of a sublexical letter sequence that is homophonous to a letter sequence occurring in other past tenses (in the case of correct spellings: suste-rustte, ‘hushed-rested’) or identical to this letter sequence (in the case of incorrect spellings: *sustte-rustte). The fact that this sublexical letter sequence straddles the morpheme boundary, i.e., should be detected in the output of the morphological decomposition process, suggests that both morphemic and

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65 Crucially, the interaction effect between Spelling and Sublexical Homophony was not significant in the RT analysis, nor in the ER analysis (ps > .05).
non-morphemic units are activated simultaneously in the visual word recognition process.

The results of both the RT and ER analysis confirm our hypothesis: when explicitly instructed to judge the spelling correctness of a past tense form, participants took longer and made more errors when classifying verb forms whose correct sublexical spelling pattern was homophonous to that in phonologically similar words (s verbs; e.g., *sust(t)e ≈ rustte), compared to verbs without such sublexical homophony (p verbs). This results from the fact that the pte-pattern is the only correct pattern for p verbs (i.e., the ptte-pattern never occurs in past tense forms or other words). In contrast, the correct and incorrect spellings of s verbs (with ste and stte, respectively) are ambiguous at the sublexical level. As both the ste and stte patterns occur in the domain of past tenses, the appearance of each of these letter sequences (e.g., suste or *sustte) temporarily activates past tenses with the presented cluster and past tenses with the homophonous cluster. The resulting competition between the correct ste-pattern and the homophonous stte-pattern leads to increased RTs/ERs for s verbs compared to p verbs, for which such competition is absent.

Since processing was affected by the presence of a competing homophonous cluster at the sublexical level, we conclude that visual processing of regularly inflected past tense forms in a minimal syntactic context is not only driven by morphological decomposition, but also by the activation of homophonous letter patterns extending across the morphemic boundary. This corroborates the findings of Chapter 2, in which we showed that participants are also more likely to make errors on s verbs than on p verbs during production.
3.2. Phonological decision task

3.2.1. Stem-final d verbs

3.2.1.1. Hypothesis

The SDT (Section 3.1.1) showed that HF homophones were accepted more easily when spelled correctly, but were more difficult to reject as an incorrect spelling. The latter finding is the result of the HF homophone becoming available so quickly (suggesting a yes-response) that it causes a response conflict when a no-response has to be given. Based on this finding, we hypothesize that HF homophones of stem-final d verbs should be processed faster than LF homophones even in the incorrect spelling condition, if a task could be devised in which such a response conflict cannot emerge. Such a finding would strengthen the conclusion of the SDT and provide an explanation as to why homophone intrusions persist in texts that have been carefully re-read.

To examine this hypothesis, we set up a phonological decision task (PDT), in which we presented participants with two-word combinations, spelled correctly or incorrectly (i.e., stimuli are identical to Section 3.1.1). In contrast to the SDT, participants had to decide whether these combinations sounded acceptable in Dutch, regardless of their spelling (i.e., both correct and incorrect spellings required a yes-response). Considering the proximity of the pronominal subject, we expected that participants would be unable to ignore many spelling errors, despite being instructed to do so. This should lead to a processing delay for these items in comparison with those with a correctly spelled verb form (i.e., a main effect of Spelling). If whole-word representations of stem-final d verbs are accessed, both the correct and incorrect spelling conditions should yield faster yes-responses for the HF spelling forms than for their LF counterpart (i.e., an interaction effect between Form and Homophone Ratio).
3.2.1.2. Method

Stimuli and Design

Stimuli. Each experimental list consisted of 192 two-word combinations, half of which were yes-responses (i.e., phonologically acceptable) and half of which were no-responses (i.e., phonologically unacceptable). The first word was the personal pronoun ik (‘I’) in half of the cases and the personal pronoun hij (‘he’) in the other half. The second word was a verb form, which was spelled incorrectly half of the time (obtained by replacing the correctly spelled form by its homophone, as in the spelling decision task with a minimal context). Yes-responses were given to three item types. The first type consisted of 24 critical stem-final d verbs (‘basic set’), half of which were d-dominant, while the other half were dt-dominant. They were presented in both their correct and incorrect form (e.g., ik meld and ik *meldt), but never in the same list (see Design). This group of critical items was supplemented with two fillers groups. A first filler group consisted of 48 past tense verbs, half of which had a correct spelling with a single t (e.g., suste vs. *sustte) and half of which required a double t (e.g., sportte vs. *sporte)\(^{66}\). The second and final filler group consisted of verbs whose correct spelling could be turned into a pseudohomophone by replacing a grapheme by another grapheme with the same pronunciation. Half of these items were present tense third person singular forms and half were past tense singular forms (e.g., hij *dwijlt instead of hij dweilt ‘he mops’; hij *verkragtte instead of hij verkrachtte ‘he raped’). For each yes-response, we created an equivalent item requiring a no-response to prevent participants from responding to the final orthographic pattern. For the critical items, half of the matched non-word verb forms were made by taking the past tense of a strong verb and adding the suffix -d or -dt (e.g., hij *begondt; ‘he *begans’). The other half of the non-words were derived from an existing stem-final d verb form (e.g., ik *veid < ik leid, ‘I lead’). Consequently, there were both yes- and no-responses for items ending in -d and -dt. Half of the no-responses to

\(^{66}\) These 48 past tense verbs’ stem ended in -p (n = 12), -s (n = 12), -rt (n = 6), -nt (n = 6), -cht (n = 12).
the past tense fillers were made up of the stem of a strong verb and the regular past tense suffix -te or its incorrect homophonic string -tte, i.e., they were regularization errors (e.g., *ik leest(t)e instead of ik las; ‘I read’). The other half consisted of a verb stem ending in a voiced obstruent and the regular past tense suffix for verbs with a stem-final voiceless obstruent, i.e., -te instead of -de (e.g., ik *dagvaart(t)e instead of ik dagvaardde; ‘I summoned’). This prevented participants from responding solely to the final letter pattern of past tenses, since letter strings ending in -t(t)e could require both a yes- and a no-response. The final group of items requiring a no-response were made by taking the past tense of a strong verb and adding -t or -t(t)e. One grapheme of this non-word was spelled in an alternative way (i.e., incorrectly), but sounded identical when pronounced (e.g., hij *sgreeft instead of hij *schreeft; ‘he wrote’).

Design. All items were incorporated into a counterbalanced design, identical to that described in Section 3.1.1.2. To summarize, Lists A/B represent the counterbalancing for the personal pronoun (half ik ‘I’, half hij ‘he’), while lists L1/L2 represent the counterbalancing for the spelling of the verb forms (half spelled correctly, half spelled incorrectly). The two homophones of a verb appeared in different lists. The 192 items of each experimental list were evenly distributed across 3 experimental blocks of 64 items and were preceded by a practice block of 24 items. We created two pseudo-random orders (R1/R2) adhering to the same criteria as mentioned in Section 2.1.2. In total, there were eight experimental versions: AL1R1, AL1R2, BL1R1, BL1R2, AL2R1, AL2R2, BL2R1 and BL2R2.

Participants and Procedure
Participants. Twenty-nine subjects took part in the experiment (mean age = 22.1; SD = 2.81). They were all native speakers of Dutch and students at Antwerp University. They had normal or corrected-to-normal vision and had no record of a reading disorder. Furthermore, we made sure that no
participated had taken part in a previous experiment on homophone intrusions.

Procedure. The procedure of this experiment was quasi-identical to that described in Section 2.1.2, except for the following two aspects. Firstly, the written instructions required participants to decide as quickly as possible and with as few errors as possible whether the presented two-word combination was an acceptable Dutch utterance for someone who can hear, but cannot see it. We explicitly instructed participants to ignore any spelling errors. Secondly, participants received feedback as to the correctness of their response during the practice session to make sure they fully understood the task demands before initiating the experimental blocks.

3.2.1.3. Results and Discussion

Results. RT analysis. Incorrect responses were removed \((n = 34)\), after which the remaining 662 observations were inverse-transformed by means of the formula \(-1000/RT\) to reduce the influence of extremely high RTs. We fitted a linear mixed effects model to these inverted RTs (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). Control variables tested for inclusion were: Length (i.e., of the two-word combination), inverted PreviousRT, Trial and Log Lemma Frequency. Due to the high correlation between Length and Log Lemma Frequency \((r = -.47)\), we regressed Length against Log Lemma Frequency and used this regression’s residuals as a fixed predictor representing Length. The theoretically relevant predictors were: Spelling (correct vs. incorrect), Form (d-form vs. dt-form) and Homophone Ratio. Crucially, we wanted to find out whether there is an interaction between Form and Homophone Ratio (i.e., the Homophone Dominance effect). The maximal random structure supported by the data consisted of a by-participant and by-lemma random intercept. Outliers whose absolute standardized residuals exceeded 2.5 standard deviations \((n = 7)\) were removed. Table 22 presents the
results of the linear mixed effects model fitted to the remaining observations. Partial effects of the model are plotted in Figure 21.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>t</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.41</td>
<td>0.04</td>
<td>-31.97</td>
<td>119.68</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Length</td>
<td>0.03</td>
<td>0.01</td>
<td>3.04</td>
<td>8.95</td>
<td>.003</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.13</td>
<td>0.03</td>
<td>3.21</td>
<td>83.57</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
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<td>-2.98</td>
<td>7.69</td>
<td>.006</td>
</tr>
<tr>
<td>Spelling</td>
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<td>0.02</td>
<td>2.60</td>
<td>6.73</td>
<td>.010</td>
</tr>
<tr>
<td>Form</td>
<td>-0.01</td>
<td>0.03</td>
<td>-0.45</td>
<td>0.20</td>
<td>.654</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>0.01</td>
<td>0.03</td>
<td>0.30</td>
<td>0.09</td>
<td>.762</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>0.08</td>
<td>0.03</td>
<td>2.65</td>
<td>6.98</td>
<td>.008</td>
</tr>
</tbody>
</table>

Table 22. Coefficients of a linear mixed effects model predicting inverse-transformed RTs from Length, PreviousRT, Log Lemma Frequency, Spelling, Form, Homophone Ratio and the interaction between Form and Homophone Ratio together with the estimate $\beta$, standard error, t-value, $\chi^2$-value and $p$-value.
Figure 21. Partial effects plot of effects represented in Table 22.

**ER analysis.** We fitted a generalized linear mixed effects model (GLMM) to all 696 observations (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The dependent variable was binomially distributed (i.e.,
correctness of the response: correct = 1 and incorrect = 0). Control and manipulated variables were the same as in the RT analysis. The maximal random structure justified by the data consisted of a by-lemma random intercept. The results of the GLMM are presented in Table 23 and partial effects are plotted in Figure 22.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>z</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
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<tr>
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<tr>
<td>Spelling</td>
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<td>0.59</td>
<td>-2.13</td>
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<td>.023</td>
</tr>
<tr>
<td>Form</td>
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<td>0.61</td>
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<td>2.46</td>
<td>.117</td>
</tr>
<tr>
<td>Homophone Ratio</td>
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<td>0.91</td>
<td>0.80</td>
<td>.372</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>0.57</td>
<td>0.73</td>
<td>0.78</td>
<td>0.65</td>
<td>.422</td>
</tr>
</tbody>
</table>

Table 23. Coefficients of a mixed logit model predicting the probability of a correct response from Spelling, Form, Homophone Ratio and the interaction between Form and Homophone Ratio together with the estimate $\beta$, standard error, z-value, $\chi^2$-value and $p$-value.
Discussion. For the RT analysis, significant control variables were Length, PreviousRT (i.e., longer RTs as Length and PreviousRT increased) and Log Lemma Frequency (i.e., shorter RTs as verbs’ lemma frequency increased). The variable Spelling was also significant, with longer RTs for incorrect spellings. In contrast to what was the case in the SDT, where a no-response was given for incorrect spellings, a yes-response was made to both correct and incorrect spellings in this FDT. This finding indicates that participants were aware of and disturbed by an incorrect spelling (i.e., $ik + dt$-form or $hij + d$-form). Neither the main effect of Homophone Ratio, nor that of Form was
significant. However, the interaction effect between both variables yielded a significant result. As Homophone Ratio increased and the d-form became the most frequent homophone of a verb pair, RTs for the HF d-form decreased while those for the LF dt-form increased. The interaction effect, however, was not present in the ER analysis. In the ER analysis, only the effect of Spelling was significant, with more erroneous no-responses to incorrect spellings (even though the error rate for incorrect verb forms was still very low). This indicates that participants were sometimes unable to suppress the incorrect spelling of the verb form and responded to its orthographic pattern instead of its pronunciation.

The results of the RT analysis confirmed our hypothesis: RTs became faster as the presented verb form became the more frequent homophone of a verb pair. In a SDT, participants easily accepted a HF homophone as a correct spelling, but had difficulties rejecting it as an incorrect spelling (third-order interaction between Spelling, Form, and Homophone Ratio). However, when asked to judge homophonous verb forms’ phonological acceptability in this PDT, they processed the HF homophone more quickly compared to its LF counterpart, both when spelled correctly and incorrectly67. We conclude that Homophone Dominance also affects visual processing in a phonological decision task: accessing the HF whole-word representation of homophonous Dutch verb forms speeded up lexical access. The finding that phonological decisions were faster for incorrect spellings corresponding to the HF homophone suggests that such spelling errors may also be missed more often in texts than spelling errors matching the LF homophone. Although someone (re-)reading a text will obviously not attempt to ignore spelling errors, the quick availability of a whole-word representation for the (incorrect) HF form and its contextually correct pronunciation (being a homophone of the correct spelling) will create a feeling of familiarity. This, in turn, may lead to a stronger tendency to accept the spelling error than in the situation where the

67 The interaction between Form and Homophone Ratio did not differ for correct and incorrect spellings, given the absence of a third-order interaction between Spelling, Form and Homophone Ratio in both the RT and ER analysis (ps > .05).
error is the LF form. We will more directly examine this claim in subsequent experiments.

### 3.2.2. Weak prefix verbs

#### 3.2.2.1. Hypothesis

Since the LDT (Section 2.2) showed that whole-word representations of weak prefix verb forms were not accessed when these forms were presented in isolation (possibly due to a bias to interpret the homophone as a past participle), the current experiment examines whether the Homophone Dominance effect does appear in a phonological decision task where these verb forms are embedded in a minimal grammatical context. Again, we asked participants to judge the phonological acceptability of two-word and three-word combinations. This time, the critical items were sequences in which a homophonous weak prefix verb form, presented either in its correct or its incorrect spelling, was preceded by the 3rd person personal pronoun *hij* (for 3rd person present tense verb forms) or by the personal pronoun *hij* and the auxiliary verb *heeft* (for past participles). Note that in a phonological decision task, a bias to interpret the verb form as a past participle (i.e., d-bias) is less likely than in an isolated word recognition task (LDT), as the preceding syntactic context makes clear whether the verb form is a 3rd person singular or a past participle. The same task yielded a significant effect of Homophone Dominance for stem-final d verbs, even though the verb forms were immediately preceded by their pronominal subject (proximity being unfavorable for the effect). If weak prefix verb forms have whole-word representations, one would therefore expect them to exhibit the same effect: shorter RTs/fewer errors should be observed for the HF homophone in comparison with the LF homophone, when spelled correctly and incorrectly (i.e., an interaction effect between Form and Homophone Ratio).

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68 This section is the result of a collaboration with Len Koolen in the context of her master’s thesis.
3.2.2.2. Method

Stimuli and Design

Stimuli. Each experimental list consisted of 192 two- or three-word combinations (hij ‘he’ + verb form or hij heeft ‘he has’ + verb form). Half of these verb forms were spelled correctly and the other half incorrectly. Yes-responses included 24 critical weak prefix verbs, identical to those used in previous experiments (see Table 3 in Appendix for their characteristics). Half were d-dominant and half were t-dominant. They were presented either in their 3rd person present tense t-form (e.g., hij bestelt) or in their past participle d-form (e.g., hij heeft besteld). In half of the cases, they were presented with the correct spelling and in the other half with an incorrect spelling (e.g., hij bestelt vs. hij *besteld, hij heeft besteld vs. hij heeft *bestelt). In addition, we inserted 24 near-homophonous verbs. Half were presented in their present tense t-form and half in their past participle d-form (e.g., hij dreigt, ‘he threatens’; hij heeft gebaseerd, ‘he has based’). In half of the cases, the verb form had an incorrect, but (non-existent) homophonous spelling (e.g., hij *drijgt, hij heeft *gebaseert). In addition, each experimental list also included 48 past tense forms. Twenty-four of these were critical items (analyzed in Section 3.2.4.3), consisting of 12 verbs whose stem ends in -st and 12 verbs whose stem ends in either -rt or -nt. Verbs forms of the former group (e.g., mestte ‘fertilized’) contain the orthographic cluster stte, which is homophonous with the ste-cluster found in other past tenses (e.g., suste). In contrast, the latter group (e.g., printte ‘printed’) has no such sublexical homophonous competitor within the verbal paradigm (there are no past tenses ending in -rte or -nte). These verbs with and without sublexical homophony (within the verbal paradigm) were matched for Log Whole-word Frequency (p = .14) and Length (p = .76). Their characteristics are shown in Table 5 of the Appendix. Since the correct spelling of critical past tense forms ended in tte, we also included 24 past tense fillers for which the correct ending is te. More particularly, these were verbs whose stem ended in -p or -k (e.g., repte). The incorrect, but homophonous spelling of these past tenses was made by
replacing the correct te-pattern by the incorrect tte-pattern or vice versa, thus creating pseudo-homophones (e.g., *meste or *reptte).

Next, we created an equivalent no-response for each yes-response. The no-counterparts of weak prefix verbs were non-words created by changing one letter of an existing weak prefix verb form. Again, half were spelled correctly given the grammatical context and half incorrectly (e.g., *vermuur < verhuur/d ‘rents/ed’). The no-responses for near-homophonous verbs consisted of two subgroups: the first group was formed by taking the past tense of a strong verb and adding a -t (e.g., *schreeft, ‘he *wrote’), while the second group consisted of changing one letter of an existing past participle (e.g., *gebaleerd instead of gebaseerd). Recall that for past tense forms, there were three main groups: verbs whose stem ended in -rt or -nt (no sublexical homophony), -st (sublexical homophony), and -p or -k (fillers). An equivalent no-response for the first critical item type was created by adding -(t)te to verb stems that should be spelled with -(d)de (e.g., *dagvaart(t)e, *summont). No-responses matching the two other categories were formed by adding -(t)te to the stem of a strong verb (i.e., regularization errors; e.g., *loopt(t)e, ‘*runned’).

**Design.** Each experimental version contained 192 items, 24 of which were critical weak prefix verbs and 24 of which were critical past tense forms. Lists A/B were counterbalanced for the grammatical construction that was used for the weak prefix verb forms. Half were presented in a present tense (PT) context, indicated by the personal pronoun *hij* ('he'), while the other half was presented in the past participle (PP) context, indicated by the sequence of the personal pronoun *hij* and the auxiliary verb *heeft* ('he has'). When a verb form was embedded in the PT context in list A, it appeared in the PP context in list B and vice versa. Note that for critical past tense forms, lists A and B were identical (i.e., the verb form always being preceded by *hij*). Lists 1 and 2 refer to the counterbalancing of spelling correctness. Half of the verb forms (both weak verb forms and past tenses) were spelled correctly and half were spelled incorrectly. When List 1 presented an incorrect spelling, the counterbalanced
form in List 2 was a correct spelling and vice versa. The filler items were identical across all experimental versions (i.e., half had a correct spelling and the other half had an incorrect spelling). All 192 items were evenly distributed across four experimental blocks of 48 items and preceded by a practice block of eleven items. Two pseudo-random orders were created (R1/R2), following the same criteria as in Section 2.1.2. The result were eight experimental versions in total: AL1R1, AL1R2, BL1R1, BL1R2, AL2R1, AL2R2, BL2R1 and BL2R2.

Participants and Procedure

Participants. Twenty-four students at Antwerp University participated for course credit (mean age = 19.71; SD = 1.88). They were native speakers of Dutch with normal or corrected-to-normal vision and without any reading disorder. None of these subjects had previously taken part in an experiment on homophone intrusions.

Procedure. Identical to Section 3.2.1.2.

3.2.2.3. Results and Discussion

Results. RT analysis. After removing incorrect responses \( (n = 34) \), the remaining 542 observations were inverse-transformed \((-1000/RT)\). Inverted RTs were fitted with a linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). Likelihood ratio tests determined which of the following control variables were taken up: inverted PreviousRT, Log Lemma Frequency, Length (i.e., of the entire letter string) and Trial. The variables under investigation were: Spelling, Homophone Ratio, Form and the interaction between the latter two variables. The maximal random structure supported by the data consisted of a by-participant random intercept. Next, we removed outliers (absolute standardized residuals > 2.5 SD; \( n = 7 \)) and fitted an identical model to the remaining subset of the data. The results of this final
model are shown in Table 24, partial effects of which are visualized in Figure 23.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
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<td>91.53</td>
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</tr>
<tr>
<td>Length</td>
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</tr>
<tr>
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<td>-3.50</td>
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<td>.005</td>
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<tr>
<td>Form</td>
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<td>0.02</td>
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<td>0.34</td>
<td>.561</td>
</tr>
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<td>-0.04</td>
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<td>.969</td>
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<tr>
<td>Form x Homophone Ratio</td>
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<td>0.19</td>
<td>.666</td>
</tr>
</tbody>
</table>

Table 24. Coefficients of a linear mixed effects model predicting inverse-transformed RTs from PreviousRT, Log Lemma Frequency, Length, Trial, Spelling, Form, Homophone Ratio and the interaction between Form and Homophone Ratio together with the estimate $\beta$, standard error, t-value, $\chi^2$-value and p-value.
Figure 23. Partial effects plot of effects represented in Table 24.

ER analysis. A generalized linear mixed effects model was fitted to all 576 observations (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The correctness of the response functioned as a binomially distributed dependent variable (correct = 1; incorrect = 0). Both the control and manipulated variables were identical to the ones used in the RT analysis. The maximal random structure justified by the data consisted of a by-participant random intercept. The results of the GLMM are shown in Table 25 and partial effects are plotted in Figure 24.
Table 25. Coefficients of a mixed logit model predicting the probability of a correct response from Log Lemma Frequency, Spelling, Form, Homophone Ratio and the interaction between Form and Homophone Ratio together with the estimate $\beta$, standard error, z-value, $\chi^2$-value and p-value.

Figure 24. Partial effects plot of effects represented in Table 25.
Discussion. In the RT analysis, significant control variables were: PreviousRT, Length (i.e., longer RTs as previousRT and Length increased), Log Lemma Frequency and Trial (i.e., shorter RTs as Lemma Frequency increased and as the experiment progressed). Spelling also yielded a significant effect: RTs were longer for incorrect spellings than for correct spellings. In contrast, neither the main effect of Homophone Ratio, nor that of Form was significant. Crucially, also the interaction between these two variables failed to reach significance. The ER analysis only yielded significant effects for Log Lemma Frequency (i.e., more correct responses as Lemma Frequency increased). No significant effects were found for Spelling, Homophone Ratio, Form or the interaction between the latter two variables.

The results indicate that participants were aware of an incorrect spelling: even though they made no more errors on items with incorrectly spelled weak prefix forms, this was at the cost of longer decision times. The interaction between Form and Homophone Ratio was non-significant, both in the RT and the ER analysis: HF forms were not processed more quickly or accurately than their LF counterpart, neither for correct nor for incorrect spellings. The results of the current experiment do not allow us to extend our conclusion for stem-final d verbs to weak prefix verbs: whole-word representations of homophonous weak prefix verb forms were not accessed in this PDT. The absence of a Homophone Dominance effect in this experiment mimics our earlier findings in the LDT, where we also failed to find a Homophone Dominance effect for this verb type.

In contrast, the facilitatory effect of Log Lemma Frequency was significant in both the RT and ER analysis. This effect was also significant in the RT analysis of the stem-final d verbs, as was that of Homophone Ratio. These findings indicate that the phonological decision task is quite capable of tapping into frequency effects. It is puzzling, then, that we failed to find evidence for whole-word retrieval of weak prefix verb homophones. Due to a strong correlation between the presence of a weak prefix and the d-suffix

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69 This conclusion is warranted given that the third-order interaction with Spelling was not significant in the RT/ER analysis (ps > .05).
(Bosman, 2005; Frisson & Sandra, 2002a), participants may have been biased to interpret the homophonous verb forms as past participles. Recall that we expected this d-bias found in isolated word recognition (LDT) to disappear in the PDT. However, our hypothesis that the presence of a (minimal) syntactic context would remove this bias might have been wrong. Unfortunately, the experimental design of this PDT makes it virtually impossible to detect a d-bias, since the PP context (i.e., two-word context) obviously elicited higher RTs than the PT context (i.e., one-word context). Since our goal is to demonstrate that intrusions are processed more quickly depending on the whole-word frequency of the verb form (disconfirmed by the present experiment), we can generalize this rationale to any information source that might facilitate processing. In the present case, this could be the earlier mentioned d-bias. To investigate whether a d-bias is responsible for the absence of an effect of Homophone Dominance, we fitted a new model from which we removed the non-significant effect of Homophone Ratio and its interaction with Form. Since we focused on intrusion errors, we only analyzed the incorrect forms and refitted the model using the main effect of Form as the only theoretically relevant variable \( (\beta = 0.18, SE(\beta) = 0.06, t = 3.15, \chi^2 = 9.65, p(> \chi^2) = .002). \) We indeed found that Form had a significant effect: incorrect d-forms were processed more quickly than the incorrect t-forms, after controlling for Length. This confirms that a d-bias may indeed have masked the effect of Homophone Dominance.

An extra factor that may have contributed to the failure to observe an effect of Homophone Dominance is the proximity of the subject or auxiliary verb in the minimal syntactic context. However, such an account is difficult to reconcile with the presence of the effect for stem-final d verbs in the same task. Nonetheless, it remains possible that linguistic differences between the

\[ 70 \] Using the same procedure as described in Section 1.1.1.3 of Chapter 2, the final model included the maximal random structure justified by the data, namely a by-participant random intercept \( (n \text{ of observations} = 238). \) The fixed part of the model contained the control variables PreviousRT, Length, Trial and the variable of interest, Form. Note that we regressed Form against Length and used the residuals of this regression as fixed effect representing Form (i.e., Form and Length did not longer correlate).
two verb types made it easier to perform the phonological decision without accessing whole-word representations when weak prefix homophones are placed in a minimal context. If so, the spelling check (subsequent to morphological decomposition) was much faster for weak prefix homophones than for stem-final d homophones. This may have been due to (a) the fact that weak prefix homophones contain both a prefix and a suffix, making their morphological structure highly salient, and (b) the fact that their suffix (-t for 3rd person singular present tense, -d for past participle) is audible, in contrast to what is the case for stem-final d homophones (i.e., a zero suffix for the 1st person singular present tense and a silent t for the 3rd person singular present tense). If these factors speed up morphological decomposition and the subsequent morphosyntactic check for weak verb homophones, this might explain why no effect of whole-word frequency was found (in the form of an effect of Homophone Dominance). To further investigate this issue, we will embed weak prefix homophones in a sentence context in which marker and verb form are not adjacent, but separated by intervening words. Under such conditions, morphological decomposition and a spelling check require a great deal of attentional resources from working memory, making it more likely that whole-word retrieval is the faster processing route and thus considerably increasing the likelihood of finding an effect of Homophone Dominance (e.g., Sandra et al., 1999).

**3.2.3. Past tense verb forms: s vs. p verbs**

**3.2.3.1. Hypothesis**

This experiment examines whether the Homophone Dominance effect at the sublexical level, found in a SDT (Section 3.1.2) also manifests itself in a PDT. In the SDT, RTs were delayed when the pronunciation of the sublexical pattern could be mapped onto two different orthographic representations (both correct and incorrect spellings of s verbs) compared to when there was a unique mapping (p verbs). In the current experiment, we used the same set of
§ 3 The Homophone Dominance Effect in Perception

s and p verbs and presented them to participants in both their correct (e.g., *sust, rep-te) and incorrect spelling (e.g., *sust-te, *rep-te). Recall that in a PDT, participants have to give a yes-response to both spellings (i.e., they are phonologically acceptable). If regularly inflected past tense forms are decomposed into their constituent morphemes and they use this morphological analysis as the only basis for responding, an incorrect spelling should lead to a similar delay for both verb types. When stripping off the past tense te-suffix from the letter string, a parsing route would attempt to access the lexicon through non-stems in both cases (*sust, *rept), leading to a processing delay for incorrect spellings. In a morphological decomposition account, RTs/ERs should obviously not depend on the frequency of a sublexical homophonous cluster, as the cluster (e.g., ste, stte, pte or ptte) would be split up as the result of morphological decomposition (e.g., into suste, *sust-te, rep-te or *rept-te). If, however, the presence of a homophonous cluster across the morpheme boundary (also) affects the processing of past tense forms, an effect of Homophone Dominance at the sublexical level will emerge. If this is the case, an incorrect spelling will cause fewer processing difficulties when the erroneous orthographic pattern is supported by a sublexical homophonous pattern in phonologically similar words than when there is no such support. More particularly, we expect the difference between the RTs and/or ERs for correct and incorrect spellings to be smaller for s than for p verbs. Since the incorrect ptte-pattern is non-existent, it will suggest a no-response. However, its phonological form is acceptable and should therefore receive a yes-response. This response conflict will inevitably lead to a processing delay compared to the correctly spelled form, which does not give rise to such a response conflict. For s verbs, however, we expect that the incorrect, but existing stte-pattern will be acknowledged as phonologically acceptable much faster than a non-existent cluster, due to its orthographic familiarity. Since both the correct ste-pattern and incorrect stte-pattern are orthographically legal letter strings, we expect little or no difference between the two spellings with respect to RTs and/or ERs in this PDT. In statistical
terms, this amounts to an interaction effect between Sublexical Homophony and Spelling.

3.2.3.2. Method

Stimuli and Design

Stimuli. Each experimental list consisted of 168 items, 84 yes-responses and 84 no-responses. Each item was made up of two words, namely the personal pronoun hij followed by a verb form. These verb forms can be divided into two groups. A first group consisted of 60 past tense items. Of these past tense items, 24 were critical items consisting of 12 s verbs (sublexical homophony) and 12 p verbs (no sublexical homophony; see Table 2 in Appendix for their characteristics). They were presented either in their correct spelling (e.g., hij suste) or incorrect, but homophonous spelling (e.g., hij *sustte). The remaining 36 filler past tenses consisted of verb stems ending in -f, -ch, -cht, -rt or -nt. Depending on the presence of a stem-final t, the correct spelling of past tenses ended in -tte or -te. Next, 48 filler homophous verbs were taken up, half of which were weak prefix verbs and half of which were stem-final d verbs. These fillers were also presented in their correct spelling in half of the cases and in their incorrect spelling in the other half.

Again, we created equivalent no-responses for each yes-response to avoid that participants could make a correct response based on the final letter pattern of the word or stem alone. No-responses matching the final spelling pattern of critical past tense forms consisted of the stem of a strong verb followed by –t(t)e (i.e., regularization errors; e.g., *slaapte, ‘*slepted’, *leestte, ‘*readed’). The no-responses for the filler past tenses were formed by adding –t(t)e to verb stems that should be spelled with -(d)de (e.g., *dagvaart(t)e). The 48 no-responses matching the final spelling pattern of the 48 filler homophous verbs were created by taking an existing Dutch verb, deleting the final letter of its stem and adding -d, -dt or -t (e.g., *versiet < versiert ‘decorates’, *mijmedt < mijmert ‘muses’).
Design. All items were counterbalanced for their spelling: half of each item type were spelled correctly (e.g., *hij suste*) while the other half were spelled incorrectly (e.g., *hij *sustte*). When a verb was spelled correctly in list A, it was spelled incorrectly in list B and vice versa. We created two pseudo-random orders (R1/R2) in which the 168 items were evenly divided across 6 blocks containing 36 items each. The same randomization procedure was used as in Section 2.1.2. Thus, we obtained four experimental versions in total, namely AR1, AR2, BR1, BR2. The six experimental blocks were preceded by a practice block consisting of 16 items.

Participants and Procedure

Participants. Twenty-seven subjects participated in the experiment (mean age = 25.93; SD = 2.46). They were all students at Antwerp University. They were native speakers of Dutch and did not have any reading disorder. Furthermore, they had normal or corrected-to-normal vision and had not previously participated in an experiment on homophone intrusions.

Procedure. Identical to Section 3.2.1.2.

3.2.3.3. Results and Discussion

Results. RT analysis. Firstly, we removed incorrect responses (*n* = 34). Next, we inverse-transformed (-1000/RT) the remaining 638 observations and fitted them with a linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The following control variables were tested for inclusion through likelihood ratio tests: inverted PreviousRT, Log Lemma Frequency, Log Whole-word Frequency, Length and Trial. The variables under scrutiny were Sublexical Homophony, Spelling and, most importantly, their interaction. The model included the maximal random structure as justified by the design, consisting of a by-lemma random intercept, a by-lemma random slope for Spelling, a by-participant random intercept, a by-participant random slope for Spelling, Sublexical Homophony and their interaction. After removing outliers (absolute standardized residuals > 2.5 SD; *n* = 9), we fitted a
model with the same predictors to the remaining data points. The results of this final model are presented in Table 26, while partial effect plots of the variables in this model can be found in Figure 25\textsuperscript{71}.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>0.04</td>
<td>-33.52</td>
<td>100.52</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.29</td>
<td>0.04</td>
<td>7.69</td>
<td>92.41</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
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<td>-4.43</td>
<td>13.84</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Spelling</td>
<td>0.10</td>
<td>0.03</td>
<td>3.27</td>
<td>8.99</td>
<td>.003</td>
</tr>
<tr>
<td>Sublexical Homophony</td>
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<td>-1.35</td>
<td>1.78</td>
<td>.183</td>
</tr>
<tr>
<td>Spelling x Sublexical Homophony</td>
<td>-0.21</td>
<td>0.05</td>
<td>-4.03</td>
<td>11.72</td>
<td>&lt; .001</td>
</tr>
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</table>

Table 26. Coefficients of a linear mixed effects model predicting inverse-transformed RTs from PreviousRT, Log Lemma Frequency, Spelling, Sublexical Homophony and the interaction between Spelling and Sublexical Homophony together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.

\textsuperscript{71}Note that the partial effects plot for the Sublexical Homophony measure is always plotted for the reference level of Spelling (i.e., correct spelling). This will also be the case in all subsequent partial effects plots where the model includes the interaction between these two variables.
ER analysis. All 648 observations were fitted with a generalized linear mixed model, with the correctness of the response functioning as a binomially distributed dependent variable (correct = 1; incorrect = 0; see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The independent control tested for inclusion and the manipulated variables were the same as in the RT analysis. The maximal random structure justified by the data consisted of a by-participant random intercept. The results of the GLMM are shown in Table 27 and partial effects are plotted in Figure 26.
<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
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<td>&lt;.001</td>
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<td>.001</td>
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<td>Spelling x Sublexical Homophony</td>
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<td>1.19</td>
<td>-0.97</td>
<td>1.10</td>
<td>.293</td>
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</table>

Table 27. Coefficients of a mixed logit model predicting the probability of a correct response from Log Lemma Frequency, Spelling, Sublexical Homophony and the interaction between Spelling and Sublexical Homophony together with the estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.

Figure 26. Partial effects plot of effects represented in Table 27.
Discussion. For the RT analysis, significant control variables were previousRT (i.e., longer RTs as previous RTs increased) and Log Lemma Frequency (i.e., shorter RTs as lemma frequency increased). Furthermore, the main effect of Spelling was also significant: longer RTs were observed for incorrect spellings. Hence, participants could not ignore the spelling errors, even though the task (phonological decision) instructed them to do so. While the main effect of Sublexical Homophony was not significant, it was modulated by an interaction with Spelling: the non-existent (hence, incorrect) but homophonous spelling pattern –ptte slowed down response times, whereas the incorrect but existing homophonous spelling pattern –stte did not (viz., our hypothesis). The ER analysis did not corroborate these findings: significant effects were found for Log Lemma Frequency (i.e., fewer errors as lemma frequency increased), Sublexical Homophony (i.e., fewer errors for s verbs) and Spelling (i.e., fewer errors for correct spellings). Most importantly, the interaction between Spelling and Sublexical Homophony was not significant: more errors were observed for incorrect than for correct spellings, both with s and p verbs.

The error results indicate that incorrect (homophonous) spellings of p and s verbs are dismissed equally often as phonologically unacceptable (i.e., an identical increase in error responses for both verb types). Apparently, an incorrect spelling creates a bias to make a no-response. The lack of an interaction between spelling correctness and sublexical homophony suggests a) an unsuccessful attempt to retrieve the full-form representation or b) an unsuccessful attempt to gain lexical access via a non-stem subsequent to morphological decomposition (i.e., after splitting off the past tense te-suffix of an incorrect spelling, the spelling pattern of a non-existent verb stem is left). Both the whole-word retrieval and the decomposition route would suggest a no-response, even though the item’s pronunciation requires a yes-response. This response conflict is the source of error responses. One expects this response conflict to cause a delay in RTs as well, again with no difference between the two verb types. However, the results of the RT analysis show that such a delay indeed occurs for p verbs (*reptte) but not for s verbs (*sustte), which manifests itself in the form of an interaction between Spelling and
Sublexical Homophony. The absence of a delay for *s* verbs suggests that participants were barely disturbed by the spelling error, apparently because they had access to other information than the output of a morphological decomposition or retrieval process. As the contrast between *s* verbs and *p* verbs consists in the presence or absence of a familiar sublexical letter string (homophonous to the correct spelling pattern in the verb form), it appears they must also have had access to the representation of this substring during the decision process. The response delay for yes-responses to incorrect spellings of *p* verbs is due to the fact that all information sources derived from the spelling of the verb forms suggest a no-response (i.e., both the output of whole-word retrieval/morphological decomposition and the unfamiliar sublexical letter string), whereas the pronunciation requires a yes-response. In contrast, the fact that a familiar sublexical letter string with the same pronunciation as the correct spelling pattern occurs at the position of the spelling error makes it possible to quickly recover from the spelling error that is signaled by a morphological analysis. Hence, there is no RT difference between the correct and incorrect spellings of the past tenses for *s* verbs.

Note that the presence of a sublexical homophonous cluster caused a processing delay when having to make a judgment on its correct spelling (i.e., in a SDT; Section 3.2.1.2), whereas it sped up processing when spelling was irrelevant, as in the current PDT. Different task demands caused the same sublexical homophonous pattern to have opposite effects on response behavior. However, the fact that the pattern did have an effect in both tasks is more important than the difference between these effects. Indeed, the recurrence of an effect testifies to the fact that such substrings indeed activate representations when processing past tense forms. As these substrings cross the morpheme boundary, these results also indicate that word forms are not only segmented in terms of their morphemes, but that representations of high-frequency letter strings are also activated (at least in word-final position), even when cutting across the units that form the output of the morphological decomposition process. The results from both the SDT and PDT lead to the same conclusion for past tense forms with sublexical homophony in the suffix.
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region: they suggest that multiple sub-units of word forms are simultaneously made available during lexical processing.

### 3.2.4. Past tense verb forms: st vs. rt-nt verbs

#### 3.2.4.1. Hypothesis

The present experiment builds on the results of the PDT that contrasted s and p verbs (Section 3.2.3). In that experiment, we found that an incorrect sublexical pattern in past tense forms was accepted more easily when it occurred as a correct spelling pattern in other past tense forms compared to when it was non-existent. To define which type of words are activated by a sublexical homophonous cluster, the current experiment compares two types of verbs. Both have (a) a stem-final t (hence, a double t in the correct spelling of their past tense) and (b) a sublexical homophonous letter pattern. One verb type was characterized by sublexical homophony in the verbal paradigm, namely st verbs (i.e., stem ends in -st; e.g., rustte, ‘rested’) for which the correct stte-pattern is homophonous with the ste-pattern found in other past tenses (e.g., suste, ‘hushed’). In contrast, verbs of the second type (labeled rt-nt verbs) did not have sublexical homophony within the verbal paradigm, but did in the inflectional paradigm of other parts of speech (e.g., startte, ‘started’ or plantte, ‘planted’, where -rte and -nte are homophonous with -rte and -nte in zwarte, ‘black’ and lente, ‘spring’, respectively). Verbs whose stem ends in rt or nt cannot have a homophonous word-final cluster (rte/nte) in past tenses, because the correct suffix for past tenses whose stem ends in the voiced obstruents r or n is -de rather than -te. We hypothesized that the RTs for incorrect spellings (e.g., *teste, *sporte or *plannte) would depend on the familiarity with the homophonous substring in final position. If the familiarity

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72 This section is the result of a collaboration with Len Koolen in the context of her master’s thesis.

73 It was impossible to select verbs without sublexical homophony in the verbal paradigm that all had the same consonant before the stem-final t. Therefore, we had to select items with both stem-final rt and nt.
of the orthographic pattern were restricted to past tense forms, we expect the same interaction effect between Spelling and Sublexical Homophony as we found for s and p verbs in the PDT. More particularly, we expect the incorrect but competing ste-pattern to be more easily accepted than the incorrect rte-/nte-pattern, which does not occur in any past tense form. However, if familiarity with an orthographic pattern is determined by its occurrence in all words, such an interaction should be absent. This would mean that the frequency of nouns and adjectives containing the same orthographic pattern adds to the frequency count of a sublexical letter string occurring in a verb form. Such an observation would be similar to the one made by Sandra and van Abbenyen (2009), who found that the frequency of homophonous nouns and adjectives co-determined the preferred spelling of a verb homophone (see Largy et al. (1996) for comparable results in French and Hare et al. (2001) for English).

3.2.4.2. Method

See Section 3.2.2.2.

3.2.4.3. Results and Discussion

Results. RT analysis. Incorrect responses were removed (n = 49) and the remaining 527 observations were inverse-transformed (-1000/RT). We fitted a linear mixed effects model to these inverted RTs (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The following control variables were tested for inclusion through likelihood ratio tests: inverted PreviousRT, Log Lemma Frequency, Log Whole-word Frequency, Length and Trial. The variables under scrutiny were: Spelling, Sublexical Homophony, and the interaction between both. The maximal random structure supported by the data consisted of a by-participant random intercept, a by-lemma random intercept and by-lemma random slope for Spelling. After removing outliers (absolute standardized residuals > 2.5 SD; n = 1), we fitted a model with the same predictors to this
subset of the data. The results of the final regression model are presented in Table 28, while partial effects are plotted in Figure 27.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>-1.31</td>
<td>0.04</td>
<td>-32.46</td>
<td>123.28</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.29</td>
<td>0.04</td>
<td>6.59</td>
<td>81.78</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial</td>
<td>-0.0007</td>
<td>0.0002</td>
<td>-3.03</td>
<td>9.05</td>
<td>.003</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>-0.16</td>
<td>0.03</td>
<td>-5.55</td>
<td>16.76</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Spelling</td>
<td>0.03</td>
<td>0.03</td>
<td>0.83</td>
<td>0.67</td>
<td>.412</td>
</tr>
<tr>
<td>Sublexical Homophony</td>
<td>-0.004</td>
<td>0.04</td>
<td>-0.10</td>
<td>0.01</td>
<td>.920</td>
</tr>
<tr>
<td>Spelling x Sublexical Homophony</td>
<td>-0.06</td>
<td>0.06</td>
<td>-0.99</td>
<td>0.98</td>
<td>.322</td>
</tr>
</tbody>
</table>

Table 28. Coefficients of a linear mixed effects model predicting inverse-transformed RTs from PreviousRT, Trial, Log Lemma Frequency, Spelling, Sublexical Homophony and the interaction between Spelling and Sublexical Homophony together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.
ER analysis. We fitted a generalized linear mixed effects model to all 576 observations, in which the correctness of the response functioned as a binomially distributed dependent variable (correct = 1; incorrect = 0; see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The control variables and the manipulated variables were identical to those in the RT analysis. The maximal random structure justified by the data consisted of a by-participant random intercept. The results of the GLMM are presented in Table 29 and partial effects are visualized in Figure 28.
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Table 29. Coefficients of a mixed logit model predicting the probability of a correct response from Trial, Log Lemma Frequency, Spelling, Sublexical Homophony and the interaction between Spelling and Sublexical Homophony together with the estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>$z$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>3.95</td>
<td>0.44</td>
<td>9.02</td>
<td>52.79</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial</td>
<td>0.01</td>
<td>0.005</td>
<td>2.68</td>
<td>8.18</td>
<td>.004</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>2.12</td>
<td>0.31</td>
<td>6.89</td>
<td>77.85</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Spelling</td>
<td>0.02</td>
<td>0.47</td>
<td>0.05</td>
<td>0.002</td>
<td>.961</td>
</tr>
<tr>
<td>Sublexical Homophony</td>
<td>1.09</td>
<td>0.48</td>
<td>2.30</td>
<td>5.93</td>
<td>.015</td>
</tr>
<tr>
<td>Spelling x Sublexical Homophony</td>
<td>0.73</td>
<td>0.92</td>
<td>0.79</td>
<td>0.63</td>
<td>.427</td>
</tr>
</tbody>
</table>

Figure 28. Partial effects plot of effects represented in Table 29.
Discussion. The RT analysis yielded significant effects for PreviousRT, Trial and Log Lemma Frequency. In other words, shorter RTs were observed as previous RTs decreased, as the experiment progressed, and as verbs’ lemma became more frequent. Surprisingly, the main effect of Spelling was not significant: both the correct and incorrect spellings were processed equally fast. Furthermore, neither the main effect of Sublexical Homophony, nor the interaction between Sublexical Homophony and Spelling was significant. For the ER analysis, we found significant effects of Trial and Log Lemma Frequency (fewer errors were made as lemma frequency increased and as the experiment progressed). Again, the main effect of Spelling and its interaction with Sublexical Homophony were not significant. In contrast, the main effect of Sublexical Homophony yielded a significant effect: fewer errors were made on st verbs.

Neither the main effect of Spelling, nor its interaction with Sublexical Homophony was significant in the RT or ER analysis. This indicates that there is no difference between the RTs/ERs for correct and incorrect spellings, neither for rt-nt verbs nor for st verbs. A decomposition mechanism should have yielded an impossible parse for incorrect spellings of both verb types. Consequently, RTs to incorrect spellings should have been delayed for both verb types in comparison with correct spellings. Since RTs did not differ, however, we conclude that these past tense forms were not processed via a decomposition route or, if they were, that participants had simultaneous access to the output of another process. Recall that the simultaneous availability of different types of sub-units (i.e., morphemes and familiar homophonous substrings crossing the morpheme boundary) accounted for the results of the preceding experiment, in which s and p verbs were contrasted. Responses to incorrect spellings of past tenses for p verbs (*reptte) were delayed because the output of morphological decomposition and the absence

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74 The main effect of Sublexical Homophony on ERs is most likely the result of the much higher token frequency for the word-final st(t)e-pattern: nte (10,856), rte (8,758) and ste (105,856) for the single t spelling, ntte (44), rtte (537), and stte (1,263) for the double t spelling. Raw frequencies are taken from SUBTLEX-NL (Keuleers et al., 2010).
of a familiar homophonous substring both signaled a spelling error. In contrast, responses to incorrect spellings of past tenses for s verbs (*sustte) were not delayed because the incorrect spelling of the sublexical pattern (stte instead of ste) was homophonous to the correct one and occurred as a correct spelling in other verb forms (rustte). If this line of reasoning can be applied to the present set of results, it should explain the lack of an interaction between Spelling and Sublexical Homophony. Even though rt-nt verbs do not present any sublexical homophony within the verbal paradigm, they do if all parts of speech are taken into account (e.g., zwarte, lente). The past tenses of st verbs are characterized by the presence of a sublexical letter pattern in word-final position that is homophonous with a spelling pattern in other past tenses (i.e., stte, having ste as a homophonous pattern in the correct spelling of past tenses for s verbs, e.g., suste). For these st verbs, sublexical homophony is also not restricted to the verbal paradigm (i.e., present in nouns/adjectives; e.g., finaliste ‘finalist’, vaste ‘fixed’). If the familiarity of a sublexical homophonous cluster in an incorrect verb form is determined by items from the verbal paradigm only, participants should have had fewer difficulties processing past tenses containing the incorrect ste-pattern compared to those containing the incorrect rte-/nte-pattern. However, this is disconfirmed by the absence of an interaction effect between Spelling and Sublexical Homophony. This result seems to suggest that it does not matter whether the sublexical homophonous letter pattern occurs in word forms within or outside the verbal paradigm. Its occurrence suffices to guarantee smooth processing, i.e., no delay in phonological decisions. Because the incorrect and correct spellings of st and rt-nt verbs both represent possible orthographic patterns for the same pronunciation, they were processed equally fast. This account also explains why the only RT delay for an incorrect spelling of past tense forms was observed for p verbs. Only the cluster ptte is non-existent both within and outside the verbal paradigm and, hence, leads to a processing delay.

Together, these findings provide evidence for the idea that a phonological representation (e.g., [st@]) is linked to all its orthographic representations (e.g., ste and stte) and that such mappings are helpful in
processing spelling errors (i.e., homophone intrusions) at the sublexical level. The results of the current experiment also indicate that these orthographic representations cannot only cross morpheme boundaries, but also ignore boundaries between lexical categories. This corroborates the results of Sandra and van Abbenyen (2009) who found that the frequency of homophonous nouns and adjectives has an additional effect on a verb’s dominance: it increases the frequency of the verb homophone sharing the same spelling pattern. Based on the findings of this phonological decision task, we conclude that the familiarity of an orthographic pattern is determined by its occurrence frequency in all words exhibiting that pattern.

Sections 2 (isolated word recognition) and 3 (word recognition in a minimal context) have revealed that Homophone Dominance affects visual word recognition both at the lexical level (i.e., for stem-final d verbs) and the sublexical level (i.e., for past tense verb forms). At the lexical level, the HF homophone of stem-final d verbs was processed more quickly than the LF counterpart when presented in isolation (i.e., in the LDT) and when embedded in a minimal context (i.e., in the SDT and PDT). However, this HF homophone was more difficult to reject as an incorrect spelling when embedded in a minimal context (i.e., in the SDT). In contrast, we did not find any evidence for whole-word retrieval of weak prefix verb forms, neither in a LDT nor in a PDT with a minimal context. At the sublexical level, we found that morphologically impossible spellings of past tense verb forms were processed as quickly as the correct ones in a PDT when the incorrect orthographic pattern was homophonous to the correct pattern (i.e., appeared as a correct spelling in other word forms). This was not the case when the incorrect pattern was non-existent. Whereas this was the case in a PDT, where spelling correctness was irrelevant, we found a different pattern of results in a SDT, where people were asked to focus on the spelling in order to judge its correctness. In the SDT, verbs whose past tenses gave rise to confusion between two possible orthographic patterns (i.e., s verbs) experienced a processing delay compared to verbs without a sublexical homophonous pattern (i.e., p verbs). The
opposite effects in a PDT and a SDT, both for lexical and sublexical homophone intrusions, reflect the impact of different task demands. When responses are based on the form’s phonology and spelling must be ignored (PDT), incorrect but homophonous spellings facilitate processing. In contrast, when responses are based on the form’s orthography (SDT), the mapping of a single pronunciation onto two sublexical letter strings creates interference compared to when there is only one correct spelling. Furthermore, we found that the familiarity of a sublexical cluster in word-final position of past tenses does not only derive from other past tenses in the verbal paradigm, but depends on all word forms sharing that orthographic pattern. If a morphological decomposition mechanism split up such sublexical clusters, processing measures should have been indifferent to the frequency of those clusters. Therefore, we conclude that visual word recognition is sensitive to the frequency of subunits, other than morphemic units.

The finding that intrusions involving a frequent homophone or sublexical homophonous cluster were processed more quickly than the LF homophone or a non-existent cluster during visual word recognition (i.e., in isolation and in a minimal context) raises the question whether these intrusions might also go unnoticed more often in a full sentence context, so that they persist in carefully re-read texts. Moreover, if the same homophonous forms/patterns are more error-prone in both spelling (causing spelling errors) and reading (causing detection failures), this would be strong evidence that the persistence of these errors is due to the fact that some homophonous forms/patterns affect the processes of reading and spelling alike (a dual trap). Several considerations lead us to expect that effects of Homophone Dominance will also be found in experiments where incorrectly spelled verb forms are embedded in sentences: (a) the fact that these effects already emerge outside a sentence context, (b) the fact that the marker and a homophonous verb form are often separated by intervening words in a sentence (thus burdening working memory and increasing the risk of homophone intrusions) and (c) the fact that sentence processing involves a stronger focus on syntax and meaning and a concomitant weaker focus on
spelling (also resulting from working memory overload by higher-order processes). The next section examines whether the Homophone Dominance effect (a) persists in sentence reading for stem-final d verbs (i.e., lexical level) and past tense verb forms (i.e., sublexical level) and (b) appears for weak prefix verbs (i.e., lexical level).

4. **WORD RECOGNITION IN A SENTENCE CONTEXT**

Contrary to the previous sections, which examined visual word recognition – either in isolation or in a minimal context – this section aims to study natural reading behavior, when people encounter homophone intrusions in a sentence context. Two tasks have been widely used as tools for examining sentence reading, namely the eye tracking task (ETT) and the self-paced reading task (SPRT). They have been shown to shed light on the cognitive operations underlying the reading process, both in terms of word recognition and word integration into a sentence context. A distinct advantage of the ETT and SPRT is their naturalness: they closely resemble normal reading situations in comparison with other reading tasks, such as the maze task\(^ \text{75} \) (Witzel, Witzel, & Forster, 2012).

In a standard SPRT (i.e., moving-window reading; see Just, Carpenter, & Woolley, 1982), sentences are presented on a left-to-right word-by-word basis, thus preventing look-aheads and regressions. The presentation duration of each word depends on participants’ speed of processing, i.e., their readiness to progress to the next word by means of a button press. The time between successive button presses is indicative of that item’s processing time and the ease with which it is integrated into the previous context (but, see spillover effects below). As such, these response times can be seen as equivalent to RTs in for instance a LDT.

In a traditional ETT, participants are asked to silently read words, sentences, or entire texts, while their eye movements are being recorded. The

\(^ {75} \) In a maze task, participants move through a sentence by making a forced-choice between two words at each word position.
reading process is marked by saccades (i.e., eyes moving from one position to another) and fixations (i.e., eyes fixating a particular position). The duration of these fixations is said to reflect both lexical access processes (e.g., morphological decomposition) and post-access integration effects during reading (Rayner, 1998). In contrast to the SPR, there is no word-by-word processing as the eyes can freely fixate across all words. This means that the eyes can skip words or make regressions (i.e., return to previously read words). Consequently, the pattern of eye movements is extremely complex. This stands in contrast with the SPRT, where an overt response has to be made, leading to a single dependent measure for each word. In an ETT, participants can adopt a multitude of reading strategies, ranging from careful reading to superficial skimming, which can influence how well fixation characteristics reflect online processing or the integration of words into the sentence context (Witzel et al., 2012). Hence, despite the fact that eye tracking resembles natural reading most closely, it does not always reveal a clear pattern of results. Still, eye tracking provides a rich source of information on different measures and therefore makes up for its inability to pick up on certain processing differences by revealing a complex picture of how cognitive operations unfold over time (Witzel et al., 2012).

Both tasks, however, also share a disadvantage: they tend to exhibit spillover effects (Witzel et al., 2012). Ideally, participants make a response or move their eyes to a new word only when the targeted word has been recognized and integrated within the sentence context. The accuracy of the reaction and reading times, however, can be influenced by specific reading strategies. To speed up reading, participants in a SPRT might give a response as quickly as possible and temporarily buffer the information for identification and integration at a later time. Such a strategy leads to a constant flow of button presses (Witzel et al., 2012). Similarly, the eyes might already leave a word and fixate on another word in an ETT before the first word has been fully identified, thus causing an underestimation of the time needed for lexical access (Forster, 2010; Niswander et al., 2000). This type of reading behavior causes the effect to manifest itself not on the critical item but to “spill over” to
the next word or region. Consequently, in both the SPRT and the ETT the effect might be delayed (i.e., located on one of the following words) or distributed across multiple following words (Witzel et al., 2012).

Both tasks have been shown to be sensitive to whole-word frequency effects, with shorter RTs and shorter fixation times for high-frequency words compared to low-frequency words (Hyönä & Olson, 1995; Inhoff & Rayner, 1986; Randall & Marslen-Wilson, 1998; Rayner & Duffy, 1986). Schilling, Rayner, and Chumbley (1998) showed that performance in a lexical decision task and in an ETT were highly correlated with respect to whole-word frequency, with a more pronounced effect in the LDT (see also Kuperman, Drieghe, Keuleers, & Brysbaert, 2013). They suggest that frequency effects in isolated word recognition underlie a common process of lexical access, which also occurs in silent sentence reading.

Few studies, however, have examined how sentence context can modulate the processing of complex and, more particularly, inflected words. Hyönä, Vainio, and Laine (2002) compared the effect of morphological complexity on word forms when they were presented in an isolated LDT to when they were embedded in a sentence context, either in a (sentence) LDT or in an ETT. Longer RTs for complex words than for monomorphemic words have been taken as evidence for morphological decomposition (i.e., an extra processing step requires extra processing time). While RTs were significantly longer for inflected Finnish nouns compared to for monomorphemic ones in the isolated LDT, RTs and fixation durations did not differ between the word types in the two sentence tasks. This pattern of results is taken to suggest that the presence of a sentence context modulates the effect of morphological complexity. The authors assign the difference between the two tasks to the absence of a fitting context in an isolated LDT. When provided with a sentence context, however, readers can make use of it to generate predictions about the morphological structure of upcoming words. A context can therefore facilitate the identification of the inflected word form, so that both the inflected and non-inflected form are equally plausible, in contrast to the situation in isolated word presentation (Hyönä et al., 2002). These results suggest that
morphological effects for inflected word forms found in the isolated LDT might not generalize to normal, continuous reading.

In our research, the question arises whether a sentence context favors the decomposition or whole-word route for inflected verb forms. Bertram, Hyönä, and Laine (2000) wondered whether a sentence context modulates whole-word and stem frequency effects for inflected Finnish nouns with the ambiguous jA–suffix, which can only be disambiguated in a sentence context. In a LDT (isolated word recognition) Bertram, Laine, et al. (2000) had already found a solid effect of whole-word frequency, but not of stem frequency. Bertram, Hyönä, and Laine (2000) hypothesized that a sentence context would prime the inflectional ending and thus speed up the decomposition route. Consequently, one would expect the effect of stem frequency to appear in a sentence context. The authors therefore used the same stimuli from the LDT in an ETT and SPRT. In both tasks, stem frequency affected processing times in the spillover region (i.e., x+1). The effect of whole-word frequency was also significant in both tasks, although the timing of the effect differed. Whereas the effect in the ETT was found for the fixation times on the target noun itself and in the spillover region (i.e., x+1), the SPRT only revealed a delayed effect of whole-word frequency (i.e., x+1). Based on these findings, Bertram, Hyönä, and Laine (2000) suggest that complex words are processed through two parallel routes (see Schreuder & Baayen, 1995). In the ETT, whole-word representations of inflected Finnish nouns were activated before their constituent morphemes: the effect of whole-word frequency already emerged on the inflected form itself, whereas the effect of stem frequency emerged on the following word. Crucially, these nouns had a noteworthy characteristic: they ended in the jA-suffix, which can mark the partitive plural case or denote a deverbal subject noun. The authors argue that for words ending in an ambiguous suffix, the computational route is slower in an isolated word recognition task (LDT) because of the competition between its two syntactic functions. In such a task, it is therefore more likely that these items access their whole-word representations first. When these inflections are embedded in a sentence context, however, the ambiguity of the suffix is
eliminated. The contextual cues speed up the decomposition route (i.e., the function of -jA is evident from the context), leading to the appearance of a stem frequency effect, as witnessed in the SPRT and ETT (Bertram, Hyönä, et al., 2000).

Further evidence for the idea that sentence context has an impact on the way morphologically complex words are processed comes from a series of experiments performed by Luke and Christianson (2011). Using a quasi-identical manipulation to the one used by Bertram, Hyönä, et al. (2000), they contrasted the results for regularly inflected English verb forms when presented in isolation (i.e., in a LDT) and when embedded in sentences (i.e., in a SPRT). However, they obtained very different results than in Finnish. Considering the differences between the two languages and the nature of the suffixes (ambiguous suffixes in Finnish, non-ambiguous ones in English) we will not attempt to interpret these differences, but only take notion of the fact that the introduction of a sentence context can radically change the effects obtained in isolated word recognition. While the LDT yielded an effect of stem frequency only, an interaction between stem frequency and whole-word frequency emerged in the SPRT. This interaction showed that while whole-word frequency was generally facilitative in a sentence context, it had an inhibitory effect when stem frequency was high. The authors argue that whole-word frequency effects are triggered by the presence of a sentence context. Indeed, such a context requires checking whether the combination of stem and affix is correct (i.e., given the grammatical context). In contrast, such checking is not required when inflected word forms are presented in isolation (i.e., lexical access can be achieved through decomposition alone) (Luke & Christianson, 2011). Note that this morphological checking mechanism is reminiscent of the morphosyntactic checking mechanism required to correctly detect homophone intrusions in the spelling of verb forms (at the lexical level).

The question also arises whether the influence of phonological neighbors (in our case Sublexical Homophony) persists in a sentence context. Ernestus and Mak (2005) built on the results of a previous study by Ernestus and Baayen (2004), targeting the production of Dutch past tense forms in
isolation. Ernestus and Baayen (2004) found that the most frequent suffix form among a verb’s phonological neighbors (i.e., past tenses of verbs with the same stem-final sound) affected which allomorph of the past tense suffix (i.e., -te or -de) was more likely to be attached to the stem. Although these forms are governed by a straightforward phonological principle (see Section 1.1 of Chapter 1), the influence of these phonological neighbors caused occasional spelling errors (i.e., substitution of the te-suffix by the de-suffix or vice versa).

Based on these findings, Ernestus and Mak (2005) examined whether phonological neighbors also affected the processing of these forms in sentence reading. In two SPR experiments, these past tenses were spelled either with the correct or incorrect allomorph (e.g., krabde and *krahte ‘scratched’) and were embedded in a sentence context. The delay resulting from the incorrect spelling was smaller when that suffix spelling received support from many phonological neighbors (e.g., stapte ‘stepped’, repte ‘rushed’, ...) than when it did not receive such support. These results led to the conclusion that phonologically similar words from different verbal paradigms affect not only the spelling, but also the acceptability of incorrectly spelled past tenses during reading (Ernestus & Mak, 2005).

In what follows, we will target both online processing measures (i.e., reaction times or reading times) and offline processing measures (i.e., error detection rates). We will examine whether (a) the HF form of a homophous verb pair is processed more quickly/overlooked more often as an error than the LF one when embedded in a sentence context. While the visual word recognition experiments reported in the previous section (LDT, SDT and PDT) suggest that this is the case for stem-final d verbs, the literature indicates that whole-word representations do not necessarily play the same role in isolated visual word recognition and sentence reading (see above). Moreover, we will also investigate whether (b) the Homophone Dominance effect for weak prefix verbs will appear in a sentence reading context. Finally, we will also investigate (c) whether errors involving sublexical homophone intrusions are processed more quickly/overlooked more often when the intrusion corresponds to a frequently occurring letter string compared to when it corresponds to a non-
existent pattern. These hypotheses will be tested in an ETT, SPRT and maze task (MT) for online processing and in a proofreading task (PRT) for offline processing.

4.1. **Online tasks**

4.1.1. **Eyetracking task**

4.1.1.1. Stem-final d verbs

4.1.1.1.1. **Hypothesis**

The section on visual word recognition revealed that for stem-final d verbs the HF representation of a homophone pair was accessed during the recognition process, leading to faster RTs for this homophone compared to the LF one. This was true both when forms were presented in isolation (LDT) and when their correct spelling was embedded in a minimal context (in a SDT and PDT). In the PDT, incorrect spellings were also processed more quickly when they contained the HF form. However, they delayed responses in the SDT as a result of the decision conflict caused by their fast lexical access (i.e., suggesting a yes-response). The question arises whether the results found in visual word recognition also transfer to sentence reading, i.e., the activity that language users normally engage in when being confronted with written words. To answer this question, we examined eye fixation patterns while participants were reading sentences containing homophone intrusions. We focussed on the incorrect spelling of verb forms to find out whether the intrusion of a HF homophone, due to its high degree of familiarity, would cause less disturbance in the pattern of eye fixations than the intrusion of a LF homophone. If so, the same verb forms that typically cause intrusion errors in spelling would also be the ones that are most easily overlooked in the reading process.

We chose an eyetracking task because it closely resembles natural reading. We embedded the dt-form of stem-final d verbs in a sentence context...
that grammatically required the d-form. The presence of a sentence context allowed us to insert intervening words between the subject and verb form. Under these conditions, the probability of making a homophone intrusion in spelling experiments was larger than when the subject and verb form were adjacent (Sandra et al., 1999, 2004). This finding suggests that the morphosyntactic analysis that is needed to compute the spelling of the suffix consumes more resources as the subject is further removed from the verb form (Sandra et al., 1999). This may also be the case when coming across a homophone intrusion while reading: when too many words separate the homophonous verb form from its marker, readers may sometimes miss the error (and not be delayed by it) because it takes them too long to check the spelling of the decomposed suffix against the subject’s grammatical properties. When the intrusion corresponds to the HF homophone, it is more likely that the whole-word retrieval route is terminated before this check is completed than when it is the LF homophone. Thus, readers’ reliance on this route will be stronger for incorrect HF forms than for incorrect LF ones, which leads to the prediction that intrusions of HF homophones will cause the smallest increase in reading times.

To summarize, our goal is to demonstrate that the erroneous dt-form receives shorter fixations as it becomes the most frequent homophone of a verb pair. If participants access whole-word representations for stem-final d homophones while reading sentences, fixations times on incorrect dt-forms should increase as their Homophone Ratio increases (i.e., as the d-form becomes the more frequent homophone).

4.1.1.2. Method

Stimuli. In the current experiment, participants were asked to read 96 sentences. In this set of sentences, 24 contained stem-final d verbs, 24 contained past tense verb forms and 48 were fillers. The 24 stem-final d verbs (half d- and half dt-dominant) were identical to the basic set used in previous experiments, except that the dt-dominant verb duiden (‘to interpret’) was
replaced by *opvoeden* (‘to raise’). The critical verb form always appeared at the end of a subordinate clause, followed by a main clause, as in for instance:

Omdat ik sinds dat onfortuinlijke werkongeval veel pijn *lijdt* zal de specialist ongetwijfeld een *extra* kuur *antiebiotika* voorschrijven.

‘Because I since that unfortunate work injury from a lot of pain *suffers*, will the specialist undoubtedly an extra round of *antibiotics* prescribe.’

We chose this particular sentence structure because it allows the subject and verb to be separated by intervening words (i.e., SOV-structure in the subordinate clause), making it more likely to detect the Homophone Dominance effect (Sandra et al., 1999, 2004). To eliminate any possible confound, exactly six words appeared between the subject and the verb form in each sentence. The word preceding the verb form was always a singular noun to keep interference from misleading morphosyntactic information constant across d- and dt-dominant verbs (see, for example Fayol et al., 1994). The subject of the sentence was always the personal pronoun *ik* (‘I’), while the verb form was the incorrect dt-form, appearing in ninth position. The verb forms’ position in the sentence was kept constant to exclude the possibility that differences in reading times on the critical verb forms were due to positional differences. The maximum length of the sentences was 22 words, so that each sentence fitted on two lines. The critical verb form always appeared on the first line, followed by three other words on that same line.

In each critical sentence, we incorporated at least two difficult-to-spell words, always appearing after the verb form. In half of the sentences, these difficult words were both spelled incorrectly (e.g., *antiebiotika*), while in the other half one was spelled correctly (e.g., *antibiotica*). Thus, critical sentences contained either two or three spelling errors. Furthermore, as the words in

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76 This was done because we had difficulties creating a natural-sounding sentence with the verb *duiden* in the first person singular. The frequency characteristics of the dt-dominant verb *opvoeden* were: (raw) Frequency d-form (6), (raw) Frequency dt-form (18), Homophone Ratio (-0.48) and (raw) Lemma Frequency (895). Frequency characteristics are taken from SUBTLEX-NL (Keuleers et al., 2010). See Table 1 in the Appendix for the other critical verbs’ characteristics.
positions x-1, x+1 and x+2\textsuperscript{77} can either affect the difficulty of the homophone’s processing (x-1 and, as regressions are possible, also x+1 and x+2) or find themselves in the region of spill-over effects (x+1, x+2), we matched these words between the sets of d-dominant and dt-dominant verbs on factors strongly affecting word recognition times, namely Length, Log Whole-word Frequency and Log Lemma Frequency (all \( ps < .05 \)). Sentences containing d- and dt-dominant verbs were also matched for sentence length (both in number of words and characters) and the number of characters before the critical verb (all \( ps < .05 \)).

Moreover, the 24 critical past tense forms were also embedded in sentences of maximum 22 words. These verb forms were identical to those used in previous experiments (see Table 2 in the Appendix for their characteristics) and will be analyzed in Section 4.1.1.2.3. The group of past tense verbs consisted of 12 s verbs (characterized by sublexical homophony) and 12 p verbs (without homophony). Half of the items from each type were spelled correctly and half incorrectly (see Design). We used the same sentence structure as for the stem-final d verbs, namely a subclause, followed by a main clause (see example below). The critical past tense form always appeared at the beginning of the main clause in ninth position (first line), followed by three other words on the same line. Following the critical verb, we inserted at least two difficult-to-spell words, one of which was spelled correctly in half of the cases, while both were spelled incorrectly in the other half. Sentences with s and p verbs were also matched for sentence length (i.e., total number of words and characters) and the number of characters before the critical verb (all \( ps < .05 \)). To exclude the possibility that the difference in reading times between s and p verbs was due to the surrounding context, we paired each s verb with a p verb.

\textsuperscript{77} The following terms will be used to denote the important elements for the analysis of the critical sentences:
- x-1 : word preceding critical verb form
- x : critical verb form
- x+1 : word following critical verb form
- x+2 : second word following critical verb form
verb. For each pair, we made sure that the words in positions x-1, x+1 and x+2 were perfectly matched (i.e., were identical words), for instance:

\[
\begin{array}{cccc}
  x & x & x & x+2 \\
  \text{Hoewel de kunsthandelaar in de gaten gehouden werd glipt(t)e hij toch onopgemerkt uit het *auditorium tijdens die oersaaie speech.} \\
  \text{‘Although the art dealer watched being was snuck he still undetected out of the auditorium during that incredibly boring speech.’}
\end{array}
\]

\[
\begin{array}{cccc}
  x & x & x+1 & x+2 \\
  \text{Hoewel die schuchtere tiener bijna zeventien jaar werd plast(t)e hij toch nog *sistematis in zijn bed na een vreselijk auto-ongeluk.} \\
  \text{‘Although that shy teenager almost seventeen turned wet he still systemically his bed after a terrible car accident.’}
\end{array}
\]

These 48 critical sentences were supplemented with 48 filler sentences, each containing at least three difficult-to-spell words not pertaining to verb inflection. In half of the cases, two of these words were spelled incorrectly and in the other half three had an incorrect spelling. Note that these spelling errors were very striking to divert participants’ attention from the goal of the experiment, as in for instance:

\[
\begin{array}{cccc}
  x & x & x & x+2 \\
  \text{Om *cellulitice te bestrijden doe ik *stevast beroep op *allerlij wondermiddeltjes die aangeprezen worden in manipulatieve reclamespotjes. (correct spellings: cellulitis, steevast, allerlei) } \\
  \text{‘In order cellulite to combat make I always use of numerous miracle cures that are being praised in manipulative advertisements.’}
\end{array}
\]

Previous research has shown that when the preceding sentence context renders certain words predictable, these words receive shorter fixation durations and/or are skipped more often (Balota, Pollatsek, & Rayner, 1985; Ehrlich & Rayner, 1981; Rayner & Well, 1996; Zola, 1984). To minimize the predictability of the critical verb forms, we subjected a set of 21 participants, taken from the same population as the participants in the actual experiment,
to a sentence completion task. In this task, participants were offered the beginning of the 48 critical sentences up to the word preceding the target verb form (e.g., *Hoewel die schuchtere tiener bijna zeventien jaar werd ____*). We also included 12 filler sentences with a highly predictable word. It was the participants’ task to continue the sentence with the first word that came to mind. Mean production probability for stem-final d verbs was very low, namely 5.4%. Crucially, an independent sample two-tailed t-test revealed that d-dominant verbs were not more predictable than dt-dominant verbs or vice versa ($t = 1.28, p = .21$). The results of the sentence completion task showed that $p$ and $s$ verbs were also unpredictable from the preceding context: the target verb was only given in 3.08% of the cases and was not more predictable for $s$ than for $p$ verbs ($t = 0.84, p = .41$). The predictability of the verb form is therefore not likely to cause any differences in reading times between the conditions.

Importantly, thirty-two of these sentences (both critical and filler) were followed by a comprehension question to ensure that participants had fully understood the content of the sentences. These questions should have prevented participants from reading the sentences superficially, without attempting to integrate each word in the preceding context.

*Design.* Each experimental list consisted of 96 sentences (i.e., 24 stem-final d verb forms, 24 past tense verb forms and 48 fillers). We created two counterbalanced lists for past tense forms: in list A, half of the $p$ and $s$ verb forms ($n = 12$) were spelled incorrectly, while the other half were spelled correctly and vice versa for list B. The fillers and stem-final d verb forms were identical across both versions (recall that all stem-final d verb forms were spelled incorrectly)\(^7\). These 96 sentences were evenly distributed across two

\(^7\) As Homophone Ratio ranges from dt-dominant to d-dominant verbs in the set of stem-final d verbs, it is possible to use only dt-intrusions in an ungrammatical context. The expectation is that dt-intrusions will cause no or a smaller increase in reading times as the dt-form becomes the more frequent homophone of a pair. In contrast, as the opposition between $s$ and $p$ verbs at the sublexical level involves the presence versus absence of a homophonous pattern between the two verb sets and not a range
blocks, with each block comprising an equal number of items from each item
type. Each block also contained 18 comprehension questions, appearing in
random order. Next, we created two randomization sequences (R1/R2),
applying the following criteria: a critical item never initiated/terminated a
block and critical sentences of the same item type were separated by at least
one other sentence from a different item type. This yielded a total of four
versions: AR1, AR2, BR1, BR2. The same set of ten practice sentences and four
questions preceded each experimental list.

**Participants and Procedure**

*Participants.* Thirty subjects, students at Antwerp University, participated in
the experiment for course credit (mean age 20.2; SD = 2.43). They had
(corrected-to-) normal vision, were native speakers of Dutch without any
reading disorder and had not previously taken part in an experiment on
homophone intrusions.

*Procedure.* Participants were seated in front of a Windows-based Dell
Precision T5500 computer connected to a 23” TFT monitor with a 1920 x 1080
pixel screen resolution. Participants’ eye movements were recorded by the
Tobii TX300 (manufactured by Tobii Technology, Stockholm, Sweden). This
eye tracker is fully integrated within the screen and registers binocular data.
Pupil location and size are sampled at a rate of 300Hz and with a variability of
0.3%. Gaze accuracy is situated between 0.4°-0.6° of visual angle while gaze
precision is 0.04°. Participants sat at a distance of about 60cm. Since
measurements from the Tobii eyetracker are robust for head movements, a
head stabilization instrument was not required. The eye tracker was calibrated
at the beginning of the experiment by asking participants to fixate on a red
circle that randomly moved across different positions on the screen.

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in dominance values within each set, the only way to examine the (different) impact of
a sublexical homophone intrusion is by comparing reading times for correct and
incorrect forms. Hence, the difference between the items for stem-final d verbs and s
and p verbs.
Recalibration took place after the first 48 experimental items. To present the sentences, we used Tobii Studio 3.1.0., which displayed the two-line sentences in the middle of the screen. The sentences were printed in black on a white background. They were printed in Calibri font (24 points) and had standard capitalization and punctuation.

Participants received written instructions about the procedure. They were asked to read each presented sentence at their natural reading speed, after which they could be asked a question about its content. They were told that the sentences originated from a previous experiment, in which participants had to type sentences under time pressure, causing them to make spelling errors. According to the instructions, the goal of the current experiment was to test what the impact of spelling errors was on reading behavior and comprehension, without referring to homophone intrusions. They were told to ignore these errors and avoid re-reading them.

In order to familiarize participants with the equipment, they were first asked to read two short articles (+/- 15 lines) about which they had to answer a question. Next, they were presented with ten practice items and four comprehension questions. If participants had no questions at this point, they could progress to the first set of 48 experimental sentences. After these 48 sentences, participants were allowed to take a break. Next, the eye tracker was recalibrated, after which they were presented with the next 48 experimental sentences.

Each trial had the same structure. The first screen contained a fixation cross in the right-bottom corner. When participants mouse-clicked this cross, the next screen appeared, containing a sentence. When having read this sentence, they had to click the cross in the right-bottom corner again. Following this mouse click, either a screen with a fixation cross appeared again, initiating the next trial, or the sentence was followed by a screen containing a comprehension question. Answers were made by mouse-clicking one of the two responses on the screen, upon which the next screen containing a fixation cross appeared. An example of such a sequence might be:
4.1.1.3. RESULTS AND DISCUSSION

Results. All participants scored more than 75% correct on the comprehension questions, with an average of 94%. Based on these scores, all participants were included in the analysis. Using the Tobii Studio 3.1.0 areas of interest function, we obtained three standard fixation time measures (Rayner, 1998): First Fixation Duration, First-Pass Fixation Time and Total Reading Time (cf. below). This was done for seven specified regions, including x-1, x, x+1, x+2. The first region (x-1) was not analyzed as such, as the verb form had not been processed yet at this point, but its values were used to calculate previous reading times (used to explain part of the variance on the critical verb form). While the second region (x) is used to examine whether the Homophone Dominance effect manifests itself on the critical verb form, the latter two regions (x+1 and x+2) were calculated to detect possible spillover effects. To account for distributed spillover effects, we also calculated these measures for multi-word regions, namely x_x+1, x+1_x+2, and x_x+1_x+2. Fixation times were not adjusted for the number of words in the region.

First Fixation Duration is defined as the duration of the first fixation in a particular region, with a minimum duration of 50ms. This measure is believed to tap into early stages of lexical access, thus revealing factors that have a strong impact on the lexical access process, as, for instance, word frequency (Rayner, 1998; Rayner & Duffy, 1986). First-Pass Fixation Time is
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defined as the sum of the fixation durations in a region before leaving that region in any direction starting with the reader’s first fixation inside the region with a minimum duration of 50ms. This measure is equivalent to that of gaze duration as specified by Rayner and Duffy (1986) if the fixation is on a single word. This measure, too, has been shown to be sensitive to whole-word frequency (Hyönä & Olson, 1995). Total Reading Time is defined as the sum of all fixation durations in a region with a minimum duration of 50ms, including fixations that have occurred after the eyes have left the region and returned to it. This measure, too, has yielded whole-word frequency effects (e.g., Rayner, Reichle, Stroud, Williams, & Pollatsek, 2006). We analyzed these three dependent measures for each of the six regions of interest described above. Missing values were assigned to these measures if the word (region) was skipped. In what follows, we will report analyses yielding a (marginally) significant effect of Homophone Ratio, which was the case for the Total Reading Time of the three-word region x_x+1_x+2 only. In all other analyses the effect of Homophone Ratio was non-significant (all ps > .05).

Total Reading Times for three-word region x_x+1_x+2 (N = 718; 2 NAs), henceforth RTs, were log-transformed and fitted with a linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The following control variables were tested for inclusion as fixed effects: (log-transformed) PreviousRT (i.e., of x-1), Trial, Log Lemma Frequency (of x-1, x, x+1 and x+2), Length (of x-1, x, x+1 and x+2) and Log Whole-word Frequency (of x-1, x+1 and x+2)

79. The theoretically relevant variable was the Homophone Ratio for the incorrectly spelled homophone at position x. The maximal random structure supported by the design consisted of a by-participant random intercept, a by-participant random slope for Homophone Ratio and a by-lemma random intercept. After outlier removal (absolute standardized residuals > 2.5 SD; n = 10), we fitted a model with the same predictors to the

Recall that we take up the characteristics of these words (x-1, x+1 and x+2) as control variables because the processing difficulties associated with them can affect RTs at x. Obviously, the whole-word frequency of x (i.e., the critical verb form) is not a control factor, but is embodied by the theoretically relevant variable Homophone Ratio.

79
remaining data points. Table 30 reveals the results of this LMM, the partial effects of which are plotted in Figure 29.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE(\beta)</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.92</td>
<td>0.06</td>
<td>124.33</td>
<td>192.72</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.19</td>
<td>0.03</td>
<td>7.02</td>
<td>47.29</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial</td>
<td>-0.001</td>
<td>0.0005</td>
<td>-2.57</td>
<td>6.53</td>
<td>.011</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>-0.09</td>
<td>0.03</td>
<td>-2.74</td>
<td>6.50</td>
<td>.011</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>0.08</td>
<td>0.04</td>
<td>1.95</td>
<td>3.56</td>
<td>.059</td>
</tr>
</tbody>
</table>

Table 30. Coefficients of a linear mixed effects model predicting log-transformed RTs from PreviousRT, Trial, Log Lemma Frequency and Homophone Ratio together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.

Figure 29. Partial effects plot of effects represented in Table 30.
Discussion. The analysis of the Total Reading Times for the three-word region \( x_{-1}x_{+1}x_{+2} \) revealed that the control variables previousRT, Trial and Log Lemma Frequency were significant. More specifically, reading times increased as the RT of \( x_{-1} \) increased, but decreased as the experiment progressed and as verbs’ lemma became more frequent. Note that the effect of Log Lemma Frequency was only significant for this particular region and reading measure. Crucially, the main effect of Homophone Ratio was marginally significant (reaching a \( p \)-value of .059), with longer total reading times for dt-forms as Homophone Ratio increased. In short, participants tended to fixate longer on dt-intrusions (and the two words following it) as the dt-form became the less frequent form of a homophonous verb pair.

These findings partly corroborate our hypothesis that during normal reading the HF homophone is accessed more quickly than the LF one, leading to shorter fixation times on the former than on the latter. As the whole-word process reveals the existence of the HF form but cannot license its spelling correctness in the grammatical context, readers tend to accept the familiar form it has accessed and read on. In contrast, when the LF homophone is the intruder, either the whole-word retrieval process will take longer or the error will be processed by means of a morpheme-based mechanism. As a result, participants’ eyes will dwell longer on the region including the error.

The trend towards an effect of Homophone Dominance in the eyetracking data also confirms our earlier findings from visual word recognition in isolation and with a minimal context, where HF homophones received shorter RTs than their LF counterpart. Note that the finding of longer RTs to HF homophones when participants had to make spelling decisions on incorrect spellings (SDT) does not contradict these results. These longer RTs for HF homophones were due to the response conflict between the required no-response and the bias toward a yes-response created by the access to the HF form. This response conflict is entirely contingent on the existence of a whole-word representation of the HF form in the mental lexicon, a conclusion that makes the experimental results nicely converge with the other findings in a minimal context and in isolated word presentation.
The results are also in line with those of Bertram, Laine, et al. (2000) who found that whole-word frequency affected RTs to inflected Finnish nouns both in an isolated LDT and in an eye-tracking task. Although they found that lemma and whole-word frequency affects arose at different moments in processing (i.e., whole-word frequency before stem frequency), we found that both effects were distributed across the verb and the two words following it.

Although the effect of Homophone Dominance came close to significance ($p = .059$), it did not actually reach the significance threshold. There are several reasons why the effect may not have been more robust. A first thing to note is that the eyetracking device took measurements at 300Hz (i.e., one measurement every 3.33 ms), while most eyetrackers have a sample rate of 1000Hz (i.e., one measurement every 1 ms). This could have been disadvantageous for detecting small effects such as Homophone Dominance. Moreover, a multitude of reading strategies might have been adopted given that an ETT allows readers to fixate freely on any word and makes it possible for readers to return to previous words or word sequences. This might have caused fine-grained processing difficulties to go undetected. Moreover, eyes often make a saccade before the previous word (region) has been fully processed and even often skip short words (Reichle, Pollatsek, Fisher, & Rayner, 1998). Accordingly, a high skipping rate could be responsible for only observing a marginally significant effect. The skipping rates were respectively 7% (51/720) for the critical verb form (x), 23% (163/720) for x+1, and 32% (228/720) for x+2. The high skipping rate, especially in the spillover region, significantly lowers the possibility of finding a robust effect of Homophone Dominance. Moreover, the present experiment only incorporated a single inflectional form in a grammatically incorrect context, namely the dt-form. An experimental set-up using both inflectional forms is more likely to reveal a statistically significant effect.

To address these two concerns, we performed a SPRT (see Section 4.1.2.1) in which we embedded both d- and dt-intrusions in a sentence context. Moreover, this experimental task requires a response to each word (i.e., no
word skipping), leading to a single dependent measure for each individual word.

4.1.1.2. Past tense verb forms

4.1.1.2.1. Hypothesis

Our hypothesis for the past tense verb forms is based on the findings in two visual word recognition experiments that yielded an effect of Homophone Dominance at the sublexical level. In a SDT, verbs containing a sublexical homophonous cluster (i.e., s verbs) were more difficult to accept when spelled correctly in a two-word sequence (e.g., *hij suste*) compared to verbs without such an alternative spelling (i.e., p verbs; e.g., *hij repte*). In addition, sublexical homophone intrusions for s verbs were more difficult to reject as an incorrect spelling (e.g., *hij *sustte*) compared to p verbs. In sum, responses on s verbs were delayed in both the correct and incorrect condition, due to the existence of verbs with the same phonological word-final sequence, but a competing orthographic pattern. However, in a PDT where participants had to ignore a verb form’s spelling and make a decision on their pronunciation instead, RTs to correctly spelled past tenses of s verbs (i.e., with the word-final pattern ste) did not differ from incorrect spellings with the homophonous stte-pattern. Conversely, we did observe a response delay for the incorrect spellings of p verbs, resulting from the fact that this incorrect ptte-pattern is non-existent. Both the SDT and the PDT corroborated our hypothesis that a homophone intrusion error at the sublexical level is more difficult to reject as a spelling error (SDT) and easier to accept as a misspelled homophone (PDT) when it involves a familiar letter pattern that is present in other words. This suggests that it is easy to miss such errors in the process of visual word recognition. The current experiment aims to extend these findings to normal sentence reading, i.e., when people make no conscious decisions about word forms. This would indicate that readers are likely to overlook sublexical homophone intrusions straddling morpheme boundaries (at least in word-final position of regular
verb forms), because they are familiar with these letter patterns in other words. Obviously, such findings impose restrictions on the nature of our mental architecture behind lexical storage and processing.

The present experiment seeks to find evidence for the involvement of phonological neighbors in sentence reading, defined as words with homophonous spelling sequences in the same word-final position. For instance, **suste** ‘hushed’ and **rustte** ‘rested’ are thus defined phonological neighbors because the word-final clusters **ste** and **stte** have the same pronunciation. Effects of phonological neighbors during sentence reading have been observed by Ernestus and Mak (2005). They performed a SPRT in which Dutch simple past forms were spelled with the correct or incorrect allomorph of the past tense suffix (i.e., **-te** instead of **-de** or vice versa). The incorrect spelling of the past tense form **krabde** is, for instance, ***krabte**. Due to the devoicing of **b**, the sequence **bte** is pronounced as [pt@]. This makes the **bte**-sequence in ***krabte** homophonous to the **pte**-sequence found in other past tenses such as **hapte** ‘bit’, **klopte** ‘knocked’, **schopte** ‘kicked’, **snapte** ‘understood’, **trape** ‘kicked’ (i.e., both sequences are pronounced as [pt@]). When the incorrect spelling was supported by many phonological neighbors with the same word-final sound sequence (as was the case with ***krabte**), the delay was smaller than when the incorrect spelling did not receive much support. In short, their experiment provides evidence for the idea that phonological neighbors can affect the processing of errors on regular Dutch verb forms in sentence reading.

While the errors studied in Ernestus and Mak’s (2005) SPRT involved an illegal combination of an existing stem (e.g., **krab**) and suffix (e.g., **-te**), sublexical intrusions in our studies involve the combination of a non-stem (e.g., **sust**) and a suffix (e.g., **-te**). Nevertheless, our hypothesis is nearly identical: participants should not be hindered (or only to a limited extent) by a sublexical homophone intrusion when the erroneous sublexical letter string is frequent in other past tenses, where it has the same pronunciation as the correct spelling sequence. While this is the case for **s** verbs (e.g., the **stre** in ***sustte** frequently occurring in past tenses like **tastte** ‘touched’, **rustte** ‘rested’,
etc.), sublexical intrusions in the past tense of p verbs contain the non-existent ptte-pattern. As this pattern receives no support from other word forms, sublexical intrusion errors in p verbs should lead to a delay in reading times compared to their correctly spelled past tense forms. In other words, we expect this eye tracking experiment to reveal an interaction between Sublexical Homophony and Spelling (i.e., the incorrect and non-existent ptte-pattern should cause a larger delay than the incorrect but existing stte-pattern, which may even cause no delay).

4.1.2.2. METHOD

Stimuli and Design
See Section 4.1.1.2.

Participants and Procedure
See Section 4.1.1.2.

4.1.2.3. RESULTS AND DISCUSSION

Results. As already discussed in the results section on stem-final d verbs, no participants were removed on the basis of their score on the comprehension questions (i.e., all scored above 75%). Again, we obtained fixation times for seven regions (i.e., x-1, x, x+1, x+2, x_x+1_x+2, x_x+1 and x+1_x+2). For these regions, we calculated three dependent measures: First Fixation Duration, First-Pass Fixation Time and Total Reading Time (see Section 4.1.1.2 for their definitions). For each of these dependent measures, we examined whether the interaction between Spelling and Sublexical Homophony was significant for the six analyzed regions (i.e., x, x+1, x+2, x_x+1_x+2, x_x+1 and x+1_x+2). Contrary to our hypothesis, none of the 18 analyses (6 regions x 3 dependent measures) yielded a significant interaction effect between Spelling and Sublexical Homophony (all ps > .05). Therefore, we will only present the analysis of Total Reading Times for the verb itself, which captures the general trends found in the data.
We log-transformed the Total Reading Times for the verb region \((N = 682; 38\) NAs), henceforth RTs, and fitted them with a linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The following control variables were tested for inclusion as fixed effects: (log-transformed) PreviousRT, Trial, Log Lemma Frequency (of \(x-1, x, x+1\) and \(x+2\)), Length (of \(x-1, x, x+1\) and \(x+2\)) and Log Whole-word Frequency (of \(x-1, x, x+1\) and \(x+2\)). The fixed predictors of interest were Spelling, Sublexical Homophony and, more importantly, their interaction. The maximal random structure supported by the data consisted of a by-participant random intercept and a by-item random intercept. Outliers (i.e., data points whose residuals exceeded 2.5 SD) were removed from the data set \((n = 7)\). A model with the same predictors was fitted to this subset of the data, the results of which are shown in Table 31. Partial effects of this model can be found in Figure 30.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>(\beta)</th>
<th>SE((\beta))</th>
<th>t</th>
<th>(\chi^2)</th>
<th>(p(&gt;\chi^2))</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>0.05</td>
<td>113.66</td>
<td>168.74</td>
<td>&lt; .001</td>
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<td>Sublexical Homophony</td>
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<td>0.07</td>
<td>2.50</td>
<td>5.53</td>
<td>.019</td>
</tr>
<tr>
<td>Spelling</td>
<td>0.13</td>
<td>0.04</td>
<td>2.96</td>
<td>8.66</td>
<td>.003</td>
</tr>
<tr>
<td>Sublexical Homophony x Spelling</td>
<td>-0.11</td>
<td>0.09</td>
<td>-1.21</td>
<td>1.47</td>
<td>.226</td>
</tr>
</tbody>
</table>

Table 31. Coefficients of a linear mixed effects model predicting log-transformed RTs from Sublexical Homophony, Spelling and their interaction together with the estimate \(\beta\), standard error, t-value, \(\chi^2\)-value and \(p\)-value.
Figure 30. Partial effects plot of effects represented in Table 31.

Discussion. The analysis of Total Reading Times for the verb itself showed significant main effects for Sublexical Homophony and Spelling\textsuperscript{80}, but not for their interaction. The main effect of Spelling indicates that an incorrect spelling causes longer total reading times than the correct spelling, both for s

\textsuperscript{80} These main effects were quite robust. Significantly shorter RTs for verbs without Sublexical Homophony (i.e., p verbs) were also found for First Fixation Duration (in regions x, x\_x+1 and x\_x+1\_x+2), First-Pass Fixation Time (in region x) and Total Reading Time (in region x\_x+1). In addition, significantly shorter RTs for correctly spelled verb forms (vs. incorrect spellings) were also found for First Fixation Duration (in regions x+1\_x+2 and x+2).
and $p$ verbs. This seems to indicate that the decomposition route had difficulties processing the illegal combination of stem and suffix and/or that the whole-word route did not find an exact match between the written word and a stored orthographic representation. The recovery from these problems (e.g., finding the closest match for the spelling error, being the correct form with a single $t$) took equally long for $s$ verbs as for $p$ verbs. The main effect of Sublexical Homophony shows that $s$ verbs received longer fixation times than $p$ verbs. The delay in RTs for incorrect spellings was the same for both verb types, given the absence of an interaction effect. The main effect of Sublexical Homophony indicates that some property of the $p$ verb forms made them easier to process than the $s$ verb forms, even when spelled correctly and despite being matched on the major factors affecting reading times (see Section 1.1.2.2 of Chapter 2). Of course, the main candidate for this property is the presence versus absence of a sublexical homophonous letter string. However, one would expect this difference to cause an interaction. As we found that both verb types were delayed equally much by an incorrect spelling, we must conclude that participants were unable to take advantage of frequently occurring homophonous letter strings (i.e., the $stte$-sequence in past tenses of $st$ verbs) to speed up the processing of sublexical homophone intrusions in sentence reading.

While we hypothesized that an ETT would replicate the interaction effect found in a PDT, i.e., a processing delay for incorrectly spelled past tenses of $p$ verbs only, the pattern of results mimics that of the SDT, i.e., an equal processing delay for the incorrect spelling of $s$ and $p$ verbs’ past tenses together with a main effect of Sublexical Homophony (i.e., slower responses to $s$ verbs). As in the SDT, participants seemed to be disturbed by the ambiguity of the $ste/stte$ clusters, although their cluster frequency is higher than that of $pte$ and $ptte$. Although it is not obvious to account for this outcome, there is a commonality between the FDT and the current ETT that hints at a possible interpretation. Recall that the sentences in the ETT not only contained verb spelling errors but also errors on other words (nouns, adjectives, ...). As many of these filler errors were made on relatively high-frequency words that
deviated considerably from their correct spelling (e.g., *sistematis for systematisch ‘systematic’, *antiebiotika for antibiotica ‘antibiotics’), these errors must have been highly salient in the experiment. This may have caused participants to develop a strong focus on spelling, despite the instruction to ignore spelling errors (or perhaps encouraged by this instruction, as the request to ignore something may have the paradoxical effect of directing one’s attention to it; e.g., Wegner, 1989). Obviously, participants in the SDT also focused heavily on spelling, as they had to decide on the spelling correctness of two-word sequences. A strong focus on spelling may have caused participants in both tasks to check the spelling of all words, including the past tense forms. If all information sources on word forms are simultaneously used during lexical processing (i.e., whole-word retrieval, morphological decomposition and support from phonological neighbors), an assessment of the spelling correctness of past tenses should be easier for * verbs than for * verbs. For both verb types, the output of the morphological decomposition process makes it clear whether the string is a possible combination of a stem and a suffix or not. However, the difference is due to the existence of phonological neighbors that exhibit a sublexical homophonic cluster. For * verbs, the presence of the sublexical letter string *pte (correct) or *ptte (incorrect) cannot give rise to hesitation, as only the pte-pattern exists. In contrast, the sublexical letter strings ste (correct) and stte (incorrect) will both cause a temporary hesitation whether the presented form is spelled correctly or not, as both letter sequences are homophonic and frequently occur in past tense forms. In other words, whereas there is a clear convergence for * verbs between the output of morphological decomposition and the support or lack of support from phonological neighbors with that cluster (i.e., the spelling is clearly correct or incorrect), the presence of sublexical homophones in the case of * verbs temporarily delays the assessment whether a past tense is spelled correctly or not. When such a spelling assessment is important in an experiment (either because it is the explicit task, as in a SDT, or because it is triggered by many salient spelling errors, as in the current ETT) participants (a) will notice spelling errors and be delayed by them and (b) will be hindered by the
existence of two sublexical spelling patterns for a single pronunciation, when being confronted with either the correct or the incorrect spelling\textsuperscript{81}. This interpretation makes it plausible why the effects of Sublexical Homophony and Spelling were additive rather than interactive in the current experiment (and in the SDT).

As for stem-final d verbs, a closer inspection of the skipping rates revealed that 5% (38/720) of the critical verbs were skipped, 64% (463/720) of the words in position x+1 and 15% (106/720) in position x+2. Because of this high skipping rate, especially for x+1, we will also perform a self-paced reading task to examine whether the hypothesized interaction effect becomes apparent when each individual word requires a response (see Section 4.1.2.3).

4.1.2. **Self-paced reading task**

4.1.2.1. Stem-final d verbs

4.1.2.1.1. Hypothesis

The results of the eyetracking experiment suggest that homophonous forms of stem-final d verbs are processed as whole-word forms during normal reading. However, the effect was only marginally significant. This is possible due to two factors: (a) there was a high skipping rate, especially in the spillover region and (b) the study was limited to dt-intrusions, i.e., the grammatical subject was always the first person singular (requiring the d-form). Although the ETT more closely resembled a natural reading situation, the self-paced reading task (SPRT) has the advantage that it elicits RTs for each word in the sentence, so that words cannot be skipped. The present experiment also tackles the second

\textsuperscript{81} Note that the similarity between the two tasks suggested here does not contradict our earlier claim that HF verb forms cause a response conflict in a SDT, leading to longer RTs, but their quick activation leads to faster reading times in the context of an ETT. A response conflict is due to a single (HF) representation suggesting the wrong response and will (obviously) be restricted to the SDT, as ETT does not require an explicit response so that there can be no response conflict. In contrast, the parallel activation of two orthographic representations will cause a delay in all tasks that focus heavily on spelling.
issue by presenting readers with sentences containing both d- and dt-intrusions.

Consequently, our hypothesis is identical to that of the ETT: if whole-word representations of stem-final d verb forms are accessed, homophone intrusions should be processed more quickly when they correspond to the HF homophone. Hence, as Homophone Ratio increases (i.e., as the d-form becomes the more frequent homophone), shorter reading times should be found for d-intrusions, while RTs should increase for dt-intrusions. If so, this would provide evidence for the idea that whole-word representations of homophonous Dutch verb forms not only affect visual word recognition (i.e., verb forms presented in isolation in a LDT or in a minimal context in a SDT and PDT), but also natural reading behavior. The theoretical implication would be that whole-word access to the orthographic representation of an incorrect but HF homophonous verb form is faster than the process of morphological decomposition and the subsequent spelling check on the basis of the subject’s grammatical properties. As a result, intrusions of HF homophones would have the highest risk of being overlooked in the reading process. However, if these forms are only accessed on the basis of their constituent morphemes, reaction times should not depend on the frequency relation between the two homophones.

4.1.2.1.2. Method

Stimuli and Design

Stimuli. The experiment consisted of 60 sentences, 24 of which contained critical stem-final d verbs. These verbs were identical to those of the ETT (basic set with opvoeden; see Table 1 of the Appendix for their characteristics), but the sentences in which they appeared differed (due to length restrictions, see below). For these stem-final d verbs, we created a single sentence context in which both the 1st (ik; ‘I’) and 3rd person personal pronoun (hij; ‘he’) could be incorporated, for example:
Since our goal is to target homophone intrusions, the verb form was always spelled incorrectly. This implies that the 1st person personal pronoun ik was always followed by the dt-form, whereas the 3rd person personal pronoun hij was always followed by the d-form. Since the sentence context was identical for both conditions, x-1, x+1 and x+2 were obviously matched for Length, Log Whole-word Frequency and Log Lemma Frequency. In addition, words in positions x-1 until x+2 were matched between d-dominant and dt-dominant verbs on each of these three characteristics (all ps > .05). This was done to equate the two verb types on the difficulty of the surrounding words, which might affect processing of the verb form (recall that there is a spillover region where the processing effects of the verb form can still be observed). All sentences, including the filler sentences, were exactly 11 words long so that each sentence fitted on a single line. Furthermore, the critical verb form always appeared in seventh position to exclude the possibility that effects were due to positional differences. In addition, the critical verb form always appeared at the end of a subordinate clause, followed by the main clause. Four words separated the subject from the verb form.

In addition to these 24 critical sentences, we also created 36 filler sentences to draw attention away from the purpose of the experiment. These can be subdivided into two groups. A first group, consisting of 24 sentences, contained the correct or incorrect spelling of a non-verb homophone (e.g., hard/hart; ‘hard/heart’). For each homophone pair, we also created a single sentence context in which either the contextually appropriate or inappropriate homophone was inserted:

\[ \text{Elke dag werk ik hard/*/hart om mijn gezin te kunnen onderhouden.} \]
\[ \text{‘Every day work I hard/*/heart for my family to be able to support.’} \]
An additional twelve sentences functioned as fillers and contained at least one spelling error that was unrelated to homophony or to the spelling of a verb suffix:

Sinds mijn opa gepensionneerd is eet hij elke dag *smeuige pannenkoeken.
‘Since my grandfather retired, makes he every day delicious pancakes.’

Twenty-four sentences were immediately followed by a comprehension question to make sure that participants had thoroughly read and understood them.

Design. Each experimental version contained 60 sentences. Two counterbalanced lists were created: when a critical sentence was presented with the incorrect d-form (+ hij ‘he’) in List A, it was presented with the incorrect dt-form (+ ik ‘I’) in List B and vice versa. As a result, participants were confronted with 12 d-intrusions and 12 dt-intrusions. Half of the non-verb homophones in the first set of 24 filler sentences were spelled correctly in list A and incorrectly in list B, while the other half were spelled incorrectly in list A and correctly in list B. The other 12 filler sentences were identical across both versions. These 60 sentences were evenly distributed across four blocks. Each block also contained six comprehension questions, which were identical for all versions. We created two randomization sequences (R1/R2) with the following restrictions: (a) a critical sentence never initiated/terminated a block, (b) critical sentences were separated by at least one filler item and (c) a maximum of three sentences could follow each other without a question being asked. The appearance of these questions was unpredictable to ensure that participants focused on the sentences’ content at all times. This yielded a total of four experimental lists (AR1, AR2, BR1, BR2). Each experimental list was preceded by the same two practice sentences, one of which was followed by a question.
Participants and Procedure

Participants. Twenty-six subjects took part in the experiment (mean age = 21.04; SD = 2.05). These were students at Antwerp University and were native speakers of Dutch without any reading disorder. They had normal or corrected-to-normal vision and had not previously taken part in an experiment on homophone intrusions.

Procedure. Participants were tested individually in a soundproof booth, after having read and understood a set of written instructions. In these instructions, participants were told that they were going to read a set of sentences at their normal reading pace. They were informed that these sentences contained spelling errors made by participants in an earlier task, but were asked to ignore them. They were also instructed that some sentences would be followed by a question about their content, necessitating them to read each sentence carefully in order to give a correct response. Participants were urged to make as few errors as possible on these questions and were instructed to use the left and right shift-button to make their response (see below). These instructions were checked orally. If no questions remained, two practice trials were initiated to allow participants to familiarize themselves with the procedure. If no problems arose at this point, the actual experiment (i.e., four blocks of 15 sentences each) began, taking about 15 minutes to complete.

The experiment was run on an OptiPlex 380 computer connected to a Dell-monitor (60-50Hz) and a Dell-keyboard. The stimuli were displayed in the Consolas font (i.e., a fixed-width font) with a size of 9 points via the DMDX software program (Forster & Forster, 2003). The stimuli were printed in white on a black background. Participants read the sentences in a word-by-word manner (i.e., non-cumulative moving-window; Just et al., 1982).

The first screen of each trial consisted of the announcement ‘Ready for the sentence?’ After approximately 2 seconds, it was replaced by a screen consisting of a series of xs that substituted the letters in all words and thus represented the visual layout of the sentence. As already mentioned, we made sure that all sentences fitted on a single line. When participants pushed the
right shift-button, the first set of xs was substituted by the first word of the sentence while the other words were still replaced by the xs. After the next button press, the first word reverted to xs again while the second word became visible and so forth. Since we used a fixed-width font, spacing of the characters did not change across screens. Pressing the right shift-button enabled participants to freely move through the sentence at their own reading pace, without allowing for regressions. If participants did not make a response after 4,000ms, the program automatically moved to the next screen. After the last word of a sentence, the announcement “End of the sentence” appeared. A sentence could either be followed by the next trial (i.e., “Ready for the sentence?” + another sentence) or a comprehension question (i.e., “Ready for the question?” + question). This question appeared on the screen for three seconds and was followed by a screen that presented two answers, one on the left and one on the right side of the screen. A response had to be made within a time limit of 4,000ms by pressing either the left or right shift-button. If no response was given, the answers disappeared and the program moved to the next trial. An example of a trial is illustrated below (Figure 31). Between each block, the sentence “Attention: the next block will start” appeared on the screen, allowing participants to take a short break. When they felt ready, they could initiate the next block by pressing the space bar. We measured the reaction times (i.e., the time elapsing between two button presses). In addition, we also registered participants’ responses to the questions.
§ 3 The Homophone Dominance effect in perception

4.1.2.1.3. Results and Discussion

Results. We did not remove any participants from the data set since they all scored 75% or more on the comprehension questions (average: 96%). Since the SPRT is sensitive to spillover effects (Witzel et al., 2012), we analyzed the reaction times not only on the critical verb form, but also on the two words following it (henceforth x+1 and x+2). However, in what follows, we will only report the analysis of x+2, since it was the only analysis in which the interaction between Form and Homophone Ratio was significant.

We removed all items on which no response was given (i.e., time-out on the second word following a critical verb form; \( n = 14 \)) and applied a logarithmic transformation to the remaining 610 RTs to reduce the positive skew. We fitted the log-transformed RTs with a linear mixed effect model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). Likelihood ratio tests determined which of the following control variables were entered into the model as fixed predictors: (log-transformed) PreviousRT, Trial, Log Lemma Frequency (of x-1, x, x+1 and x+2), Length (of x-1, x, x+1 and x+2) and Log Whole-word Frequency (of x-1, x+1 and x+2). The variables of interest were: Homophone Ratio, Form (i.e., d- vs. dt-form) and their interaction. The

Figure 31. Example of a trial in the SPRT. Each line represents one screen.
maximal random structure supported by the data consisted of a by-participant random intercept, a by-participant random slope for Homophone Ratio and a by-item random intercept. Data points whose absolute standardized residuals exceeded 2.5 SD were removed from the data set, after which we fitted a model with the same predictors to the remaining data points. The results of this LMM are presented in Table 32, while its partial effects are visualized in Figure 32.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
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</thead>
<tbody>
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<td>180.77</td>
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<td>0.04</td>
<td>2.65</td>
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<td>.008</td>
</tr>
</tbody>
</table>

Table 32. Coefficients of a linear mixed effects model predicting log-transformed RTs from PreviousRT, Trial, Form, Homophone Ratio and the interaction between Form and Homophone Ratio together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.
Discussion. The significant control variables were previousRT and Trial: reaction times increased as previous RTs became longer, but decreased as the experiment progressed\textsuperscript{82}. While the main effects of Form and Homophone Ratio were not significant, their interaction was. The partial effect plot for their interaction shows that as Homophone Ratio increased (i.e., the d-form becoming the more frequent homophone), RTs on x+2 decreased for d-intrusions but increased for dt-intrusions.

\textsuperscript{82} The control variable Log Lemma Frequency was significant in the x+1-analysis.
The results confirm our hypothesis: whole-word representations for regularly inflected stem-final d verbs are not only accessed when verb forms are presented in isolation or in a minimal context, but also during sentence reading. This caused intrusion errors to be processed more quickly when they corresponded to the HF homophone of a verb pair. The results from this SPRT also corroborate the marginally significant effect of Homophone Dominance for dt-intrusions \((p = .059)\) in the ETT (Section 4.1.1.1) and extend it to intrusion errors of the d-form. Furthermore, the results also fit in well with those obtained by Bertram, Laine, et al. (2000) who found that whole-word frequency effects modulated RTs to inflected Finnish nouns in a SPRT, but only in the spillover region (i.e., \(x+1\)). The theoretical significance of these results is that readers are faster to move on when encountering a homophone intrusion that corresponds to the HF spelling. This means that the risk of missing such an error increases as the frequency of the error form increases.

The fact that the Homophone Dominance effect surfaced only on the second word following the target is not too surprising, as the marginally significant effect of Homophone Dominance was also distributed across the three-word spillover region in the ETT. The difference between the two tasks results from the fact that participants had to make a response to each individual word in the SPR task, while they could freely fixate in the ETT. The commonality between the two tasks concerns the fact that the two experimental procedures allowed no control over the moment at which the verb form was integrated in the preceding part of the sentence. Because both tasks yielded delayed or distributed effects, we will examine whether the effect is observed on the verb form itself in a third type of reading task, one which requires full integration before moving on to the next word, namely a maze task (see Section 4.1.3.1).
4.1.2.2. Weak prefix verbs

4.1.2.2.1. Hypothesis

In contrast to the results for stem-final d verbs, we did not find an effect of Homophone Dominance for weak prefix verbs in the visual word recognition tasks. In these tasks, verb forms were either presented in isolation or embedded in a minimal context (i.e., marker and verb were adjacent). Hence, the morphosyntactic analysis that is required to detect homophone intrusions was either not required (LDT) or relatively easy to perform (i.e., the marker appeared immediately before the verb form in a PDT). These conditions might make it difficult to detect an effect of Homophone Dominance. However, this account is not satisfactory, as this effect did appear in the same tasks for stem-final d verbs (the two verb types being matched on the Homophone Ratio measure). Possibly, however, the strong association between weak prefixes and the d-spelling of the homophonous verb form may have been strong enough to wipe out an effect of Homophone Dominance when using either no syntactic context or a minimal syntactic context. The current experiment examines whether the Homophone Dominance effect emerges for weak prefix verbs when embedded in a sentence context that separates marker and verb form. Previous research on homophone intrusions in spelling has shown that the probability of making an intrusion error increased as marker and verb form were separated by intervening words. This is probably the case because the time needed to access the whole-word representation of the HF homophone is shorter than the time it takes to identify the grammatical marker and select the appropriate suffix spelling, making the HF homophones the most likely intruders (Sandra et al., 1999, 2004). Applying this rationale to the process of reading, we hypothesize that the process that checks the suffix spelling against the marker’s grammatical properties (following the process of morphological decomposition) is also less likely to be successfully terminated when words intervene between marker and verb form. Under these conditions,
the fast process of whole-word retrieval for HF homophones can be completed before this time-consuming checking mechanism is terminated.

This SPRT investigates whether reading homophone intrusion errors on weak prefix verb forms embedded in a sentence context indeed causes access to their whole-word representations (at least for the HF homophone). If so, we expect similar results as for stem-final d verbs, i.e., shorter RTs when the homophone intrusions involve the HF homophone compared to the LF homophone. More specifically, as the Homophone Ratio increases (i.e., the d-form becoming the more frequent homophone), longer RTs are expected for t-intrusions and shorter RTs for d-intrusions.

4.1.2.2.2. Method

Stimuli and Design

Stimuli. Each experimental list consisted of 60 sentences. Twenty-four of these sentences contained weak prefix verb forms (see Appendix Table 3 for their characteristics). Since the homophonous verb forms are either present tenses or past participle forms, it is impossible to create a single sentence context in which both forms can be embedded. Therefore, we created two sentence contexts, one present tense (PT) context and one past participle (PP) context. Because our goal was to examine whether a HF intrusion is processed more quickly than a LF one, all verb forms in the PT and PP contexts were spelled incorrectly. This means that the d-form always appeared in the PT context and the t-form in the PP context. The PT context consisted of a subordinate clause followed by a main clause, for example:

Omdat hij zijn computer tegen virussen *beveiligd loopt hij weinig risico.

'Because he his computer against viruses *protected runs he little risk.

Even though this sentence context targets the PT interpretation (the d spelling being a homophone intrusion), it is highly plausible that participants will initially attempt to treat the d-spelling as a correctly spelled past participle
form. Importantly, the PP interpretation is still possible at this point in the sentence because the auxiliary verb can follow the PP in Dutch (e.g., *Omdat hij zijn computer tegen virussen beveiligd heeft* ...; ‘Because he his computer against viruses protected has’). Hence, the danger is that participants process the verb homophone as a correctly spelled PP (expecting an auxiliary verb downstream the sentence), rather than as an incorrectly spelled PT. This would create a garden path and, hence, seriously interfere with our measurements. In an attempt to eliminate this interpretation and force participants to immediately process the verb form as a misspelled PT, we inserted a comma after the subordinate clause (the verb homophone being the final word of that clause), indicating that no auxiliary verb would follow. In contrast, the past participle (PP) context consists solely of a main clause. The ambiguity between the PT and PP interpretation is non-existent here since the auxiliary verb preceding the weak prefix verb form indicates that the homophone can only be a past participle, as in:

Hij heeft zijn computer tegen virussen *beveiligd* om risico’s te vermijden.
‘He has his computer against viruses *protects* to risks to avoid.’

All other sentence manipulations were identical to that of the SPRT with stem final d verbs: the sentence length was identical for all sentences, namely 11 words. Moreover, we also kept the distance between the marker (subject or auxiliary verb) constant at four intervening words, in analogy to the condition producing most homophone intrusions in spelling research (Sandra et al., 1999, 2004). Again, the verb form always appeared in seventh position to make sure that RTs did not differ because of differences in sentence position. Because both sentence structures are syntactically very different, it was only possible to match x-1 for the two contexts but not x+1 and x+2.

---

83 Although it was impossible to match x+1 and x+2 in the PT and PP contexts on length and frequency measures, we will take these differences into account by taking these factors up as control variables in the statistical analysis.
To avert attention from the homophone intrusions, we created 36 filler sentences that contained at least two difficult-to-spell words, one of which was indeed spelled incorrectly (cf. SPRT with stem-final d verbs). Furthermore, we devised comprehension questions for 24 of the sentences (both critical and filler) to verify whether participants had paid sufficient attention to their content.

Design. In each experimental list, half \((n = 12)\) of the critical verb forms were presented in the PP context (i.e., in the t-form) and half in the PT context (i.e., in the d-form). These lists were counterbalanced so that when a verb form was presented in the PP context in list A, it was presented in the PT context in list B and vice versa. Filler sentences were the same for both versions. We divided the 60 sentences into four blocks of 15 sentences, with an equal number of items from each item type in each block. Furthermore, six comprehension questions were asked in each block to make sure that participants focused on the sentences’ content (i.e., to prevent thoughtless button pressing). These questions were identical for both versions. We made it impossible for participants to predict when a question would follow a sentence, so that their attention was required at all times. Two randomization sequences (R1/R2) were made with the same restrictions as in Section 4.1.2.1.2, yielding a total of four experimental versions (AR1, AR2, BR1, BR2). Two practice sentences (one followed by a question) preceded each experimental version.

Participants and Procedure

Participants. Twenty-seven students at Antwerp University participated in the experiment (mean age = 20.2; SD = 2.22). They were native speakers of Dutch with normal or corrected-to-normal vision and without any reading disorder. They had not previously taken part in a homophone intrusion experiment.

Procedure. Identical to the procedure described in Section 4.1.2.1.2.
4.1.2.2.3. RESULTS AND DISCUSSION

Results. One participant was removed from the data set because he did not push any buttons for 8 of the 24 critical sentences. None of the participants were removed based on their score for the comprehension questions (i.e., all scored above 75%; average: 91%). We analyzed reaction times for the critical words as well as for the two following words to account for possible spillover effects. Since the interaction between Form and Homophone Ratio was not significant in any of the three analyses, we only report the analysis of x+2, in analogy with the analysis of x+2 reported above for stem-final d verbs (Section 4.1.2.1.2).

All items without responses (n = 3) were removed from the data set after which we log-transformed the remaining 621 RTs to approach the normal distribution. A linear mixed effects model was fitted to the log-transformed RTs of x+2 (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The following control variables were tested for inclusion as fixed effects: (log-transformed) PreviousRT, Trial, Log Lemma Frequency (of x-1, x, x+1, and x+2), Length (of x-1, x, x+1, and x+2) and Log Whole-word Frequency (of x-1, x+1, and x+2). The variables under investigation were: Homophone Ratio, Form and their interaction. The maximal random structure supported by the data was made up of a by-participant random intercept, a by-participant random slope for Form and a by-lemma random intercept. After removing outliers (absolute standardized residuals > 2.5 SD; n = 16), we fitted a model with the same predictors to the remaining data points. Table 33 presents the results of the final LMM, while the partial effects of its fixed predictors are plotted in Figure 33.
§ 3 The Homophone Dominance effect in perception

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>5.96</td>
<td>0.04</td>
<td>139.99</td>
<td>172.65</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.31</td>
<td>0.03</td>
<td>9.69</td>
<td>152.81</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial</td>
<td>-0.005</td>
<td>0.0006</td>
<td>-7.81</td>
<td>56.45</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Log Whole-word Frequency x+2</td>
<td>-0.04</td>
<td>0.01</td>
<td>-3.38</td>
<td>10.92</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Form</td>
<td>0.05</td>
<td>0.02</td>
<td>2.58</td>
<td>6.34</td>
<td>.012</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>-0.01</td>
<td>0.02</td>
<td>-0.53</td>
<td>0.28</td>
<td>.598</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>-0.006</td>
<td>0.03</td>
<td>-0.18</td>
<td>0.03</td>
<td>.854</td>
</tr>
</tbody>
</table>

Table 33. Coefficients of a linear mixed effects model predicting log-transformed RTs from PreviousRT, Trial, Log Whole-word Frequency x+2, Form, Homophone Ratio and the interaction between Form and Homophone Ratio together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.

Figure 33. Partial effects plot of effects represented in Table 33.
Discussion. At position x+2, the control variables PreviousRT (i.e., of x+1), Trial and Log Whole-word Frequency of x+2 were significant: RTs decreased as the experiment progressed and as the whole-word frequency of the word at x+2 increased, while they increased as previous RTs became longer. The main effect of Form was significant: shorter RTs were observed for d-forms. Neither the main effect of Homophone Ratio, nor its interaction with Form was significant. Note that we also failed to find a significant effect of Log Lemma Frequency for x, x+1 or x+2. Extra analyses on two- or three-word regions (i.e., as in the ETT) also failed to reveal a significant effect for the interaction effect or the effect of Log Lemma Frequency.

As in previous experiments with weak prefix verb forms, we could not find a significant interaction between Homophone Ratio and Form. We hypothesized that in experiments where the homophone was presented in isolation or in a minimal context the strong connection between the presence of a weak prefix and a d-spelling of the suffix might have been stronger than the Homophone Dominance effect. Hence, the current experiment tested the possibility that the interaction might emerge when the homophone was presented in a sentence where a number of words intervened between the grammatical marker and the verb form. However, once again we failed to find the sought-for interaction.

There are two possible reasons for this pattern of results. Firstly, the sentence context might have eliminated both whole-word and lemma frequency effects. However, this is highly unlikely since we found an effect of Homophone Dominance (and lemma frequency on x+1) for stem-final d verbs, validating the self-paced reading task. Moreover, SPRTs have consistently yielded frequency effects for inflected words embedded in a sentence context (Bertram, Hyönä, et al., 2000; Luke & Christianson, 2011). Secondly, it is possible that the effect of Homophone Dominance was difficult to pick up in the spillover region because the PT and PP sentence contexts differed considerably, not only because x+1 and x+2 were not the same words in both
contexts, but also because they differed in terms of syntactic integration processes. Therefore, we will also examine whether the Homophone Dominance effect can be observed in a task that captures syntactic integration processes on each individual word. The maze task offers this opportunity as it has been shown to reveal more localized effects, i.e., effects on the critical homophone form itself (Witzel et al., 2012).

4.1.2.3. Past tense verb forms

4.1.2.3.1. Hypothesis

Our hypothesis is identical to the one described for the ETT (see Section 4.1.1.2.1).

4.1.2.3.2. Method

Stimuli and Design

Stimuli. The current experiment consisted of 60 sentences, 24 of which contained a critical past tense verb form. We used the same set of 12 s verbs (with sublexical homophony) and 12 p verbs (without homophony) as in the ETT (see Table 2 in Appendix for their characteristics). Since the purpose of the experiment was to investigate whether homophone intrusions involving an existing sublexical homophonous pattern (stte) are processed more quickly than those involving a non-existent pattern (ptte), we created a sentence context in which verbs’ correct and incorrect spelling could be embedded. The structure of the critical sentences was always the same: a subordinate clause followed by a main clause. All sentences had a fixed length of 11 words (cfr. the SPRT with stem-final d and weak prefix verbs). Critical past tense forms appeared in fifth position. Again, we made pairs of sentences with s and p

Filtering out these mismatches across the two contexts by taking up relevant control variables for x+1 and x+2 is obviously a good attempt to solve the matching problem but offers no guarantee and could have masked an effect of Homophone Dominance at x+2.
verbs in which the words on positions x-1, x+1 and x+2 were perfectly matched (i.e., identical words). An example of such a pair is the following:

<table>
<thead>
<tr>
<th>x-1</th>
<th>x</th>
<th>x+1</th>
<th>x+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omdat</td>
<td>haar</td>
<td>totaal</td>
<td>niet</td>
</tr>
<tr>
<td></td>
<td></td>
<td>past(t)e</td>
<td>wou</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>zij</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>snel</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>de</td>
</tr>
<tr>
<td></td>
<td></td>
<td>winkel</td>
<td>verlaten</td>
</tr>
</tbody>
</table>

‘Because her totally *nothing* fitted *wanted she* quickly the shop leave.’

<table>
<thead>
<tr>
<th>x-1</th>
<th>x</th>
<th>x+1</th>
<th>x+2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Omdat</td>
<td>de</td>
<td>leerlinge</td>
<td>niets</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>snapt(t)e</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>wou</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>zij</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>meteen</td>
</tr>
</tbody>
</table>

‘Because the student *nothing* *understood* *wanted she* immediately stop with to study.’

To prevent participants from becoming aware of the goal of the experiment, we also introduced 36 fillers sentences. These sentences contained at least two words involving notorious spelling issues (never a verb spelling problem), one of which was spelled incorrectly, for instance:

Tenzij we een *hyiena* zien, is onze *safari* niet helemaal geslaagd.
‘Unless we a *hyena* see, is our *safari* trip not entirely successful.’

We created a comprehension question for 24 of these sentences, which urged participants to thoroughly read all of them. By doing so, we also diverted attention further away from the purpose of the experiment.

**Design.** Each experimental list contained 24 critical sentences, which were counterbalanced for spelling correctness. This meant that half \((n = 12)\) of the \(s\) and \(p\) verbs were spelled incorrectly in version A and correctly in version B and the other way around for the other half. Thus, each participant saw six correct \(s\) verb forms, six correct \(p\) verb forms, six incorrect \(s\) verb forms and six incorrect \(p\) verb forms. Filler sentences were identical for both versions. These 60 sentences were evenly distributed across four blocks of 15 sentences, with
six comprehension questions per block. To take fatigue/familiarization effects into account, we created two randomization sequences (R1/R2) based on the same restrictions as in Section 4.1.2.1.2. The resulting four experimental versions (AR1, AR2, BR1, BR2) were preceded by two practice sentences and one comprehension question.

Participants and Procedure

Participants. Twenty-five native speakers of Dutch participated in the experiment. They were aged 20 to 25 and were students at Antwerp University or College. They had normal or corrected-to-normal vision and did not have any reading disorder, nor had they previously taken part in an experiment on homophone intrusions.

Procedure. Identical to Section 4.1.2.1.2.

4.1.2.3.3. Results and Discussion

Results. The RTs of one participant were removed from the data set because he had made more than 25% errors on the comprehension questions, making his RTs unreliable. The other participants scored on average 90% on these questions. Reaction times for positions $x$, $x+1$ and $x+2$ were analyzed to take into account that the effect might manifest itself in the spillover region. We only report the analysis in which the interaction between Spelling and Sublexical Homophony was significant, which was the case for RTs on the verb form itself.

All 576 responses to the critical verb forms (24 items x 24 participants) were log-transformed to approximate the normal distribution. We fitted a linear mixed effects model to these log-transformed RTs (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The following control variables were tested for inclusion as fixed effects: (log-transformed) PreviousRT, Trial, Log Lemma Frequency (of $x-1$ and $x$), Length (of $x-1$ and $x$) and Log Whole-word Frequency (of $x-1$ and $x$). The fixed predictors under investigation were:
Spelling, Sublexical Homophony and, most importantly, their interaction. The maximal random structure supported by the data consisted of a by-participant random intercept. Data points whose absolute standardized residuals exceeded 2.5 SD were considered as outliers and excluded from the analysis ($n = 13$). We fitted a model with an identical structure to the remaining data points, the results of which are shown in Table 34. Partial effects of the predictors included in this model are visualized in Figure 34.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>SE($\beta$)</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(\rangle \chi^2)$</th>
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<tbody>
<tr>
<td>Intercept</td>
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<td>136.23</td>
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<td>PreviousRT</td>
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<td>14.48</td>
<td>170.85</td>
<td>&lt; .001</td>
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<tr>
<td>Trial</td>
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<td>0.0006</td>
<td>-7.99</td>
<td>58.74</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Spelling</td>
<td>0.07</td>
<td>0.02</td>
<td>3.76</td>
<td>13.93</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Sublexical Homophony</td>
<td>-0.007</td>
<td>0.02</td>
<td>-0.35</td>
<td>0.12</td>
<td>.727</td>
</tr>
<tr>
<td>Spelling x Sublexical Homophony</td>
<td>-0.12</td>
<td>0.04</td>
<td>-3.08</td>
<td>9.40</td>
<td>.002</td>
</tr>
</tbody>
</table>

Table 34. Coefficients of a linear mixed effects model predicting log-transformed RTs from PreviousRT, Trial, Spelling, Sublexical Homophony and the interaction between Spelling and Sublexical Homophony together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.
Figure 34. Partial effects plot of effects represented in Table 34.

Discussion. Two control variables, namely PreviousRT and Trial were significant, with longer RTs as previous RTs increased, but shorter RTs as the experiment progressed. The main effect of Sublexical Homophony was not significant, while that of Spelling was: longer RTs were observed for incorrect spellings. However, this effect was modulated by an interaction with Sublexical Homophony: an incorrect spelling only caused a delay for verb forms without sublexical homophony (i.e., \( p \) verbs), but not for \( s \) verbs, whose misspelled past tense forms experience support from a sublexical homophonous cluster.
The results confirm our hypothesis: during sentence reading, RTs also exhibit an effect of Homophone Dominance at the sublexical level. If morphological decomposition and/or whole-word retrieval were the only driving forces behind the processing of these misspelled past tenses during sentence reading, one would expect an incorrect spelling to lead to an equal processing delay for both verb types. In contrast, sublexical homophone intrusions did not cause a processing delay for \(s\) verbs (e.g., \(*\text{stte}\)). The explanation for this finding must be sought in the only difference between the two verb types: the presence or absence of the incorrect spelling cluster in other past tenses (in the same position and with the same pronunciation). This is the case for \(\text{stte}\) but not for \(*\text{ptte}\). Hence, it appears that processing the incorrect spelling of the final sublexical cluster in \(s\) verbs benefited from the support of past tenses containing the same (homophonous) orthographic pattern (e.g., \(\text{rustte}\)). However, when the incorrect spelling pattern was non-existent (i.e., \(*\text{reptte}\) as for \(p\) verbs, no such processing benefit could occur and RTs were slowed down compared to the correct spelling (e.g., \(\text{repte}\)). Therefore, we conclude that the processing of regularly inflected verb forms in a sentence context is affected by homophonous orthographic patterns found in word-final position with phonological neighbors. Crucially, these orthographic patterns straddle the morpheme (i.e., stem-suffix) boundary.

These results replicate our findings obtained in a task where the past tense forms for \(s\) and \(p\) verbs were presented in a minimal context, namely a PDT. Here, participants were not slowed down by sublexical intrusions when the error involved a frequently occurring homophonous letter string that is present in other past tenses (i.e., \(\text{stte}\) in \(s\) verbs). However, they were slowed down when the error pattern involved a non-existent letter string (i.e., \(*\text{ptte}\) in \(p\) verbs). Our results also corroborate the findings of Ernestus and Mak (2005) in a SPRT: phonologically similar words influenced the processing of Dutch past tenses in sentence reading. These forms were either spelled with the correct or with the incorrect allomorph of the past tense suffix. When the (underlying) stem-final obstruent is voiceless, the correct suffix is \(-\text{te}\), but \(-\text{de}\)
when that obstruent is voiced (e.g., *krabde*, pronounced as [krAbd@])\(^85\). While an incorrect spelling delayed processing, the delay was smaller when the incorrect allomorph received support from phonological neighbors, defined as word forms whose final letter string (stem-final obstruent + allomorph) has the same pronunciation as the final letter string in the incorrect past tense form. The incorrect spelling *krabte* (pronounced as [krApt@]), for instance, received support from other past tense forms that share the pronunciation [pt@] (e.g., *repte* ‘rushed’, *schopte* ‘kicked’, *stapte* ‘stepped’, ...).

The finding that an incorrect spelling only delayed responses on past tenses for *p* verbs is not in line with our findings in two other tasks. In the SDT and ETT, we did not observe an interaction between Spelling and Sublexical Homophony (i.e., an incorrect spelling yielded a similar delay for verbs with and without sublexical homophony). Note, however, that the difference between the two verb types – the presence or absence of a sublexical homophonous letter string in other word forms – was also a crucial factor in these two tasks (i.e., a main effect of Sublexical Homophony). In our discussion of the ETT results for past tenses, we suggested that whenever the task or the experimental materials cause participants to strongly focus on the spelling of words, processing difficulties will occur for verb forms with a sublexical homophonous letter pattern in word-final position, i.e., past tenses of *s* verbs (for both their correct and incorrect spellings). The presence of such a sublexical homophonous string will activate a phonological sequence ([st@]) that in turn activates word forms with the corresponding spelling patterns, namely *ste* and *stte*. This ambiguity temporarily delays the processing of both correct and incorrect spellings for *s* verbs. Such a processing delay will not occur for verb forms without a sublexical homophonous letter string (i.e., past tenses of *p* verbs) as both the correct and incorrect spelling patterns (*pte* and

\(^85\) Besides this similarity, there is also a difference between our experiment and that of Ernestus and Mak (2005). In their experiment, the incorrect past tenses were presented with the wrong allomorph (i.e., an incorrect morphological rule was applied), which automatically resulted in a spelling error. In our experiment, an incorrect past tense was presented with the correct allomorph but the letter string extending from the stem-final letter to the end of the word form was misspelled.
*ptte) map onto a phonological sequence that can only activate forms with a single spelling pattern (pte). In addition to this phonologically mediated processing delay, the presence of a spelling error will lead to a separate and identical processing delay for both verb types (s and p verbs), as a morphological decomposition mechanism or whole-word retrieval route will detect that the orthographic sequence is not the concatenation of a verb stem and the past tense suffix, nor an existing full-form (leading to a main effect of Spelling). Hence, when there is a strong focus on spelling errors, main effects of Sublexical Homophony and Spelling are expected, but no interaction between the two.

The fact that such an interaction was obtained in the present SPRT suggests that participants were not as much focussed on spelling errors as in the SDT and ETT experiments. We tentatively suggest that this is due to the fact that the errors were more salient in the ETT experiment (they obviously were in a spelling decision task). Firstly, two types of verb spelling errors occurred in the ETT experiment (errors on stem-final d verb forms and on past tense forms), whereas only one type of verb spelling error occurred in the SPRT (errors on past tense forms). Secondly, there were more sentences (hence, more errors) in the ETT experiment than in the SPRT (i.e., 228 spelling errors in the ETT vs. 48 in the SPRT with past tense forms). Finally, the spelling errors on non-verb forms (filler errors) were more striking in the ETT (e.g., *sistematis instead of systematisch) than in the SPRT (e.g., *accesoire instead of accessoire). Together, these differences may have caused a stronger error awareness in the ETT than in the SPRT, which would explain why the interaction between Sublexical Homophony and Spelling was not significant in the former experiment but was significant in the latter. In this sense, the SPRT may have more closely mimicked the natural reading situation (i.e., spelling errors are rare) than the ETT.

A final remark concerns the timing of the interaction effect. It is not surprising that the effect surfaced on the verb form itself, given that the spelling correctness of past tenses depends solely on their morphological structure (i.e., does the spelling of the verb form reflect a legal stem + suffix...
structure?). In contrast to stem-final d and weak prefix verbs, there is no need for a time-consuming grammatical analysis of the sentence to determine whether the spelling of the verb form’s suffix is congruent with the grammatical information of another word in the sentence (e.g., subject or auxiliary verb). It therefore does not come as a surprise that the effect already appeared on the past tense form itself and was not distributed across words or delayed, as for stem-final d verbs. Because the effect was already located on the past tenses themselves, we deemed it irrelevant to perform a maze task with these verb forms.

4.1.3. Maze task

In this section, we will examine the Homophone Dominance effect at the lexical level in a maze task (MT). In this experimental task, the words of a sentence are not presented on a one-by-one basis as in a SPRT, but participants have to run through a sequence of two-choice alternatives to complete the sentence. In a sense, they actively construct the sentence. Each screen contains two words presented alongside each other, only one of which is a grammatical continuation of the sentence. The initial screen shows the first word of the sentence (e.g., The --). On subsequent frames, participants have to decide as quickly and accurately as possible which of the two alternatives forms a possible continuation of the sentence (e.g., cat give). A response is made by pressing the button corresponding to the left or right word (i.e., in this case the left one). If participants make a correct response on each frame, they can continue until the end of the sentence. If, however, an error is made, the trial is terminated and the experiment moves on to the next sentence. We will use the grammaticality version of this task (i.e., G-Maze), where both alternatives are existing words, but only one fits the sentence context both semantically and syntactically. While eyetracking and, to a lesser extent, self-paced reading are natural reading tasks (i.e., closely resemble ordinary reading situations), the maze task is not. In natural reading, participants do not have to choose which word will be the next word in the
sentence; they just have to process the sequence of words that were selected by
the writer. The maze task, however, does present a distinct advantage over the
other two tasks: it has been shown to be less sensitive to spillover-effects
(Witzel et al., 2012). In an ETT or SPRT, a response or eye movement can be
made before a word has been fully recognized and integrated into the previous
sentence context, such that factors that are expected to affect the recognition
of the target word (e.g., frequency) only reveal their influence on the words
following it. This wait-and-see strategy cannot be adopted by participants in
the maze task since each frame requires a forced choice between two
alternatives (Forster, Guerrera, & Elliot, 2009). This means that a choice for
the proper alternative requires (a) lexical access to the word’s representation
to be completed and (b) the word to be correctly integrated into the sentence
(both syntactically and semantically), before the participant can move on to
the next pair of alternatives. If these requirements are not met, the wrong
alternative might be selected (unless a random decision is correct), leading to
an abortion of the trial. Therefore, the reaction times in a maze task provide
“highly localized indications of processing time differences during online
sentence comprehension” (Witzel et al., 2012, p. 109). Consequently, targeted
effects are more likely to occur on the individual words under investigation,
rather than in the spillover region. This technique also presents another
advantage: since a sentence can only be completed if the right sequence of
choices is made (i.e., each word must be correctly interpreted), it renders
comprehension questions, testing participants’ semantic processing of the
sentence (as in the SPRT and ETT), superfluous.

The maze task has already been used to detect whole-word frequency
effects. Forster et al. (2009) compared the size of the frequency effect in an
isolated lexical decision task (without sentence context) to that in a maze task
(with sentence context). In both tasks, high-frequency words were processed
significantly faster than low-frequency ones, although the effect was larger in
the MT (91ms) compared to the LDT (67ms). The authors conclude that a
sentence context does not attenuate the frequency effect. Rather, HF words are
both processed and integrated in a sentence context more quickly than LF
words. Moreover, no spillover effects were found, indicating that reaction
times in the maze task provide “a good measure of processing cost for
individual words” (Forster et al., 2009, p. 170). Therefore, the maze task
allows us to examine whether the Homophone Dominance effect surfaces on
the verb itself, for both stem-final d and weak prefix verbs.

4.1.3.1. Stem-final d verbs

4.1.3.1.1. Hypothesis

Our hypothesis builds on the findings in the two previous sentence reading
experiments. While the ETT showed a marginally significant effect of
Homophone Dominance in the total reading times for the three-word region
x_x+1_x+2, the SPRT revealed a lagged effect on x+2. This could be due to the
task demands: participants in the ETT were able to freely move on to the next
word without having fully accessed and/or integrated the previous word(s)
(i.e., previous words are buffered). This leads to (a) high skipping rates and (b)
spillover effects (i.e., either delayed or distributed) for the ETT. The SPRT only
suffers from spillover effects, as the word-by-word presentation of a sentence
makes it difficult to skip a word. As in the SPRT, the maze task requires a
response to be made to each individual word in the sentence and hence does
not experience any statistical power problems (i.e., too few data points)
relating to a high skipping rate. Moreover, the MT necessitates an incremental
processing mode, requiring each word to be correctly identified and integrated
before moving on the next word, thus making it less prone to spillover effects
(Forster et al., 2009). Consequently, the major goal for using the MT is to
examine whether the Homophone Dominance effect manifests itself on the
critical word, rather than in the spillover region. If readers access whole-word
representations of stem-final d verbs, homophone intrusions should be
processed more quickly when the incorrect spelling of the verb form coincides
with that of the HF homophone. As Homophone Ratio increases (i.e., the d-
form becomes the more frequent homophone), shorter RTs should be
observed for d-intrusions, while RTs should become longer for dt-intrusions. This experiment also has a second goal: if an effect is found for stem-final d verbs in this maze task, it validates the experimental task in terms of being able to target whole-word frequency effects for regularly inflected verb forms. Anticipating the experiment with weak prefix verbs this means that, if a Homophone Dominance effect reveals itself on the critical verb for stem-final d verbs, but not for weak prefix verbs, we will be able to exclude the possibility that the absence of an effect for weak prefix verbs in the SPRT was due to problems with detecting this effect in the spillover region of that experiment. The difficulty associated with targeting the effect lies in the mismatch between the words following the two homophones, which is the inevitable result of the different grammatical functions of the homophones, namely a present tense and a past participle form.

4.1.3.1.2. Method

Stimuli and Design

Stimuli. The 60 sentences used in this MT were (nearly) identical to those in the SPRT (Section 4.1.2.1.2), consisting of 24 stem-final d sentences (basic set; see Table 1 in Appendix) and 36 filler sentences. Only the sentence containing the stem-final d verb opvoeden (‘raise’) was replaced by one containing another dt-dominant verb, namely duiden (‘explain’). Recall that we created a single sentence frame for each verb, in which both intrusions types could be embedded (i.e., ik + dt-form or hij + d-form, both being spelling errors). For each word in the sentence, we also selected a word that formed a non-grammatical continuation of the preceding sentence context. This word functioned as the second member in a forced-choice decision at that sentence position. This incorrect alternative was identical across conditions (i.e., the same for the sentence containing the d- and dt-intrusion). The correct continuation appeared randomly on the left or the right side of the screen. Length, Log Whole-word Frequency and Log Lemma Frequency of these alternatives were matched between d- and dt-dominant verbs (ps > .05), such
that the competing word was equally difficult in processing terms for both dominance types. As already indicated, no comprehension questions were required, as a full understanding of the sentence was needed to complete the sentence.

**Design.** The design was identical to that described in Section 4.1.2.1.2, apart from the fact that no comprehension questions were asked.

**Participants and Procedure**

**Participants.** Twenty-four subjects participated in the experiment (mean age = 20.71; SD = 3.04). These were students at Antwerp University taking part for course credit. They were native Dutch speakers with normal or corrected-to-normal vision and without any reading disorder. They had not previously taken part in an experiment on homophone intrusions.

**Procedure.** Participants were seated in a soundproof booth and received written instructions, informing them that they would be presented with sentences containing spelling errors. They were told to ignore these errors. The experimenter checked whether these instructions were clearly understood before initiating the two practice trials. If no questions remained after these practice trials, the four experimental blocks began, which took approximately 15 minutes to complete. The experiment was run on an OptiPlex 380 computer connected to a Dell-monitor (60-50Hz) and a Dell-keyboard. The stimuli were displayed in the Courier New font (14 points) in a white color on a black background. This was done via the DMDX software program (Forster & Forster, 2003).

Each sentence or trial was made up of a sequence of screens (see example below). The first one displayed the announcement ‘Ready?’. After 1,500ms, it was replaced by a second screen containing the first word of the sentence (on the left side) flanked by x-x-x (i.e., no alternative). Participants could freely press any button to move on to the next screen. The next and subsequent nine screens (i.e., each sentence was 11 words long) contained two
existing words presented alongside each other. Participants had to decide as quickly and accurately as possible which of these two words grammatically continued the sentence. A response was made by pressing either the left or right shift-key, corresponding to the word on the left or on the right. Reaction times were measured for each decision and reflected the time that elapsed between the onset of the two alternatives and a button press. If a correct response was made, the following screen with the next set of alternatives was displayed. If participants were able to select the correct alternative on each frame, the message ‘Correct. Next sentence’ appeared at the end of a sentence, followed by a new trial. If, however, participants chose the incorrect alternative at a particular sentence position, the error message ‘Incorrect. Next sentence’ appeared. In that case, the trial was aborted and the program moved on to the next sentence. The message “Attention: the next block will start” appeared before each block, allowing participants to take a short break. The next block could be initiated by pressing the space bar.

Example of a trial (each line = one screen):

KLAAR?
Terwijl x-x-x ‘READY?’
wanneer ik ‘While I’
jaagt groenten ‘hunts vegetables’
voor mogen ‘for can’
kiest de ‘chooses the’
soep ondanks ‘soup despite’
warmte snijdt ‘heat cut’
das kookt ‘tie boils’
zij zeggen ‘she say’
de heren ‘the gentlemen’
vaak. pasta. ‘often pasta’
CORRECT. Volgende zin ‘CORRECT. Next sentence’

4.1.3.1.3. RESULTS AND DISCUSSION

Results. Recall that if participants selected the incorrect alternative, the trial was aborted and the RTs of the entire trial were discarded. All participants completed the sentences correctly in at least 75% of the cases. Therefore, no participants were deleted from the data set. Given the incremental processing
mode required in the maze task (Witzel et al., 2012), we only analyzed reaction times on the critical words and not on those in the spillover region. We deleted 53 missing values (due to an incorrect selection at a particular sentence position) after which we log-transformed the remaining 523 RTs and fitted them with a linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The control variables tested for inclusion were: log-transformed PreviousRT, Trial, Switch, Hand (left or right), Length (of \( x, x-1 \) and the incorrect alternative (IA)), the Log Lemma Frequency (of \( x, x-1 \) and the IA) as well as the Log Whole-word Frequency of \( x-1 \) and the IA. The control variable Switch refers to whether the response on the target and its preceding word were made with the same hand (no switch) or with a different hand (switch). Switching response hands between the target and its preceding word might indeed be more difficult than using the same hand for both words. The whole-word and lemma frequencies of the previous target will likely have determined its processing difficulty, which in turn may have affected the processing difficulty of the verb form itself. This is not the same as a spillover effect of these measures but a possible correlation between the degree of difficulty of successive items. Similarly, the characteristics of the incorrect alternative might have affected the time needed to select the target and were therefore tested as possible control variables. The manipulated variables were Homophone Ratio and Form, while the theoretically relevant effect was the interaction between the two variables (i.e., the Homophone Dominance effect). After removing outliers (absolute standardized residuals > 2.5 SD; \( n = 15 \)), we refitted the model using the same predictors. The maximal random structure supported by the data consisted of a by-participant random intercept and a by-lemma random intercept. The results of this LMM are shown in Table 35, while the partial effects are plotted in Figure 35.
Table 35. Coefficients of a linear mixed effects model predicting log-transformed RTs from PreviousRT, Log Lemma Frequency, Form, Homophone Ratio and the interaction between Form and Homophone Ratio together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
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<td>0.05</td>
<td>150.67</td>
<td>191.25</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.11</td>
<td>0.04</td>
<td>2.52</td>
<td>5.89</td>
<td>.015</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>-0.11</td>
<td>0.05</td>
<td>-2.13</td>
<td>4.16</td>
<td>.041</td>
</tr>
<tr>
<td>Form</td>
<td>-0.05</td>
<td>0.02</td>
<td>-2.06</td>
<td>4.22</td>
<td>.040</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>0.06</td>
<td>0.06</td>
<td>1.12</td>
<td>1.22</td>
<td>.268</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>0.07</td>
<td>0.03</td>
<td>2.50</td>
<td>6.20</td>
<td>.013</td>
</tr>
</tbody>
</table>

Figure 35. Partial effects plot of effects represented in Table 35.
Discussion. The analysis revealed significant effects for the control variables PreviousRT (i.e., longer RTs as previous RTs increased) and Log Lemma Frequency (i.e., shorter RTs as verbs’ lemma became more frequent). The main effect of Homophone Ratio was not significant, while that of Form was: shorter RTs were found for dt-intrusions than for d-intrusions. The crucial interaction between both variables was also significant, indicating that RTs to homophone intrusions were influenced by the whole-word frequency relation between the two competing homophonic forms (i.e., an effect of Homophone Dominance).

The partial effects plot for the interaction between Form and Homophone Ratio (final plot of Figure 35) shows that as Homophone Ratio increased (i.e., verbs became more d-dominant), RTs increased for both d- and dt-intrusions. However, the effect is more pronounced for dt-intrusions, with an almost flat line for d-intrusions. Although this suggests that the dominance of the d-spelling had no effect at all on the RTs of these intrusions, an alternative account we also proposed in the offline spelling-to-dictation task might also be able to explain this finding. As in that production task, we inserted intervening words between the subject and verb form (to increase the likelihood of finding an effect of Homophone Dominance). Some of these intervening words were 3rd person singular nouns (e.g., Als ik/hij na de verkiezingen minister word(t) … ; ‘If I/he after the elections minister become(s)). We hypothesize that when such nouns appeared close to the verb form, they might have caused the processor under time pressure to take this noun with verb-relevant grammatical properties (3rd person singular) as a basis for determining the verb form’s suffix spelling (i.e., so-called proximity concord errors; see Bock & Miller, 1991; Fayol et al., 1994; Sandra et al., 2000). In this case, this favors a 3rd person dt-form. Therefore, the effect of the local context might have created such a strong dt-bias that it counteracted the processing advantage caused by a spelling error matching the high-frequency d-form of d-dominant verbs. Consequently, d-intrusions were processed equally fast, regardless of the verb’s d-dominance.
§ 3 The Homophone Dominance Effect in Perception

The dominance of the dt-form, however, will have increased this dt-bias, causing the steep line for dt-intrusions. This finding suggests that when the dt-intrusion was the HF homophone (left side of the plot), it did not cause much interference. Due to its high familiarity, the dt-form was not likely to be noticed as a spelling and responses were fast. However, as the dt-form becomes the LF homophone (moving from the left to the right side of the plot), responses were delayed. In that case, the dt-intrusion caused more interference, probably because it was more likely to be noticed due to its low familiarity.

Taken together, these results suggest that homophones forms of stem-final d verbs are accessed as whole-word forms, not only during word recognition of isolated words or of words in a minimal (i.e., two-word) context, but also during sentence reading, thus confirming the effect found in the ETT and SPRT. Crucially, the Homophone Dominance effect did not occur in the spillover region (as was the case in the ETT and SPRT), but emerged on the verb form itself. As in the MT performed by Forster et al. (2009), whole-word frequency effects were not delayed but highly localized. Moreover, the current experiment shows that MT is able to pick up on whole-word (and lemma) frequency effects of regular verb forms, more particularly, on the verb form itself. Hence, if whole-word representations are accessed for weak prefix verbs in sentence reading, the Homophone Dominance effect should also reveal itself for these verb homophones in the MT. The next experiment addresses this issue.

4.1.3.2. Weak prefix verbs

4.1.3.2.1. Hypothesis

Recall that we did not observe an effect of Homophone Dominance for weak prefix verbs in two tasks (i.e., a LDT and PDT) where word recognition took place outside a sentence context, whereas we did for stem-final d verbs. This was a surprising outcome, as the homophone ratios did not differ between
stem-final d verbs and weak prefix verbs ($ps > .05$). Hence, it seems unlikely that the homophones of these verbs would not have developed whole-word representations (but see General Discussion for a more in-depth discussion of this issue). The absence of the effect in these two experiments might be due to two factors. Firstly, it might result from the fact that, for some reason or another, these whole-word representations were not accessed for this verb type or that such access was masked by another factor. We already pointed out that the strong association in weak prefix verb homophones between a weak prefix and the d-spelling may indeed have been the masking factor for an effect of Homophone Dominance in the LDT and PDT. Secondly, it may be due to the fact that working memory did not have to allocate all its resources to a time-consuming morphosyntactic analysis (the verb form and its subject being adjacent), which spelling research has shown to be the optimal condition for obtaining an effect of Homophone Dominance (Sandra et al., 1999)\textsuperscript{86}.

In order to test the second option, we devised a SPRT in which we embedded these homophonous forms in a sentence context, where four words separated verb form and marker. This set-up provides the ideal condition to observe an effect of Homophone Dominance: the computational process is time-consuming, thus giving leeway to the whole-word retrieval process. While the effect was lagged for stem-final d verbs in the SPRT, it did not manifest itself for weak prefix verbs. Surprisingly, even overburdening working memory did not shed light on the existence of whole-word representations for these homophones. However, there is a crucial difference between the homophones of stem-final d verbs and those of weak prefix verbs, which may account for the diverging results in the SPRT: the former are both present tense forms, whereas the latter have a different grammatical function, i.e., a present tense form (PT) versus a past participle form (PP). This has implications for the sentence structures in which the homophones appeared in the SPRT. Whereas the sentence contexts for the two homophones of stem-final d verbs could be perfectly matched (only differing in the subject of the

\textsuperscript{86} Note, however, that we did obtain an effect of Homophone Dominance when stem-final d verb homophones were adjacent to their subject.
sentence: 1st vs. 3rd person singular), this was not the case for the homophones of weak prefix verbs. More particularly, the words following the PT and PP homophones, i.e., the words in the spillover region, necessarily differ between the two sentences as a result of the grammatical differences between PT and PP verb forms. As PT and PP contexts differ considerably in terms of their syntactic structure, frequency effects might arise at different locations for the two contexts (cf. distributed spillover effects), which may have prevented us from measuring an effect of Homophone Dominance in the SPRT.

Therefore, we performed the current MT, which requires an incremental processing mode (i.e., full identification and integration) and has been shown to uncover frequency effects on the target word itself (Forster et al., 2009). As the maze task with stem-final d verbs indeed revealed an effect of Homophone Dominance on the critical verb itself (Section 4.1.3.1), this finding validated the experimental task for our purpose. If the Homophone Dominance effect in the SPRT with weak prefix verbs did not emerge because it could not be measured on the verb homophones themselves, the maze task seems to be a much better tool for measuring the effect.

In the current experiment, we used both correct and incorrect spellings of the homophones (in contrast to the experiment with stem-final d verbs). Introducing spelling correctness as an additional factor offered us an extra possibility for finding evidence of Homophone Dominance. If verb homophones have whole-word representations, spelling errors are likely to cause a smaller response delay (compared to the correct spelling) when they correspond to the HF form. An intrusion error of the HF form would not only be processed faster than an intrusion of the LF form, the familiarity with its orthographic pattern would also be expected to make the error less salient (hence, giving rise to a smaller time penalty) than in the case of LF intrusions. This means that for d-spellings (correct for PP vs. incorrect for PT), the delay caused by a spelling error should decrease with increasing d-dominance. The reverse would be predicted for t-spellings (correct for PT vs. incorrect for PP). This would manifest itself in the form of a third-order interaction: the interaction between Homophone Ratio and Form should in turn be modulated...
by the spelling correctness of the homophone (as we observed in the SDT for stem-final d verbs). However, in case both homophones give rise to the same delay for incorrect spellings, we expect to find an interaction between Homophone Ratio and Form (indicating that HF homophones are processed faster) and a main effect of Spelling (as in the PDT).

The introduction of the factor Spelling also introduced a second advantage, namely the possibility of detecting garden-paths effects on the word following an incorrect spelling. Indeed, the absence of spillover effects does not preclude the occurrence of garden-path effects (Forster, 2010; Forster et al., 2009). More particularly, it is possible that an incorrect spelling in the maze task (and possibly all word-by-word reading experiments) might trigger a misinterpretation of the homophone (i.e., the form being interpreted as the correct spelling of the alternative homophone). Such a misinterpretation will (a) make it difficult to detect an effect of Homophone Dominance on the homophone itself and (b) increase the RTs to the following word (a garden-path effect). Hence, if the effect of Homophone Dominance does not emerge on the verb form itself, we will also consider RTs on x+1.

4.1.3.2.2. Method

Stimuli and Design

Stimuli. Each experimental version consisted of 60 sentences, 24 of which contained weak prefix verb forms. These 24 critical verbs and the corresponding PT and PP context sentences were identical to those in the SPRT (Section 4.1.2.2.2). In contrast to the SPRT, no comma followed the subclause of the PT context since the maze task encourages “readers to close the current clause or constituent whenever possible” (Witzel et al., 2012, p. 125).\(^87\) Next to the 24 critical sentences, we created 36 filler sentences that contained at least two difficult-to-spell words, one of which was indeed spelled

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\(^87\) Note that if this statement were true, garden-path effects should not occur (i.e., the d-intrusion should be interpreted as an incorrect PT form and not as a correct PP form).
incorrectly to draw attention away from homophone intrusions. As in the previous experiment, the maze task required each word in a sentence to be paired with a non-grammatical continuation of the preceding sentence context. Alternatives were matched between d-dominant and t-dominant verbs for Length, Log Whole-word Frequency and Log Lemma Frequency (ps > .05). By equating the choice difficulty for both dominance types we avoided that dominance effects could (in part) arise from this confounding factor. For critical sentences, the alternatives were identical across both the PT and PP context, so that the difference between the two homophones could only be due to the homophones’ frequencies and not to the rejection difficulty of the alternative.

*Design.* Each experimental list contained 24 critical sentences with weak prefix verb forms, counterbalanced for sentence context (PT vs. PP) and spelling correctness (correct vs. incorrect), these factors being orthogonal to each other. Half ($n = 12$) were PP context sentences and half were PT context sentences. When a verb was embedded in the PP context in list A, it was presented in the PT context in list B and vice versa. Moreover, lists were also counterbalanced for Spelling. In half of the cases ($n = 12$), the verb form was spelled correctly given the grammatical context, while it was spelled incorrectly in the other half. The half that was spelled correctly in version 1 of list A or B was spelled incorrectly in version 2 and vice versa. In sum, each participants saw six PT sentences with a correct t-form, six PT sentences with an incorrect d-form, six PP sentences with a correct d-form, and six PP sentences with an incorrect t-form. Filler sentences were identical across all versions. The 60 sentences were evenly distributed across four blocks of 15 sentences. Two randomization sequences (R1/R2) were made with the same restrictions as in Section 4.1.2.1.2. In total, there were eight experimental versions (A1R1, A1R2, B1R1, B1R2, A2R1, A2R2, B2R1, B2R2), each preceded by two practice sentences.
Participants and Procedure

Participants. Twenty-six subjects, students at Antwerp University, participated in the experiment for course credit (mean age = 20.04; SD = 1.8). Participants were all native speakers of Dutch with normal or corrected-to-normal vision and without any reading disorder. They had not previously taken part in an experiment on homophone intrusions.

Procedure. Identical to the procedure described in Section 4.1.3.1.2.

4.1.3.2.3. Results and Discussion

Results. Every participant had completed the entire sentence in at least 75% of the cases. RTs from trials that participants were unable to complete (due to an erroneous choice at one of the word positions) were deleted (n = 51). The remaining 573 observations on the critical verb forms (position x) were log-transformed. A linear mixed effects model was fitted to these observations (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). We tested which of the following control variables explained additional variance in the data: log-transformed PreviousRT, Trial, Switch (cf. supra), Hand (cf. supra), Length (of x, x-1 and the incorrect alternative (IA)), Log Lemma Frequency (of x, x-1 and the IA), as well as the Log Whole-word Frequency (of x-1 and IA). The manipulated variables were Homophone Ratio, Form and Spelling. The effects under investigation were the interaction between Homophone Ratio and Form (i.e., the Homophone Dominance effect) and its interaction with Spelling. As this third-order interaction between was non-significant, it was removed from the model to assess whether a significant interaction between Homophone Ratio and Form would emerge, next to a main effect of Spelling. The maximal random structure for this model supported by the data consisted of a by-participant random intercept, a by-participant random slope for Homophone Ratio, a by-lemma random intercept and a by-item random intercept. Data points whose absolute standardized residuals exceeded 2.5 SD from zero (n = 15) were considered as outliers and were removed from the data.
set. Next, we fitted a model with an identical fixed and random structure to the remaining data points. The results of the final LMM (i.e., with the second-order interaction only) are given in Table 36 and partial effects are plotted in Figure 36.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
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<tbody>
<tr>
<td>Intercept</td>
<td>6.90</td>
<td>0.03</td>
<td>231.22</td>
<td>228.23</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
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<td>5.36</td>
<td>25.73</td>
<td>.015</td>
</tr>
<tr>
<td>Trial</td>
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<td>-4.03</td>
<td>15.79</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Spelling</td>
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<td>3.95</td>
<td>.047</td>
</tr>
<tr>
<td>Form</td>
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<td>.568</td>
</tr>
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<td>Homophone Ratio</td>
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<td>0.04</td>
<td>-1.01</td>
<td>1.00</td>
<td>.316</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
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<td>0.04</td>
<td>0.44</td>
<td>0.19</td>
<td>.660</td>
</tr>
</tbody>
</table>

Table 36. Coefficients of a linear mixed effects model predicting log-transformed RTs from PreviousRT, Trial, Spelling, Form, Homophone Ratio and the interaction between Form and Homophone Ratio together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.
Figure 36. Partial effects plot of effects represented in Table 36.

**Discussion.** The control variables PreviousRT and Trial were significant (i.e., longer RTs as previous RTs increased and shorter RTs as the experiment progressed). Note that the control variable Log Lemma Frequency was not significant. Moreover, the effect of Spelling was significant: an intrusion error caused significantly longer RTs than when the correct spelling of the target form was presented. However, the main effect of Form, Homophone Ratio and their interaction were all non-significant.

The maze task did not reveal an effect of whole-word nor lemma frequency for weak prefix verbs, mimicking the results from the SPRT. The
hypothesis behind the current maze task was that the different syntactic structures of the PT and PP contexts could lead to different distributed spillover effects, which would have masked frequency effects in the SPRT. Consequently, we performed the current maze task, which has been shown to produce localized effects. Indeed, the MT with stem-final d verbs revealed lemma and whole-word frequency effects on the target verb form itself. As both frequency effects did not emerge on the weak prefix homophones in the MT (nor in the spillover region\textsuperscript{88}), we conclude that the absence of the effects in the SPRT was not likely due to differences in spillover effects between the two context. For one reason or another, frequency effects for weak prefix verbs seem to have been wiped out in the presence of a sentence context. Whereas the Homophone Dominance effect was absent across the board in the perception experiments, lemma frequency effects were observed in the LDT (i.e., isolated word recognition) and PDT (i.e., word recognition in a minimal context), but disappeared when weak prefix verb forms were embedded in a sentence context as in the SPRT and MT. Note that lemma frequency effects did occur in the SPRT and MT for stem-final d verbs (at position x+1 in the SPRT and on the homophone itself in the MT). Whereas the absence of an effect of Homophone Dominance for weak prefix verbs seems to confirm a systematic pattern (whatever be its explanation, cf. General Discussion in Chapter 4), the discrepancy between, on the one hand, the presence of a lemma frequency effect for these verbs' homophones in tasks without a sentential context and, on the other hand, the absence of this effect in two experiments where the homophones appeared in a full sentence, is an unexpected finding.

The current experiment and the SPRT therefore present us with a paradox that neither the morpheme-based process, nor the whole-word based process is operational in the word recognition of weak prefix verb homophones. This is obviously impossible. Nonetheless, the data pattern

\textsuperscript{88} Extra analyses of x+1 and x+2 revealed that neither the interaction between Form and Homophone Ratio, nor the effect of Log Lemma Frequency was significant in the spillover region.
provides no support for the involvement of either route. Note that this cannot be due to the fact that participants did not take the task seriously, which would have made it impossible to measure standard effects, as (a) most of them successfully completed a large majority of sentences (i.e., made few choice errors), (b) the effect of Spelling was significant in the LMM and (c) the traditional effects of PreviousRT and Trial were significant as well.

The absence of an effect of Homophone Dominance and lemma frequency for weak prefix verbs may have been due to the local ambiguity caused by an incorrect spelling of the d-form in the PT context, which at that point might still be considered as a correctly spelled past participle whose auxiliary is still to follow (see hypothesis). If so, two predictions follow. On the verb form itself, no RT difference should be observed between a correct and incorrect d-spelling (PP vs. PT, respectively), whereas RTs should be delayed for an incorrect t-spelling (i.e., an interaction effect between Form and Spelling on x). In other words, the d-intrusion is not perceived as a spelling error, but as a past participle. On the word following the verb form, a garden-path effect should be found. As participants will now notice their initial misinterpretation, a delay in RTs should be observed for incorrect d-forms (PT context) relative to their correct spelling. However, no delay is expected for incorrect t-forms (PP context) (i.e., the interaction effect between Form and Spelling will go in the opposite direction on x and x+1).

Applying the same procedure as in the other statistical analyses (see Section 1.1.1.3 of Chapter 2), Table 37 and Table 38 represent the LMMs for x and x+1, partial effects of which are plotted Figure 37 and Figure 38, respectively.\footnote{The random effect structure (as justified by the data) was identical for both analyses, consisting of a random intercept for participant, lemma and item.}
Table 37. Coefficients of a linear mixed effects model predicting log-transformed RTs at position x from PreviousRT, Trial, Spelling, Form, and the interaction between Spelling and Form together with the estimate $\beta$, standard error, $t$-value, $\chi^2$-value and $p$-value.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt; \chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.90</td>
<td>0.03</td>
<td>226.81</td>
<td>229.39</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.24</td>
<td>0.04</td>
<td>54.93</td>
<td>31.63</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Trial</td>
<td>-0.003</td>
<td>0.0008</td>
<td>-3.83</td>
<td>14.31</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Spelling</td>
<td>0.05</td>
<td>0.03</td>
<td>1.93</td>
<td>3.67</td>
<td>.056</td>
</tr>
<tr>
<td>Form</td>
<td>-0.02</td>
<td>0.03</td>
<td>-0.67</td>
<td>0.45</td>
<td>.501</td>
</tr>
<tr>
<td>Spelling x Form</td>
<td>0.12</td>
<td>0.05</td>
<td>2.31</td>
<td>5.18</td>
<td>.023</td>
</tr>
</tbody>
</table>

Figure 37. Partial effects plot of effects represented in Table 37.
Table 38. Coefficients of a linear mixed effects model predicting log-transformed RTs at position \( x+1 \) from PreviousRT, Trial, Length, Spelling, Form, and the interaction between Spelling and Form together with the estimate \( \beta \), standard error, \( t \)-value, \( \chi^2 \)-value and \( p \)-value.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>( \beta )</th>
<th>( SE(\beta) )</th>
<th>( t )</th>
<th>( \chi^2 )</th>
<th>( p(&gt; \chi^2) )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>6.96</td>
<td>0.02</td>
<td>288.73</td>
<td>229.61</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>PreviousRT</td>
<td>0.15</td>
<td>0.05</td>
<td>3.18</td>
<td>9.40</td>
<td>.002</td>
</tr>
<tr>
<td>Trial</td>
<td>-0.004</td>
<td>0.0009</td>
<td>-4.95</td>
<td>22.03</td>
<td>&lt; .001</td>
</tr>
<tr>
<td>Length</td>
<td>-0.03</td>
<td>0.01</td>
<td>-2.87</td>
<td>7.02</td>
<td>.008</td>
</tr>
<tr>
<td>Spelling</td>
<td>0.07</td>
<td>0.04</td>
<td>1.72</td>
<td>2.88</td>
<td>.090</td>
</tr>
<tr>
<td>Form</td>
<td>-0.06</td>
<td>0.04</td>
<td>-1.65</td>
<td>2.62</td>
<td>.105</td>
</tr>
<tr>
<td>Spelling x Form</td>
<td>-0.53</td>
<td>0.08</td>
<td>-7.09</td>
<td>38.11</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Figure 38. Partial effects plot of effects represented in Table 38.
The results reveal the basic assumption of the maze task, i.e., it encourages “readers to close the current clause or constituent whenever possible” (Witzel et al., 2012, p. 125). Such closure was possible in the PP context, where the auxiliary verb preceded the past participle and in the PT context with a correctly spelled t-form. In contrast, an incorrectly spelled d-form in the PT context triggered a PP interpretation, which did not allow participants to close the clause, because an auxiliary could still follow90. This caused equal RTs on the correct and incorrect spellings of the d-form, but a garden-path effect on the following word (i.e., participants only then noticed that they initially interpreted the d-form as a correct past participle instead of a misspelled present tense form). In contrast, the difference in RTs for t-forms was situated on the target verb form itself, but not on the following verb (i.e., the spelling error was immediately noticed), causing an interaction in the opposite direction than the one for d-forms on x+1. In sum, the local ambiguity of the PT context led to a garden-path effect for the incorrect d-form, which may have seriously contaminated the RT data and obscured an effect of Homophone Dominance and lemma frequency.

The above problem implies that, in the case of weak prefix verbs, the experimental design of the MT (and SPRT) was unfit to detect an effect of Homophone Dominance. Therefore, we cannot draw any conclusions for this verb type with regard to the interaction between Form and Homophone Ratio on the basis of the sentence reading experiments. It is important to emphasize that despite the serious but unexpected drawback, this was the only methodologically valid design if we wanted to orthogonally combine Spelling and Form and at the same time equate the cognitive load for homophone processing (i.e., introduce intervening words between marker and verb form) between (a) the PT and PP context and (b) the experiments with stem-final d and weak prefix verbs.

90 By extension, the whole PT context may have been contaminated: even correctly spelled t-forms may have been temporarily ambiguous between a PT and PP interpretation. The RT increase on x+1 for correct t-spellings in the PT context relative to incorrect t-spellings in the PP context might support this interpretation.
The SPRT and MT examined the online processing of homophone intrusions in full sentence contexts, thus more closely approaching a natural reading situation than the isolated word recognition experiment (LDT) or the experiments with a minimal grammatical context (SDT and PDT). They revealed two findings. Firstly, lexical intrusions corresponding to the HF homophone of a stem-final d verb are processed more quickly than those corresponding to the LF counterpart, suggesting that a HF intruder is less detrimental to processing than a LF intruder. Secondly, sublexical homophone intrusions involving an existing letter string are processed more quickly than errors in which the intruding letter string is non-existent, even though the latter would have had the same pronunciation as the correct letter sequence if it had existed (e.g., *ptte and pte would both have been pronounced as [pt@]).

The observation that faster responses are made on spelling errors that correspond to the HF homophone suggests that such intrusions cause a smaller reading delay because the familiarity of their letter pattern makes the error less salient. However, an alternative account is that the error penalty is the same for HF and LF intrusions and that the longer processing time for LF intrusions simply reflects the longer lexical processing time that is required for LF forms. In other words, the question remains whether faster processing times of intrusion errors matching the HF spelling really makes these errors less salient than intrusions involving the LF form, such that they escape participants’ attention more often. If this were indeed the case, it would lead to fewer error detection rates for intrusions of the HF homophone during offline processing. Exactly the same line of reasoning could be applied to sublexical intrusions where the opposition does not involve HF vs. LF homophones but existent vs. non-existent homophonous patterns: since sublexical intrusions whose incorrect spelling pattern is supported by that of phonologically similar words are processed more quickly compared to those whose incorrect pattern does not exist, they might also more likely to be left undetected. To test these hypotheses, we performed a final offline experiment that required participants
to proofread sentences. Such a task closely resembles the re-reading process of a text or (at least) the reading of somebody else’s text.

4.2. **Offline task: proofreading**

Using the proofreading task (PRT), we examine whether homophone intrusion errors go unnoticed more often when the intruder is the HF homophone (lexical intrusion) or an existing sublexical homophonous pattern (sublexical intrusion). Contrary to the previous online experiments, this is an offline experiment in which the number of correctly identified homophone intrusions is the dependent variable rather than reaction or reading times. As mentioned above, the fact that these forms were processed more quickly in the online experiments does not directly imply that they are less salient errors that go unnoticed less often and, hence, are more likely to persist in carefully scrutinized texts. In order to examine this issue, we devised the current proofreading task, which closely resembles a situation in which people re-read their texts or proofread other people’s texts for errors. If it turns out that intrusions of HF homophones or of existing sublexical homophonous patterns cause more error detection failures, this would offer an explanation as to why so many texts are plagued by these errors: the presence of a higher-frequency homophonous verb form or a homophonous letter pattern would (a) cause the spelling process to be most vulnerable to intrusions of this form/pattern and (b) cause the reading process to be most vulnerable to overlook these very same errors during proofreading. This would mean that the same types of representations and processes affect both the spelling and reading processes, creating a double trap that is responsible for the persistence of intrusions on regular Dutch verb forms.

Two studies have directly compared performance in production and proofreading experiments. With respect to verbal agreement, Largy (2001) observed a dissociation between the spelling and detection skill of 2nd and 3rd graders of primary school. Their performance when having to detect and correct erroneous verbal agreements in a proofreading task exceeded their
performance in a dictation task where they needed to produce these agreements (e.g., *la bague brille* vs. *les bagues brillent* ‘the ring sparkles’ vs. ‘the rings sparkle’). Specifically for homophone spellings, White, Abrams, and Zoller (2013) showed that Homophone Dominance affected production and perception in a similar way. In production, both young and older adults were less accurate at spelling subordinate (i.e., non-dominant) homophones (e.g., *beech*) than dominant homophones (e.g., *beach*) when embedded in a sentence context. In other words, fewer spelling errors were found on the higher-frequency homophone. During proofreading, both age groups also left intrusion errors undetected more often when the subordinate homophone was substituted by the dominant homophone rather than vice versa, again indicating a preference for the higher-frequency form. Older adults were better at the detection task, whereas younger adults performed better in the production task.

Although both studies examined the contrast between production and proofreading performance, they also differed from the current experiment in some important respects. Similarly to our study, Largy (2001) focused on verbal agreement errors, where a homophone from within the verbal paradigm substitutes the correct verb form. However, he did not explicitly address frequency effects, i.e., he did not analyze whether the errors made during spelling or left undetected during proofreading depended on their whole-word frequency. The White et al. (2013) study did examine the Homophone Dominance effect, but the homophones used were not inflectional variants. Obviously, the results obtained with such homophones do not necessarily translate to the role of homophony when proofreading regular verb forms (homophonous words vs. homophonous word variants). The proofreading task we designed combines both issues: are lexical and sublexical intrusions that are more likely to be made in production, due to their highly familiar orthographic pattern (see Chapter 2), also overlooked more often during proofreading? We examined this issue for lexical intrusions (stem-final d and weak prefix verbs) and sublexical intrusions (i.e., past tense verb forms).
4.2.1. **Stem-final d verbs**\(^91\)

4.2.1.1. **Hypothesis**

In Chapter 2, we showed that the HF homophone of stem-final d verbs is more likely to cause a homophone intrusion in spelling than the LF one. In the current chapter on the perception of regularly inflected verb forms, we have already demonstrated that the HF homophonous form of a stem-final d verb was processed more quickly in a visual recognition task (LDT), a task involving a single-word grammatical context (PDT) and online reading tasks involving full sentences (ETT, SPRT and MT). To complement these online perception studies, we performed an offline proofreading task during which participants had to detect intrusions. This task will enable us to further substantiate our claim that the Homophone Dominance effect indicates (a) that whole-word representations are accessed for these HF forms during perception, (b) that this causes faster response times than for their homophonous LF counterparts and (c) that the ensuing feeling of familiarity induced by the fast access to a HF form is responsible for their persistence in carefully re-read texts. In line with our previous findings, we hypothesized that intrusions involving the HF homophone will go undetected more often than intrusions involving the LF one. Hence, we predict an interaction effect between Form and Homophone Ratio: as verbs become more d-dominant, the d-intrusion should be overlooked more often, whereas we expect more undetected dt-intrusions as verbs become more dt-dominant.

4.2.1.2. **Method**

**Stimuli.** The current proofreading task (PRT) incorporates the same 24 stem-final d sentences as those in the offline spelling-to-dictation task (see Section 1.1 of Chapter 2 for their characteristics), as well as the same 24 past tense sentences.

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\(^91\) This section is the result of a collaboration with Astrid Schoenmaeckers in the context of her master's thesis.
sentences (s vs. p verbs; analyzed in Section 4.2.3.3). This time, critical verb forms did not have to be spelled, but had to be checked for spelling correctness. All critical sentences contained one homophone intrusion and at least one other difficult-to-spell word. Next to these critical sentences, 24 fillers of the online spelling-to-dictation experiment were also selected for the current task. Recall that these filler sentences contained non-homophonous verb forms and two extra difficult-to-spell words unrelated to verb spelling. To ensure that participants did not develop a response strategy (“all verb forms with a stem-final d are incorrect”), we created 8 filler sentences containing correctly spelled stem-final d verbs, unrelated to the verbs used in the critical sentences. Half of these fillers were sentences containing the 1st person d-form and half were sentences containing the 3rd person dt-form. These were formed using the same criteria as in the offline spelling-to-dictation task (see Section 1.1.1.2 of Chapter 2; e.g., an extra difficult-to-spell word). An example of such a stem-final d filler was:

Als het vliegtuig op de smalle baan snel landt, kan de wachtende dokter de passagier redden met een defibrillator.

‘If the plane on the small runway quickly lands, can the waiting doctor the passenger save with a defibrillator.’

In a further attempt to draw attention away from the homophones verb forms, the difficult-to-spell words were spelled correctly or incorrectly in an unpredictable way: 1/3 of the sentences contained zero errors on these words, 1/3 contained one error, and 1/3 contained two errors. As far as the critical sentences were concerned, half contained only the homophone intrusion (i.e., one error) while the other half also contained another spelling error (i.e., two errors in total).

Design. Each experimental version contained 48 sentences (i.e., 8 with a stem-final d homophone, 8 with a past tense form and 32 filler sentences). The 24 critical stem-final d verb forms and past tense verb forms were divided across
three subsets (1, 2, 3). Thus, only 16 of the 48 sentences contained lexical or sublexical homophone intrusions, making it less likely that participants would notice the purpose of the experiment. The sentences with stem-final d homophones were counterbalanced for intrusion type: half \( (n = 4) \) contained d-intrusions (i.e., 3rd person subject + d-form) and the other half dt-intrusions (i.e., 1st person subject + dt-form). When List A targeted the d-intrusion, the counterbalanced form in list B was the dt-intrusion and vice versa. In addition, each version contained 8 sentences with an incorrectly spelled past tense form (i.e., 4 s verbs and 4 p verbs) and 32 filler sentences (8 of which contained a correctly spelled stem-final d filler verb). These fillers were identical across all versions. The 48 sentences were printed on four pages (i.e., 12 sentences on each page). We made sure that each item type appeared equally often on each page. Furthermore, each page contained four zero-error sentences, four 1-error sentences and four 2-error sentences. To counterbalance the materials for fatigue/familiarization, we created two randomization sequences (R1/R2). The page sequence for R1 was 1-2-3-4, while this sequence was 3-4-1-2 for the second randomization (i.e., the two halves of the sentence list were reversed). The sequence of sentences on each page respected the following criteria: (a) a page never started/ended with a critical sentence and (b) a maximum of two critical sentences could follow each other. In total, there were 12 different experimental versions (i.e., 1AR1, 1AR2, 1BR1, 1BR2, 2AR1, 2AR2, 2BR1, 2BR2, 3AR1, 3AR2, 3BR1, 3BR2).

**Participants and Procedure**

**Participants.** Seventy-three students from the sixth grade of general secondary education\(^{92}\) at the Xaverius College in Borgerhout took part in the experiment (mean age = 16.95; SD = 0.44). Dutch was their native language and none of them had any record of a reading disorder.

**Procedure.** Participants were given a 5-page booklet. The first page required

\(^{92}\) For a justification regarding this participant group, see Section 1.1.1.2 of Chapter 2.
them to fill in personal information (e.g., name, gender, education type, native language, reading disorders) and contained the following written instructions:

In a previous experiment, participants were asked to write down sentences under time pressure. During this process, they made a number of spelling errors. It is your task to detect these errors in the following sentences. If you have identified a spelling error, you simply need to mark the error. There is no need to correct it. When you are finished, do not reread the sentences but simply turn over the page and the experimenter will collect your booklet. If you are not ready within the 7-minute time frame, draw a line under the last sentence that you have read and finish the rest of the sentences with a different pen color.

These instructions were repeated orally and the experimenter emphasized that re-reading was not allowed. Crucially, the instructions did not inform participants about the actual goal of the experiment. Rather, they were told that this was part of a large-scale spelling research program with Flemish teenagers. The next four pages of the booklet each contained 12 experimental sentences. Sentences were printed in Calibri (12 points), with the restriction that each sentence fitted on two lines. As mentioned in the instructions, participants received seven minutes to complete this task, after which they had to draw a line under the last sentence they had read. After this, they could complete the task using a different pen color. Spellers have been found to be especially prone to making homophone intrusions under conditions of time pressure, as the result of working memory overload (Sandra et al., 1999, 2004). We believe that the 7-minute time restriction imposed in this task would similarly burden readers’ working memory during proofreading.

4.2.1.3. Results and Discussion

Results. As mentioned earlier, we will postpone the analysis of the past tense forms in this experiment to Section 4.2.3.3 and focus here on the analysis of the stem-final d verbs. Correctly identified intrusions (‘hits’) received a 1-score, whereas those that were left undetected (‘misses’) were given a 0-score.
The results from participants with a perfect score (i.e., 8/8) were removed from the data set because they did not contribute any variance across the experimental conditions ($n = 22$). Furthermore, one participant was removed from the data set because he completed less than 75% of the experiment\(^{93}\). We analyzed both the scores obtained within the 7-minute time frame and those obtained for the entire task. Since the results between these analyses did not differ, we will only report the results of the latter.

In total, there were 389 observations from 50 participants (missing values $n = 11$). The dependent variable was binomially distributed (hit = 1; miss = 0). The responses were analyzed via a generalized linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). Control variables tested for inclusion were: (word) Length, Trial (i.e., position of sentence on the page, ranging from 1-12) and Log Lemma Frequency of the verb. The manipulated variables were Homophone Ratio and Form. The effect under investigation was the interaction effect between these two variables. The random structure of the final model contained a by-participant random intercept, by-participant random slope for Form and a by-lemma random intercept. Regression Table 39 shows the results of this analysis, followed by a partial effects plot of the variables contained in the GLMM (Figure 39).

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
<th>$t$</th>
<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.68</td>
<td>0.20</td>
<td>3.32</td>
<td>10.23</td>
<td>.001</td>
</tr>
<tr>
<td>Log Lemma Frequency</td>
<td>-0.41</td>
<td>0.20</td>
<td>-2.03</td>
<td>3.93</td>
<td>.048</td>
</tr>
<tr>
<td>Form</td>
<td>-0.29</td>
<td>0.37</td>
<td>-0.77</td>
<td>0.54</td>
<td>.464</td>
</tr>
<tr>
<td>Homophone Ratio</td>
<td>-0.10</td>
<td>0.23</td>
<td>-0.42</td>
<td>0.16</td>
<td>.686</td>
</tr>
<tr>
<td>Form x Homophone Ratio</td>
<td>1.36</td>
<td>0.38</td>
<td>3.59</td>
<td>13.82</td>
<td>&lt; .001</td>
</tr>
</tbody>
</table>

Table 39. Coefficients of a mixed logit model predicting the probability of detecting an intrusion error from Log Lemma Frequency, Form, Homophone Ratio and their interaction, together with their estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.

\(^{93}\) After removal of the data from these participants, the distribution of participants across experimental versions (excluding randomization orders) was the following: 1A ($n = 7$), 1B ($n = 9$), 2A ($n = 5$), 2B ($n = 9$), 3A ($n = 11$), 3B ($n = 9$).
Discussion. The control variable Log Lemma Frequency was significant: errors were overlooked more often as verbs’ lemma became more frequent. Whereas the main effects of Form or Homophone Ratio were not significant, their interaction was. This interaction effect is visualized in the final plot of Figure 39: as verbs become more d-dominant (i.e., Homophone Ratio increases), d-intrusions were overlooked more often, whereas dt-intrusions were marked as an error more often (and vice versa as verbs become dt-dominant).

The results confirm that Homophone Dominance also modulates the error pattern during proofreading (as it does in spelling): in the case of stem-
final d verbs, lexical intrusion errors are more often missed when the LF homophone is replaced by the HF one than when the reverse intrusion occurs. This corroborates our conclusion from the online perception experiments: whole-word representations are accessed for these regular inflections, not only causing them to be processed more quickly when the error involves the HF homophone, but also to be noticed less often. We conclude that the feeling of familiarity that is created by the HF homophone’s orthographic pattern is responsible for overlooking these intrusion errors on stem-final d verb homophones, even in carefully re-read texts. The role of this factor in reading in part explains the persistence of homophone intrusions on regular verb forms (especially of the HF form) in written texts.

Note that the effect of Homophone Dominance is consistent with that of Log Lemma Frequency: due to the strong correlation between Log Lemma and Log Whole-word Frequency ($r = .91$), both homophones of a high-frequency lemma will have a relatively high whole-word frequency too, such that they will more often be missed as spelling errors. However, on top of this, the frequency difference between the two homophones introduces an extra frequency effect, i.e., the effect of Homophone Dominance.

### 4.2.2. Weak prefix verbs

#### 4.2.2.1. Hypothesis

While the Homophone Dominance effect modulated the performance on weak prefix verbs in production tasks (Chapter 2), we were unable to find any evidence of such an effect in a broad range of online perception tasks. HF forms were not processed more quickly than LF ones when presented in isolation, in a minimal grammatical context or when embedded in a sentence context that required a great deal of attentional resources for checking the spelling correctness of these verb homophone (i.e., long distance between verb...)

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94 This section is the result of a collaboration with Astrid Schoenmaeckers in the context of her master’s thesis.
form and marker). As a result, we are currently unable to explain why intrusions on weak prefix verb homophones go unnoticed so often.

However, as already indicated, it is not necessarily the case that results from online experiments transfer to offline experiments or vice versa. There might be a reason why the online measures could not capture an effect of Homophone Dominance, whereas an offline measure can tap into the effect. The current PRT therefore examines whether the Homophone Dominance effect affects detection performance for weak prefix verbs. If whole-word representations were indeed accessed for this verb type, we expect the same pattern of results as for stem-final d verbs: intrusions should be left undetected more often when they correspond to the HF homophone, i.e., an interaction effect should emerge between Homophone Ratio (degree of d-dominance) and Form (d-intrusion vs. t-intrusion).

We want to emphasize that although the current task makes use of the same sentence contexts as in the MT and SPRT to create a cognitive load on working memory (i.e., intervening words between marker and verb form), it avoids the issue of the garden-path effect observed in the former (and possibly the latter) task. It is quite reasonable that a local ambiguity on incorrectly spelled verb forms occurs when sentences are presented to participants one word at a time (i.e., the following words being unknown). In the current PRT, however, participants had access to all words of the sentence before correcting errors (i.e., incorrect d-forms in the PT context could immediately be disambiguated).

4.2.2.2. Method

Stimuli. The current experiment examined both weak prefix verbs and past tense verb forms (st vs. rt-nt verbs; analyzed and discussed in Section 4.2.4.3). The same set of weak prefix verbs used in all experiments was used for this proofreading experiment (see Table 3 in the Appendix). Again, two sentence contexts were created, i.e., a present tense (PT) and past participle (PP) context. Both contexts were equated as closely as possible in terms of the
semantic and/or syntactic context preceding the verb. Examples of these two contexts are:

**PT context**

Doordat mijn broer zijn oude paswoord nooit *veranderd, vormt zijn emailaccount een makkelijk slachtoffer voor een cyberaanval. ‘Because my brother his old password never *changed, is his mail account an easy prey for a cyber attack.’

**PP context**

Mijn broer heeft zijn oude paswoord nooit *verandert waardoor zijn e-mailaccount een makkelijk slachtoffer vormt voor een cyberaanval. ‘My brother has his old password never *changes because of which his mail account an easy prey is for a cyber attack.’

These sentences were designed using the same criteria as the online spelling-to-dictation experiment and sentence reading experiments, i.e., four items were inserted between the marker (i.e., two-word subject for a PT or auxiliary verb for a PP) and the verb form in an attempt to overload working memory capacities in a time pressure situation (see Section 1.2.2 of Chapter 2). In order to keep the cognitive load constant across both contexts, the same four words were used in the PT and PP contexts (cf. example above). To accomplish this, verb forms appeared at the end of a subclause in the PT context, but in a main clause in the PP context. Recall that in the proofreading experiment, all homophones were spelled incorrectly (i.e., were homophone intrusions), as was the case in the PRT with stem-final d verbs.

As already indicated, we also examined the error detection rates for past tense verb forms, namely the same set of *st* and *rt-nt* verbs as used earlier in the PDT (see Table 5 in the Appendix).\(^5\) Recall that half of these past tense forms had stems ending in -*st* and half ending in -*rt* or -*nt*. In past tenses of the former type, the erroneous word-final pattern *ste* was the sublexical

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\(^5\) The past tense form *haastte* was replaced by *restte* (‘remained’; raw whole-word frequency = 12; raw lemma frequency = 72; frequency characteristics taken from SUBTLEX-NL (Keuleers et al., 2010)).
homophone of the correct past tense cluster \textit{stte} (e.g., \textit{*ruste} instead of \textit{rustte} ‘rested’). This homophonous string occurred within the verbal paradigm (e.g., \textit{waste} ‘washed’), but also outside that paradigm, i.e., in nouns and adjectives (e.g., \textit{vaste} ‘fixed’). In contrast, the incorrect past tense ending \textit{rte} or \textit{nte} of the latter type was the sublexical homophone of the correct spelling pattern \textit{rtte} or \textit{ntte} (e.g., \textit{*printe} instead of \textit{printte} ‘printed’), but this homophone only appeared outside the verbal paradigm (e.g., \textit{aparte} ‘separate’, \textit{lente} ‘spring’). The past tense forms were embedded in sentences of the same structure as weak prefix verbs (i.e., subclauses and main clauses) and were all spelled incorrectly (i.e., with a single \textit{t}; e.g., \textit{*poste}). No restrictions were imposed on the characteristics of the subject (or its position in the sentence), as this is irrelevant for the correct spelling of the inflectional ending (i.e., is determined by the voicing characteristics of the stem-final consonant only). An example of a past tense sentence is the following:

\begin{verbatim}
Toen de bibliothecaresse deze voormiddag de brief \textit{*poste}, wist ze nog niet dat hij de geadresseerde nooit zou bereiken.
‘When the librarian this morning the letter \textit{posted}, knew she yet not that it the addressse never would reach.’
\end{verbatim}

Moreover, two extra difficult-to-spell words, not related to verb spelling issues (e.g., \textit{bibliothecaresse}, ‘librarian’), were incorporated in the critical sentences. To avoid putting too much focus on the homophone intrusions, these extra errors did not appear in the verb region.

To avoid that all homophonous forms were intrusion errors, we created 8 filler sentences containing correctly spelled weak prefix verbs, using the same sentence criteria as for the critical sentences. Half were PT context sentences (i.e., containing the \textit{t}-form) and the other half PP context sentences (i.e., containing the \textit{d}-form). An example of such a filler sentence with a weak prefix verb form is the following:

\begin{verbatim}
Omdat ons nichtje op zaterd\textit{ag vijf oktober verjaart, bereiden haar ouders een groot verrassingsfeest voor met taart en cadeautjes.}
\end{verbatim}
'Because our niece on Saturday five October celebrates her birthday, prepare her parents a big surprise party with cake and presents.'

These 8 weak prefix filler sentences were complemented by 24 extra filler sentences containing non-homophonous verb forms and at least two difficult-to-spell words (e.g., onmiddellijk; ‘immediately’). These 24 fillers were identical to the ones used in the previous proofreading experiment. The occurrence of a spelling error was again unpredictable: 1/3 of the sentences contained zero errors, 1/3 one error, and the other 1/3 contained two spelling errors. For the critical sentences, half contained only one error (i.e., the homophone intrusion) and the other half contained the homophone intrusion error and an error on a difficult-to-spell word (i.e., two errors in total).

Design. The design was identical to that of the previous PRT: each experimental version contained 48 sentences (i.e., 8 with weak prefix verb homophones, 8 with regular past tenses and 32 filler sentences). Critical sentences were evenly distributed across three subsets: each participants saw homophone intrusions on four d-dominant and four dt-dominant verbs, as well as incorrect past tenses for four st and for four rt-nt verbs. For sentences including weak prefix verbs, counterbalancing was applied with respect to the type of intrusion: half (n = 4) were d-intrusions (i.e., PT-context + d-form) and half were t-intrusions (PP-context + t-form). If participants saw the d-intrusion in version A, version B contained the t-intrusion and vice versa. The 32 fillers were the same for all versions. The 48 sentences were evenly divided across 4 pages (i.e., 12 sentences on each page). Two randomization sequences were created (R1: 1-2-3-4 and R2: 3-4-1-2) with the same restrictions as in Section 4.2.1.2. Again, there were 12 versions in total (i.e., 1AR1, 1AR2, 1BR1, 1BR2, 2AR1, 2AR2, 2BR1, 2BR2, 3AR1, 3AR2, 3BR1, 3BR2).

Participants and Procedure

Participants. Eighty-two students from the fifth grade of general secondary education at the Xaverius College in Borgerhout participated (mean age =
16.20; SD = 0.46). They all had Dutch as their native language and did not have any history of a reading disorder.

Procedure. Identical to Section 4.2.1.2.

4.2.2.3. Results and Discussion

Results. The analysis and discussion of past tenses will be postponed until Section 4.2.4.3, while the present section focuses on the results for weak prefix verbs. The dependent variable was binomially distributed: misses (i.e., error was not detected) were given a 0-score and hits received a 1-score. Participants who had a perfect score (8/8) were removed from the data set \( n = 20 \)\(^96\). Again, the analysis based on the responses from within the 7-minute time frame did not differ from the one based on all responses. Therefore, we prefer to report the latter. The 491 responses (missing values: \( n = 5 \)) were analyzed via a generalized linear mixed effects model (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The following control variables were tested for inclusion: Length, Trial and Log Lemma Frequency of the weak prefix verb. The manipulated variables were Homophone Ratio and Form, while the interaction between these two variables is the theoretically relevant effect. The model's random structure is justified by the design and contains a by-participant random intercept and by-participant random slope for Form, Homophone Ratio and their interaction, as well as a by-lemma random intercept and by-lemma random slope for Form. The results of the regression analysis are shown in Table 40, partial effects of which are plotted in Figure 40.

\(^{96}\)After removal of the data from these participants, the distribution of participants across versions (leaving out the two randomization sequences) was the following: 1A \( n = 10 \), 1B \( n = 7 \), 2A \( n = 7 \), 2B \( n = 13 \), 3A \( n = 12 \), 3B \( n = 13 \).
### Table 40

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
<th>$SE(\beta)$</th>
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<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
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</thead>
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<td>.454</td>
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<td>-0.05</td>
<td>0.003</td>
<td>.958</td>
</tr>
</tbody>
</table>

Table 40. Coefficients of a mixed logit model predicting the probability of detecting an intrusion error from Form, Homophone Ratio and their interaction, together with their estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.

**Figure 40.** Partial effects plot of effects represented in Table 40.
Discussion. The results of the GLMM show that neither the main effect of Form, Homophone Ratio, nor their interaction significantly modulated the probability of detecting an error. In other words, the experiment does not yield any evidence for the idea that intrusions containing the HF homophone are left undetected more often than those containing a LF homophone. In contrast, both d- and t-intrusions were noticed equally often. This disconfirms the hypothesis that Homophone Dominance is responsible for the persistence of homophone intrusions on weak prefix verbs in texts that have been submitted to proofreading. The absence of an effect is in line with the entire pattern of results coming from the online perception experiments: apparently whole-word representations for weak prefix verbs are not accessed, whether verb forms were presented in isolation, in a minimal context or in a full sentence context. The current experiment confirms this general pattern.

There are two striking observations. Firstly, there was no preference for a d-form (cf. the d-bias was absent). Hence, the Homophone Dominance effect cannot have been masked by this factor. The General Discussion (Chapter 4) will elaborate on the consistent failure to observe this effect across the entire set of experiments. Secondly, the average detection rate is much lower (i.e., around chance-level, 49.5%) than in the experiment with stem-final d verbs (i.e., 60.9 %). This might suggest that participants made a random decision about the spelling correctness of weak prefix homophones. However, this suggestion is contradicted by an analysis of the false positives, i.e., the number of correctly spelled homophones of weak prefix verbs (used as distractor items) that were nonetheless marked as an intrusion error. If participants’ behavior were indeed random, they should also mistakenly mark these forms as errors half of the time. The analysis, however, revealed that this was only so in 4.6% of the cases. It is important to note that this percentage is comparable to the 4.5% of false positives in the experiment with stem-final d verbs\textsuperscript{97}. As

\textsuperscript{97} Despite the difference between the two experiments with respect to the number of correct identifications of homophone intrusions, this underscores an interesting similarity: for both verb types, participants made considerably fewer errors on correctly spelled verb homophones (i.e., identifying a spelling error when there was
random guessing cannot explain the low average detection rate, it seems that it should in principle have been possible to detect an effect of Homophone Dominance.

The argument that a low overall detection rate should still allow the emergence of an effect of Homophone Dominance is also supported by the findings of an unreported study performed in our lab. The set-up of this PRT with stem-final d verbs was identical to the one reported above, except for the fact that there were three age-matched participant groups: sixth-graders attending general, technical and professional secondary education. While there is much emphasis on grammatical knowledge in the first group, this is considerably less so in technical education and even less so in professional education. Our results revealed a Homophone Dominance effect across the three education types, while the overall detection score decreased from general to professional education. Applying these findings to the current experiment leads to the conclusion that, despite the overall low detection rate weak prefix verbs (i.e., lower than for stem-final d verbs), it should still have been possible to detect an effect of Homophone Dominance.

The results from the present experiment lead to the conclusion that participants were in considerable doubt when having to identify spelling errors on weak prefix verb forms, but that their correct identifications of these errors were not shaped by Homophone Dominance. The recurrent absence of an effect of Homophone Dominance across all perception experiments (including the PRT) suggests that readers do not rely on whole-word representations of the homophones of weak prefix verbs.

As the homophones are regular verb forms, there seem to be few possibilities for their processing. Either participants rely on whole-word representations or a process of morphological decomposition and a subsequent check on the suffix spelling. However, the very low success rate in the current PRT does not confirm the use of an explicit spelling check either. If anything, such a check would guarantee a high success rate for regular verb none) than on incorrectly spelled verb homophones (i.e., failing to identify a spelling error when there was one).
forms. At this point, one might argue that the spelling check of this morpheme-based processing can often not be terminated in time, causing a high error rate. This may well be true, but the implication of such a statement would be that, in contrast to the situation for stem-final d verbs, homophones from weak prefix verbs have no or very weak whole-word representations that mediate recognition upon a failure of the morpheme-based process. It seems that the data compel us to accept such a conclusion. However, bearing in mind that there was no significant difference between the homophone ratios for the stem-final d and the weak prefix verbs (cf. \( t = 1.05, p = .3 \)), both verb types have equal opportunities for producing an effect of Homophone Dominance. Therefore, it is very unlikely that whole-word representations would have developed for one verb type but not for the other. The latter statement seems supported by the finding of an effect of Homophone Dominance for both stem-final d verbs and weak prefix verbs in the production experiments, although the effect for weak prefix verbs was also less outspoken in these experiments. These findings suggest that weak prefix verb homophones do have whole-word representations, but that these might be much weaker than those for stem-final d verbs (a) such that they can be used for production purposes (i.e., spelling) but (b) cannot be accessed sufficiently fast in perception experiments. Moreover, the perception data for weak prefix verbs are also likely to be masked by additional noise factors. As mentioned earlier, an important difference to bear in mind is the syntactic mismatch between the PT and PP context. We will return to the reasons for this systematic absence of an effect of Homophone Dominance for weak prefix verbs in the General Discussion (Chapter 4).

In the next two sections, we will present and discuss the results for the intrusion errors at the sublexical level. First, we will present the data for the past tenses included in the experiment on stem-final d verbs (s vs. p verbs) and then turn to the results for the past tenses included in the experiment on weak prefix verbs (st vs. rt-nt verbs). The former set of past tense forms examines a sharper contrast concerning sublexical homophony than the latter
set. The verb forms that will be reported in 4.2.3 contrast spelling errors where an incorrect sublexical string is homophonous to the correct substring (i.e., a string that occurs in other past tense forms) to spelling errors where an incorrect sublexical string does not appear in the spelling of any Dutch word (form). The verb forms that will be reported in 4.2.4 contrast spelling errors where an incorrect substring is homophonous to the correct substring (i.e., occurs in both other past tense forms and words from other lexical categories) to spelling errors where an incorrect substring does occur in other words, but not in other past tense forms (i.e., only in words from other lexical categories).

4.2.3. Past tense verb forms: s vs. p verbs

4.2.3.1. Hypothesis

The findings of the online visual word recognition and sentence reading experiments performed so far suggest that lexical access to Dutch past tense forms is not strictly morpheme-based. Since sublexical intrusions on these forms involve an illegal combination of a non-stem and a past tense suffix, they should always lead to a processing delay compared to their correctly spelled forms, if they were decomposed into their constituent morphemes. However, the results of the perception experiments (PDT and SPRT) reported earlier indicate that sublexical intrusions do not delay RTs when the erroneous orthographic pattern appears in phonologically similar words whose final orthographic sequence has the same pronunciation as that of the correct spelling pattern. Crucially, this orthographic pattern does not coincide with a morphemic boundary, but crosses it (i.e., consists of the stem-final letter(s) and the suffix). This suggests that the effect of sublexical homophony is not mediated by a morphological parsing device.

However, it remains a question whether errors involving a sublexical homophonous cluster will also go unnoticed more often during proofreading. 

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98 This section is the result of a collaboration with Astrid Schoenmaeckers in the context of her master’s thesis.
§ 3 THE HOMOPHONE DOMINANCE EFFECT IN PERCEPTION

If so, these errors would not only affect lexical processing during perception, but also (sometimes) escape a conscious spelling check. In that case, their impact on lexical processing would make them more vulnerable to detection failures, which would offer a second account of their presence in written texts (besides the factors causing their emergence during spelling in the first place).

The present experiment tests this hypothesis by contrasting sublexical intrusions in the past tense forms of s verbs (e.g., *sustte) and p verbs (e.g., *reptte). Recall that s verbs exhibit sublexical homophony (e.g., rustte, ‘rested’), whereas p verbs do not involve a homophonous pattern, as no single past tense or other word ends in the orthographic sequence ptte. If participants are sensitive to the occurrence of cross-morphemic letter strings, intrusions of the former type (e.g., *sustte), which are orthographically acceptable in other verb forms (e.g., rustte), should be overlooked as an error more often than the latter (e.g., *reptte) (i.e., a main effect of Sublexical Homophony). A purely morpheme-based processing mechanism, however, predicts that the errors for both verb types should be noticed equally often.

4.2.3.2. Method

See Section 4.2.1.2.

4.2.3.3. Results and Discussion

After assigning a 0-score to misses and a 1-score to hits, participants who detected all sublexical intrusions (n = 21) were removed from the data set, as were participants who did not detect any intrusions (n = 3) or had more than 25% missing values (n = 5). We will report the analysis that covers all responses, i.e., those made within the 7-minute time limit and those made outside this time frame. We analyzed the remaining 341 observations (missing values n = 11) by means of a generalized linear mixed effects model with a

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99 After deleting these participants from the data set, the distribution of participants across versions was the following (ignoring the two randomizations): 1A (n = 6), 1B (n = 9), 2A (n = 6), 2B (n = 7), 3A (n = 8), 3B (n = 8).
binomially distributed dependent variable (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). Likelihood ratio tests determined which of the following control variables should be included into the final model: Length, Trial, Log Whole-word Frequency and Log Lemma Frequency. Next, the variable of interest, namely Sublexical Homophony was entered into the model. The random structure of the model is justified by the design and includes a by-participant random intercept, a by-participant random slope for Sublexical Homophony, as well as a by-item random intercept. Table 41 shows the results of the final model, partial effects of which are visualized in Figure 41.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>$\beta$</th>
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<th>$\chi^2$</th>
<th>$p(&gt;\chi^2)$</th>
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<td>.005</td>
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<td>-4.49</td>
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</table>

Table 41. Coefficients of a mixed logit model predicting the probability of detecting an intrusion error from Log Lemma Frequency and Sublexical Homophony, together with their estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.
Discussion. The analysis revealed a significant effect for the control variable Log Lemma Frequency. Intrusions were overlooked more often as verbs’ lemma became more frequent. We propose a similar account as for the effect of lemma frequency in the PRT with stem-final d verbs. Rather than activating the whole-word representation of an existing homophone, as in the case of lexical intrusions, the incorrect past tense spelling will partially activate the
whole-word representation of the correct spelling. Due to the large orthographic overlap, this partial activation will suggest the existence of the form and thus cause more detection errors in comparison to incorrect verb forms that partially activate LF word representations (which take longer to access and are detected more often as an error). This mimics the results with $s$ and $p$ verbs in a SDT, where fewer errors were made as lemma frequency increased (i.e., verbs with a high lemma frequency were accepted more easily). As mentioned earlier, this emphasizes that the PRT is the naturalistic version of the SDT (see also below).

Moreover, the effect of Sublexical Homophony was also significant: sublexical intrusions were left undetected more often for past tense forms with a sublexical homophonous cluster ($s$ verbs) than for past tense forms whose incorrect orthographic pattern is non-existent ($p$ verbs). The results confirm our hypothesis that spelling errors on verb forms without sublexical homophony (i.e., $p$ verbs) should be noticed more often than intrusions on verb forms whose incorrect spelling was supported by the existence of an orthographic pattern in phonologically similar words (i.e., $s$ verbs). For the latter verb type, the incorrect word-final letter string $stte$ occurred in other past tenses and was homophonous to the correct sublexical spelling pattern. In other words, the presence of a homophonous word-final pattern in other past tenses does not only affect lexical processing of sublexical intrusions on past tense forms, making them easier or more difficult to process depending on the experimental task (cf. online perception experiments), but also causes these intrusions to be overlooked more often in a PRT, i.e., a reading task involving conscious error detection.

The nature of a PRT comes closest to the nature of a spelling decision task in the series of online perception experiments. In both cases, participants are explicitly instructed to detect spelling errors. In the SDT with past tense forms (also $s$ vs. $p$ verbs), a main effect of Sublexical Homophony was observed – responses to past tenses of $s$ verbs being longer than responses to

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100 The correlation between lemma and whole-word frequency being .92 in this experiment.
past tenses of $p$ verbs – in the absence of an interaction with Spelling. The presence of two sublexical homophonous letter strings in the case of $s$ verbs apparently created doubt (leading to slow responses), whereas the presence of a single sublexical spelling pattern in the case of $p$ verbs created clarity (leading to fast responses). It is likely that the same underlying process was operative in the proofreading task: participants were sure that the past tense with the ptte-pattern did not exist and immediately noticed the spelling error. In contrast, they were familiar with the stte-pattern, which may have supported the acceptance of the form and the consequent failure to (consistently) notice that they were dealing with a spelling error. This caused significantly fewer correct error detections of sublexical homophone intrusions on $s$ verbs than on $p$ verbs.

If participants relied solely on a morpheme-based processing mechanism, the detection rates for the two verb types should not have differed. Therefore, we conclude that readers do not rely solely on a decomposition mechanism, but are also sensitive to the frequency of orthographic patterns that straddle the morpheme boundary. Stated otherwise, Homophone Dominance is also responsible for not noticing intrusion errors during proofreading, more particularly, when these errors involve a sublexical homophonous cluster.

4.2.4. Past tense verb forms: $st$ vs. $rt$-$nt$ verbs

4.2.4.1. Hypothesis

In the PDT, we showed that RTs to past tenses exhibiting sublexical homophony within and outside the verbal paradigm ($st$ verbs) did not differ from RTs to verbs that only display sublexical homophony outside the verbal paradigm ($rt$-$nt$ verbs). For $st$ verbs, the correct stte-pattern in past tenses such as $testte$ (‘tested’) is homophonous with the ste-pattern in, for instance,
suste (‘hushed’) and feministe (‘feminist’). For rt-nt verbs, the correct rtte/ntte-pattern in past tenses such as startte (‘started’) or plantte (‘planted’) is homophonous with the rte/nte-pattern in adjectives and nouns only, for instance, zwarte (‘black’) or lente (‘spring’). We concluded that familiarity with a sublexical orthographic pattern is determined by its occurrence frequency in all words containing that pattern and is not restricted to forms from the past tense paradigm itself. To further support this claim, we performed the current proofreading experiment: we tested whether sublexical errors on the past tenses of both verb types were also noticed equally often when participants are explicitly checking for errors. If the familiarity with a sublexical orthographic pattern is indeed insensitive to lexical categories, the detection rate should be similar for st and rt-nt verbs. If this orthographic familiarity is restricted to the verbal paradigm, however, errors should be detected more often for rt-nt verbs (no homophony within the verbal paradigm) than for st verbs (sublexical homophony within the verbal paradigm).

4.2.4.2. Method

See Section 4.2.2.2.

4.2.4.3. Results and Discussion

Hits and misses were assigned a score of 1 and 0, respectively. Participants who detected all or no sublexical errors ($n = 14$ and $n = 6$) were removed from the data set, as they contribute no variance across the experimental conditions. In total, there were 492 observations from 62 participants left (missing values $n = 4$). The analysis reported below covers all responses, also those outside

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102 The participant distribution across versions after participant removal was the following (ignoring the difference between the two randomization orders): 1A ($n = 9$), 1B ($n = 10$), 2A ($n = 11$), 2B ($n = 12$), 3A ($n = 8$) and 3B ($n = 12$).
the 7-minute time limit. A generalized linear mixed effects model was fitted to the data (see Section 1.1.1.3 of Chapter 2 for the full statistical procedure). The following control variables were tested for inclusion: Length, Trial, Log Whole-word Frequency and Log Lemma Frequency. The manipulated variable in this case was Sublexical Homophony within the verbal paradigm (yes for st verbs vs. no for rt-nt verbs). The random structure justified by the design contains a by-participant random intercept, a by-participant random slope for Sublexical Homophony, as well as a by-item random intercept. The results of this regression analysis are displayed below in Table 42. Partial effects of this model are plotted in Figure 42.

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<tr>
<th>Parameter</th>
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</tbody>
</table>

Table 42. Coefficients of a mixed logit model predicting the probability of detecting an intrusion error from Log Whole-word Frequency and Sublexical Homophony, together with their estimate $\beta$, standard error, $z$-value, $\chi^2$-value and $p$-value.
Discussion. The control variables Trial and Log Whole-word Frequency yielded significant effects, with more detection failures (a) as the experiment progressed and (b) as the (correct) verb form itself became more frequent. More importantly, the effect of Sublexical Homophony was not significant: intrusion errors on *st* verbs were noticed equally often as those on *rt-nt* verbs.

The finding that more detection errors were made when the whole-word frequency of the (correctly spelled) past tense forms increased confirms the earlier effects of lemma frequency in the PRTs with stem-final *d* verbs and
past tenses of s versus p verbs. The same explanation obtains as for the past tenses in the previous experiment: partial activation of the HF whole-word representation of the correct spelling makes participants accept the intrusion, leading to more detection failures.\textsuperscript{103} The finding of an effect of lemma or whole-word frequency on the number of detection failures on three different occasions emphasizes the reliability of the effect.

The current findings also corroborate our hypothesis that the familiarity of a sublexical orthographic pattern is not only determined by the words or word forms in a particular grammatical category (in the present case: past tenses), but is based on all words exhibiting that pattern, provided that this pattern has the same pronunciation and the same position in these words\textsuperscript{104}. If the detectability of sublexical intrusions on past tense forms were only determined by the existence of homophonous clusters within the past tense paradigm, errors on st verbs (sublexical homophony within and outside the verbal paradigm) should have been more difficult to detect than errors on rt-nt verbs (homophony outside the verbal paradigm only). Rather, detection rates did not differ between both verb types, suggesting that sublexical homophony from both within and outside the verbal paradigm affects the familiarity of a sublexical letter string and, hence, the probability of detecting an error. Interestingly, the finding that familiarity with a sublexical string is not restricted to the verbal paradigm confirms the findings of the PDT, where intrusions for both verb types did not delay RTs. Note also that a morphological decomposition process would predict that all sublexical intrusions would be equally detectable (i.e., a 100% success rate for both verb types).

This finding for st and rt-nt verbs stands in contrast with the results of the PRT targeting the other sets of past tense verb forms (s and p verbs), where we did find a difference between the two verb types: intrusions on past

\textsuperscript{103} The correlation between lemma and whole-word frequency was .79 in this experiment.

\textsuperscript{104} As homophonous relationships between sublexical patterns in all our experiments were based on substrings sharing their pronunciation and word position, we cannot generalize beyond this subset.
tenses with a sublexical homophonous cluster in their verbal paradigm (i.e., \textit{s} verbs) were noticed less often than matched sublexical errors whose incorrect orthographic pattern did not occur in the past tense paradigm or in any other written word and, hence, was not a homophonous intruder (i.e., \textit{p} verbs). However, despite this contrast, the explanation boils down to the same logic: spelling errors on past tense forms where an intruding letter string is homophonous to the correct spelling of the substring (i.e., occurs in other word forms) give rise to a considerable number of detection failures (\textit{s} verbs, \textit{st} verbs, \textit{rt-nt} verbs), whereas matched spelling errors whose misspelled letter string does not occur in other word forms are more easily detectable and yield significantly fewer detection errors (\textit{p} verbs). Note that the average detection rate was similar for both experiments, namely 63.5\% (\textit{st} and \textit{rt-nt} verbs) and 62.6\% (\textit{p} and \textit{s} verbs). Consequently, the absence of an effect for the contrast between \textit{st} verbs and \textit{rt-nt} verbs is not due to a difference in the overall detection rate across the two experiments. Taken together, these findings suggest that the orthographic familiarity of a sublexical letter string is insensitive to (a) morpheme boundaries and (b) lexical categories.

5. Conclusion of Chapter 3

In Chapter 3, we examined whether the persistence of (sublexical) homophone intrusions in carefully re-read texts is due to the fact that the Homophone Dominance effect is not only operative during production, but also during perception. This would mean that the mental lexicon traps language users twice. During production, it would put forward the most frequent homophone or the competing sublexical homophonous cluster, leading to homophone intrusions when the alternative spelling is required. During perception, these high-probability intrusions would be processed more quickly and/or overlooked more often. We contrasted the results from online experiments, where verb forms were presented either in isolation (LDT), embedded in a minimal (i.e., one- or two-word) grammatical context (SDT and PDT) or embedded in a full sentence context (ETT, SPRT and MT) to those of an offline
experiment (PRT). We targeted both intrusions at the lexical level, i.e., intrusion errors corresponding to inflected verb forms (stem-final d or weak prefix verb forms) and at the sublexical level, i.e., intrusion errors corresponding to a sublexical pattern (past tense forms). The sublexical pattern we investigated was a letter sequence consisting of a stem-final consonant (cluster) and an inflectional suffix. An overview of the results can be found in Figure 43:

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Figure 43. Overview of the results from Chapter 3. ✓: no significant effect; ✓: significant effect conform the hypothesis; (✓): marginally significant effect; hatched: not available; HD = Homophone Dominance effect; LEMMA = Log Lemma Frequency effect.

In a first experiment – a lexical decision task – we asked participants to decide whether visually presented isolated verb forms were existing Dutch words. We will first discuss the results for lexical homophones. In the absence of a grammatical context, both homophonous forms of a verb were obviously correct spellings. Since a morphosyntactic analysis is impossible under such conditions (there being no grammatical context), this experiment provided the ideal conditions for a purely decomposition-based processing mechanism. What makes morpheme-based processing of homophonous regular verb forms so time-consuming (as demonstrated in spelling experiments) is not so much the process of morphological decomposition itself as the subsequent process in which the spelling of the inflectional suffix is compared to the grammatical properties of the word determining its spelling, i.e., the verb form’s marker. It is the process of identifying this marker in working memory that consumes a lot of attentional resources. Hence, when regular verb forms are presented in isolation, morphological decomposition would be expected to be a very fast
process, likely to overtake a whole-word based access process. Nevertheless, we found that the speed with which homophonous forms of stem-final d verbs were processed depended on the frequency relation between these two homophones, indicating a strong role for their whole-word frequencies. RTs to d-forms decreased as verbs became more d-dominant, whereas they increased as verbs became more dt-dominant (and vice versa for dt-forms). Since homophones were not embedded in a sentence context — such that working memory resources were not allocated to this task — it is surprising that participants still accessed whole-word representations for these regular verb forms.

The LDT also allowed us to directly compare whole-word frequency effects for regularly inflected homophones and non-homophones Dutch verbs. A non-homophous verb form is spelled as it sounds (i.e., adheres to the phonological principle). In contrast, much more abstract morpheme-based spelling rules are needed to spell homophones, as applying the principle ‘spell what you hear’ would result in identical spellings for grammatically different verb forms, something which is avoided in Dutch spelling. The results showed that lexical decision latencies decreased as homophones’ whole-word frequency increased (cfr. supra). Conversely, whole-word frequency did not affect the processing speed of non-homophous verb forms. We suggested that homophones are by definition more heavily dependent on an orthographic representation than their non-homophous counterparts. For the latter verb forms, the orthographic representation is redundant to their phonological representation (there often being a one-to-one mapping between the phonemes and graphemes). For homophones, however, the existence of two spelling patterns for a single phonological representation necessitates the development of two orthographic representations to be able to discriminate between the two forms.

Since the LDT yielded significant results for stem-final d verbs, we expected Homophone Dominance to also affect the results for the second type of Dutch verbs with homophones in their paradigm, namely weak prefix verbs.
While participants in earlier *spelling* experiments preferred the HF homophone of a weak prefix verb (Assink, 1985; Bosman, 2005; Sandra et al., 1999; see also the online spelling-to-dictation task in Chapter 2), we did not find any evidence supporting the idea that readers access whole-word representations when confronted with isolated verb forms: the HF homophone was not processed faster in comparison with its LF counterpart. Since the same task (LDT) yielded significant frequency effects for the homophones of stem-final d verbs, we concluded that the absence of a Homophone Dominance effect for weak prefix verbs was not due to the LDT being insensitive to whole-word frequency effects of (homophonous) regular verb forms. Furthermore, we also ruled out the possibility that differences in the results for stem-final d and weak prefix verbs were due to higher frequency ratios for the stem-final d verbs (making an effect of Homophone Dominance more detectable). A plausible suggestion for the lack of a Homophone Dominance effect in the LDT with weak prefix verbs is the strong association between their prefix and the past participle d-spelling of the inflectional suffix. The resulting d-bias may have been particularly strong in an isolated word recognition experiment and have masked a whole-word frequency effect of the homophones. As this effect may be expected to be less pronounced when the verb forms are embedded in a syntactic context (which requires the checking of the suffix spelling), we hypothesized that an effect of Homophone Dominance would emerge when these verb forms were embedded in a minimal context that required a morphosyntactic analysis (see below for the outcome in the phonological decision task).

A second visual word recognition experiment was a SDT. This time, homophonous forms of stem-final d verbs were embedded in a minimal (i.e., one-word) grammatical context, the verb form being preceded by a personal pronoun *ik/hij* (‘I/he’). Participants had to decide whether these two-word combinations were correctly spelled in Dutch, given the preceding grammatical context. Contrary to the LDT, where all verb forms required a yes-response (i.e., both verb forms being existing words), the preceding subject now determined whether the homophone was spelled correctly or not.
Correctly spelled verb forms required a yes-response (e.g., *hij meldt*), whereas incorrect spellings required a no-response (e.g., *hij *meld*). Because marker and verb form were adjacent, the morphosyntactic analysis that is necessary to make a correct response should be relatively easy and fast, i.e., not create a large burden on working memory. If readers attempt to rely on a morpheme-based mechanism implementing the spelling rule in order to assess the spelling correctness of the verb homophone, this experiment should reveal its operation. In contrast to what might be expected, the results for stem-final d verbs once again (as in the LDT) exhibited a pattern that is consistent with whole-word retrieval. For correct spellings (yes-responses), RTs to HF homophones were significantly shorter than those to LF homophones. In contrast, when having to reject the homophone as an incorrect spelling (no-response), RTs were longer for the HF form than for the LF one. The delay found in the incorrect spelling condition is the result of a response conflict: since incorrect spellings require a no-response, the initial tendency to give a yes-response to the HF homophone due to its orthographic familiarity has to be overcome. As the HF homophone was accepted more quickly than the LF one when spelled correctly, but dismissed more slowly than the LF one when spelled incorrectly, these results unambiguously indicate the involvement of whole-word representations for the homophones of stem-final d verbs in the SDT as well. Note that the fact that whole-word representations of the homophones clearly played a role in this task does not deny the possibility that participants’ decisions may also have been based on the output of a morpheme-based computational process on a number of occasions (decomposition followed by a suffix spelling check). Our findings only indicate that the morpheme-based processing mechanism was occasionally bypassed by a process of whole-word access, which is a crucial observation for the research question underlying this chapter.

Contrary to lexical intrusions, where both spellings represent existing words, sublexical intrusions can be detected by making use of a morphological analysis only. In the case of a lexical intrusion, a morphological decomposition process yields a legal combination of a stem and an inflectional suffix, such
that error detection is only possible by comparing the suffix spelling to the grammatical properties of the homophone’s marker. However, in the case of sublexical intrusions, simple morphological decomposition reveals the spelling error. For instance, when stripping off the te-suffix (or the allomorphic variant -de when the stem-final consonant is voiced) in an incorrectly spelled past tense form, the remaining letter string does not represent an existing verb stem (e.g., *sustte > non-stem *sust + -te). We argued that such a morphological decomposition process does not (always) take place, but that language users may also be sensitive to the recurrence of homophonous letter strings that sometimes straddle the morpheme boundary (e.g., the pattern stte in *sustte ‘hushed’, where the morpheme boundary is situated in-between the two t’s). Therefore, these sublexical clusters (and their occurrence frequency) should not play a role when lexical access is always mediated either by a process of whole-word access or a process of morpheme-based access.

In production (i.e., in an offline and online spelling-to-dictation task discussed in Chapter 2), we found that sublexical intrusions were more likely to occur for past tenses whose correct word-final orthographic pattern is homophonous to that of other past tenses with an alternative spelling (s verbs; e.g., *sustte instead of suste, analogous to rustte) in comparison with past tenses without such sublexical homophony (p verbs; e.g., repte; no words ending in ptte). Since the incorrect, but homophonous orthographic pattern did not coincide with a morphemic letter string, we concluded that regular past tense forms are not only spelled by means of a rule-based mechanism. The results cannot be explained without taking recourse to a process that is sensitive to the co-occurrence frequencies of letter and sound sequences and thereby ignores linguistically relevant distinctions.\textsuperscript{105} Based on these findings, we hypothesized that a similar process might be operational in visual word recognition as well. Whereas regular verb forms like past tenses may well be decomposed into their constituent morphemes on many occasions or be

\textsuperscript{105} However, the results obviously do not rule out spellers’ reliance on a concatenative process, nor their reliance on a whole-word retrieval mechanism for other regular verb forms.
recognized on the basis of whole-word access when they have a sufficiently high frequency, it seems likely that the repeated co-occurrence of letter and sound patterns also makes these patterns salient ‘units’ during visual word recognition. Hence, we hypothesized that the sublexical intrusions that were made most often in production (i.e., those involving a sublexical homophonous pattern) would be processed more quickly in perception, too.

We performed a SDT with a minimal (i.e., one-word) grammatical context to examine whether sublexical intrusions in past tense forms, involving an illegal combination of a non-stem and a suffix, are processed solely via a decomposition or also activate word forms in which the erroneous letter pattern is a homophone of the correct spelling. Participants were asked to judge the spelling correctness of two-word combinations, consisting of the personal pronoun hij ('he') and (in)correctly spelled past tense forms (e.g., hij suste versus hij *sustte). Contrary to what a morphological decomposition account would predict, RTs to verb forms with a homophonous pattern at the sublexical level (s verbs) differed from those to forms whose correct spelling did not have a sublexical homophone (p verbs). Participants experienced more difficulties when having to respond to both the correct and incorrect spellings of the past tense of s verbs compared to p verbs. The pronunciation of the final part of past tenses from s verbs corresponds to two orthographic patterns, giving rise to confusion and a consequent response delay relative to past tenses of p verbs, for which the pronunciation of their word-final part corresponds to a single spelling only.

To eliminate the response conflict observed for stem-final d verbs in the SDT, we performed a PDT in which participants had to judge the phonological acceptability of the same two-word combinations (i.e., “does this letter string sound as an acceptable Dutch utterance?”). In other words, a yes-response had to be given to both correct and incorrect spellings, which required participants to ignore the spelling errors in order to give a correct response. For stem-final d verbs, we found that response speed increased as the presented form became the more frequent homophone of a verb pair, both when spelled correctly and incorrectly. In contrast to what we observed in the
SDT, incorrect spellings now behaved like correct spellings. As an incorrect spelling also required a yes-response, the familiarity of the HF homophone did not cause a response conflict in this task. This Homophone Dominance effect confirmed our conclusion from the SDT: a process of whole-word access is operative during visual word recognition of stem-final d verbs, even when the marker is adjacent. Note, once more, that this fingerprint of a whole-word access process does not preclude the parallel use of a morpheme-based processing mechanism and, therefore, does not exclude the possibility that each mechanism ‘won the race’ on a number of occasions. In contrast, weak prefix verbs did not give rise to any processing advantage for the HF homophone in this PDT, as was the case in the LDT and SDT. We concluded that whole-word access for homophonous weak prefix verb forms was not triggered by the presence of a minimal grammatical context or was masked by another factor (e.g., a d-bias).

Finally, the phonological decision task used the same set of s and p verbs to examine whether the existence of homophony at the sublexical level affects RTs to past tense forms in a task focusing on pronunciation rather than spelling (i.e., a yes-response had to be given to both the incorrect and correct spellings). While a decomposition account predicts that incorrect spellings will lead to a similar delay for both verb types (i.e., due to an incorrect parse), the results showed that this was not the case. There was no processing delay for the incorrect spelling of s verbs, whereas such a delay was found for the incorrect spelling of p verbs. Both sublexical errors are impossible from a morphological perspective and would, hence, be equally quickly rejected by a morphological decomposition process. However, errors involving an orthographic pattern that was homophonous to the correct spelling pattern, i.e., one that is supported by a pattern appearing in phonologically similar past tenses (e.g., *sustte in analogy to rustte ‘rested’, tastte ‘touched’, pestte ‘bullied’, etc.) were accepted more quickly than those involving a non-existent pattern that has the same pronunciation as the correct pattern (e.g., *reptte). The delay between the correct and incorrect spellings of p verbs results from overcoming a response conflict between the required yes-response and the no-
response that is triggered by the unacceptability of the orthographic pattern in the incorrect spelling form. When not having to make a judgment on spelling correctness (as in the SDT), but when having to ignore spelling errors (as in this PDT), the sublexical homophony characterizing the past tenses of s verbs did not cause a processing delay compared to the past tenses of p verbs. In a PDT, the presence of two orthographic patterns for a single pronunciation does not create confusion as it did in the SDT. Quite on the contrary, it is a clear signal that the presented verb form has an existing pronunciation. This demonstrates that the same representational differences between s and p verbs lead to different response patterns for these verbs, depending on task demands.

The phonological decision task also allowed us to answer the question whether the familiarity of a sublexical homophonous cluster (for past tenses) is restricted to the verbal paradigm or is co-determined by all words in which that pattern occurs. The results showed that RTs on incorrect past tense forms of verbs with a homophonous pattern that appeared only outside the verbal paradigm (rt-nt verbs; e.g., startte, ‘started’ or plantte, ‘planted’) were not delayed relative to their correct spelling, as was also the case for verbs with sublexical homophony both within and outside the verbal paradigm (i.e., st verbs such as testte, ‘tested’). If sublexical orthographic familiarity were only determined by the presence of a letter string within the verbal paradigm itself, incorrect spellings of st verbs should have been accepted more easily than those for rt-nt verbs. Since (a) spelling errors on past tenses containing a sublexical homophonous pattern did not lead to a response delay relative to their correct spelling and (b) there was no effect of the locus of sublexical homophony (within or outside the verbal paradigm), we conclude that sublexical intrusions – although they are impossible from a morphological perspective – are processed more quickly when they involve an existing orthographic pattern (s, st and rt-nt verbs) than when the erroneous pattern is non-existent (p verbs). These findings also confirm the conclusion for s verbs, i.e., that the existence of two orthographic patterns for a single pronunciation is a clear signal that the verb form sounds correctly, so that a yes-response in a
PDT can (quickly) be given. Moreover, we can conclude that the familiarity of such a sublexical orthographic pattern is insensitive to (a) morpheme boundaries and (b) lexical categories.

While this series of visual word recognition experiments provided evidence that Homophone Dominance affects the processing of stem-final d verbs (lexical level) and past tense forms (sublexical level), this does not necessarily imply that readers benefit from a frequent orthographic word form or sublexical pattern when processing homophone intrusion errors during sentence reading. Four experimental tasks were used to examine the impact of homophone intrusions on sentence reading, both at the lexical and sublexical level: an eyetracking task, a self-paced reading task, a maze task and a proofreading task.

In the most natural reading task – the eyetracking experiment – we found a non-significant but very strong trend of Homophone Dominance for stem-final d verbs \( (p = .059) \): dt-intrusions embedded in a sentence context tended to receive shorter total reading times when the dt-form was the homophone of the verb pair with the higher frequency. Crucially, this trend was only visible when the spillover area was taken into account. More specifically, it was distributed over the three-word region starting with the homophone and including two words following it (i.e., \( x, x+1 \) and \( x+2 \)). Spillover effects are not an exceptional finding in eye tracking experiments (e.g., Bertram, Hyönä, et al., 2000). For past tenses, the eyetracking data revealed that the delay in total reading times associated with a sublexical error was the same for errors whose letter pattern was non-existent (i.e., for \( p \) verbs) as for errors that contained homophonous letter patterns, i.e., which were supported by other past tenses (i.e., for \( s \) verbs). The results mimicked those of the spelling decision task: both reaction times and total reading times were equally delayed by a sublexical intrusion (i.e., an effect of spelling) for both \( s \) and \( p \) verbs. Moreover, past tenses with a homophonous cluster at the sublexical level had significantly longer reaction and total reading times than those with no such homophonous relation, both when spelled correctly and incorrectly. It seems that in both the SDT and ETT, participants did not take
advantage of the existence of homophonic letter strings (ste vs. stte) but were disturbed by the ambiguity they caused. We argued that each task presenting a strong focus on spelling correctness (the SDT, but there are reasons to believe that the materials in the ETT also triggered such a focus) caused participants to encounter problems whenever two sublexical orthographic patterns are associated with the same pronunciation. Understandably, this ambiguity caused a processing delay, which is reflected in the dependent measure (i.e., reaction time or total reading time).

We hypothesized that a high skipping rate could be responsible for the observation that the effect of Homophone Dominance was only marginally significant at the lexical level and that the interaction between Spelling and Sublexical Homophony was nonsignificant at the sublexical level. To address this problem, we performed a self-paced reading task, requiring a response to each individual word (i.e., word skipping is not allowed).

For stem-final d verbs, we obtained an effect of Homophone Dominance in the SPRT: sentences containing both d-intrusions and dt-intrusions were processed more quickly as the presented homophone became the more frequent homophone of a verb pair. This effect only manifested itself in the spillover region, i.e., on the second word following the critical verb form. The SPRT was also performed with weak prefix verbs, which did not yield an effect of Homophone Dominance in the visual word recognition tasks. When discussing the latter experiments, we argued that the strong association between a weak prefix and the d-spelling of the inflectional suffix may have masked an effect of Homophone Dominance. This does not mean that whole-word access did not occur on some occasions (causing faster responses to intrusions of the HF homophone), but this may have been countered by a strong d-bias. The situation, however, is likely to be different when the intrusions are embedded in a sentence context that separates verb form and marker, as in the SPRT. Since both homophones are morphologically correct forms, a morphological decomposition mechanism needs to be complemented by a time-consuming and resource-consuming checking mechanism that verifies whether the spelling of the inflectional ending matches the
morphosyntactic properties of the marker. As marker and verb form are removed a number of words from each other, it becomes quite effortful for working memory to retrieve the required morphosyntactic information in time. Hence, the whole-word retrieval route might achieve lexical access before this check can be completed, which would produce an effect of Homophone Dominance. In the visual word recognition tasks with weak prefix verbs, such a resource-consuming morphosyntactic analysis was either impossible because there was no syntactic context (in the LDT) or relatively easy because the marker and verb form were adjacent (in the PDT). The results of the SPRT, however, did not confirm our prediction that an effect of Homophone Dominance would emerge when weak prefix verbs were embedded in a sentence context: homophone intrusions corresponding to the HF homophone were not processed more quickly than those corresponding to the LF one. Crucially, not only the involvement of whole-word representations (measured by the effect of Homophone Dominance) was absent, but that of lemma frequency was too. Because the SPRT did not yield significant results for either of the two frequency effects, we were unable to draw any conclusion with respect to the processing of the homophones of weak prefix verbs embedded in a sentence context.

The results for past tense forms in the SPRT confirmed that Homophone Dominance at the sublexical level (i.e., the presence or absence of a sublexical homophonous letter pattern) modulates RTs during sentence reading. As in the PDT, an incorrect spelling (i.e., a sublexical intrusion) delayed RTs to \(p\) verbs but not to \(s\) verbs. For the latter verb type, the incorrect spelling pattern was supported by its appearance as a sublexical orthographic cluster in other past tenses, being homophonous with the to-be-spelled cluster. For \(p\) verbs, however, such a sublexical homophonous cluster is non-existent, causing a delay for the incorrect spelling. Since both clusters cross the morpheme boundary, a decomposition mechanism should have yielded a comparable processing delay for the incorrect spellings of both verb types. Crucially, this effect was not found in the spillover region (as for stem-final d verbs), but was located on the verb form itself. The fact that the impact of a
spelling error arose on the verb form itself makes sense as the spelling correctness of a past tense form can be assessed by analyzing the verb form itself (the spelling of the morphemes in the word structure being correct or incorrect). In contrast, assessing the spelling correctness of a verb homophone at the lexical level requires the identification of the grammatical properties of its marker, which is a time-consuming process. Note that in the SPRT and PDT, a processing delay was restricted to the incorrect spelling of the past tense for \( p \) verbs, in contrast to equal processing delays for the incorrect past tense forms of both verb types in the SDT and ETT tasks (combined with a main effect of Sublexical Homophony). These findings suggest that the SPRT and PDT tasks caused participants to be less focused on the spelling of the verb forms than the other two tasks.

One of the most striking results of the online perception experiments is the systematic dissociation (across all experiments reviewed so far) between the results for stem-final \( d \) verbs and weak prefix verbs. Whereas verbs of the former type always give rise to an effect of Homophone Dominance (with the exception of a borderline significant effect in the ETT), verbs of the latter type never yield this effect. A possible reason for the failure to observe an effect of Homophone Dominance for weak prefix verbs is the strong \( d \)-bias that is created by the high co-occurrence frequency of the weak prefix and the \( d \)-spelling of the suffix. Although we argued that this bias might have a smaller effect in a sentence reading task, the SPRT only confirmed the absence of an effect of Homophone Dominance for weak prefix verbs. However, we wanted to exclude the possibility that different spillover effects for the two homophones caused the Homophone Dominance effect (and lemma frequency effect) to be undetectable for weak prefix verbs, due to the different syntactic contexts associated with these homophones (i.e., PT vs. PP context). Therefore, we performed a maze task, which has been shown to be less sensitive to spillover effects since the task requires full integration of a word before participants can make a correct forced-choice decision and move on to the following word in the sentence.
To validate this task for targeting whole-word frequency effects, we first examined stem-final d verbs. The Homophone Dominance effect indeed appeared on the verb form itself, allowing us to extend our conclusion from the SPRT: homophones of stem-final d verbs are accessed as whole-word forms, not only during word recognition in isolation and in a minimal (one-word) syntactic context, but also during sentence reading. In contrast, the Homophone Dominance effect was once again absent for weak prefix verbs (as was the effect of lemma frequency). However, an additional analysis of the MT showed that the incorrect d-form in the PT context was initially interpreted as a correct past participle, revealed by the absence of a processing delay relative to a correct d-form in a PP context. This misinterpretation led to a garden-path effect for these forms that emerged on the word following the verb form and is likely to have obscured an effect of Homophone Dominance on the verb form itself. Due to this unforeseen issue with the experimental design, both online sentence readings experiments (i.e., SPRT and MT) were unfortunately uninformative on the involvement of whole-word representations for weak prefix verbs.

The aforementioned studies examined the online processing of homophone intrusions. While they showed that homophone intrusions containing a HF homophone (for stem-final d verbs) or a sublexical homophonous cluster (for past tenses) are processed more quickly than those containing the LF homophone or a non-existent cluster\textsuperscript{106}, it does not directly result that these errors are also more likely to persist in carefully re-read texts. In a final experiment targeting offline reading, we examined whether these dominant spelling errors were also overlooked more often when proofreading texts for errors. For stem-final d verbs, we found that, as verbs became more d-dominant, d-intrusions were left undetected more often than dt-intrusions

\textsuperscript{106} This statement is too general for past tense forms with a sublexical homophonous pattern (either spelled correctly or incorrectly). Such verb forms are processed either faster (PDT, SPRT) or more slowly (SDT, ETT) than matched verb forms whose critical sublexical pattern does not have a homophonous counterpart. This seems to depend on task demands, i.e., a focus on spelling correctness causing verb forms with sublexical homophonous clusters to slow down processing.
§ 3 THE HOMOPHONE DOMINANCE EFFECT IN PERCEPTION

(and vice versa when verbs became more dt-dominant). In short, intrusions corresponding to the HF homophone were overlooked more often than those corresponding to the LF homophone. In contrast, Homophone Dominance did not affect the detection performance for weak prefix verbs: both d- and t-intrusions were overlooked in about 50% of the cases. Importantly, this was not due to guessing, as correctly spelled weak prefix verb forms (added as fillers) were virtually never misidentified as a spelling error. Crucially, neither a d-bias, nor a garden-path effect (the PT context was not ambiguous as in word-by-word sentence reading tasks) can account for the absence of the Homophone Dominance effect.

From a descriptive point of view, there are a number of linguistic differences between the homophones of the two verb types. Firstly, one of the homophonous forms for stem-final d verbs is a stem form (i.e., marked by a zero suffix), whereas both forms of weak prefix verbs have overt suffixes (-t or -d). Secondly, the present tense t-form of weak prefix verbs can be spelled by means of the phonological route ('spell what you hear'; bestelt > [b@stElt], ‘orders’), while the other three homophonous forms require a morphosyntactic analysis to determine the correct spelling. Thirdly, the presence of both a prefix and suffix for weak prefix verbs might favor the operation of the decomposition route compared to verb forms containing only a suffix, as is the case for stem-final d verbs. However, it is difficult to see how these descriptive differences would account for processing differences. If the presence of an inflectional suffix triggers morphological decomposition, the same would apply to the dt-form of stem-final d verbs (ending in the suffix -t). However, in all perception experiments, this dt-form (whether presented as a correct spelling form or as an intrusion error) is processed faster as it becomes the more dominant verb homophone in its verb pair. Hence, the presence of an overt suffix does not prevent that the verb’s dominance affects the processing of this inflected verb form. It is also difficult to see how the phonological spelling of the t-form for weak prefix verb forms could account for the absence of a dominance effect on the non-phonological spelling of the d-form. There is no reason why the latter form (whose spelling is morpheme-based, like the
homophones of stem-final d verbs) would not be subject to the verb’s dominance. Still, none of the perception experiment showed that the d-form of weak prefix verbs is processed faster as its dominance in relation to the t-form increases (whether the homophone is presented as a correct form or as an intrusion error). Finally, there is no evidence in the literature that the presence of a derivational prefix increases the likelihood that an inflectional suffix will be split off. It is also difficult to see how the morphological decomposition of an inflected verb form could be enhanced by the presence of a prefix, as that prefix would first have to be identified and the outcome of this process would have to be communicated to the suffix decomposition process. We will postpone a full discussion about the potential reasons behind the absence of a Homophone Dominance effect for weak prefix verbs to the General Discussion (Chapter 4).

Finally, the proofreading task with past tense verb forms revealed that sublexical intrusions involving an orthographic pattern that appears in other past tenses (s verbs) are not only processed more quickly than those containing a non-existent orthographic pattern (p verbs), as revealed in the online experiments (but see Footnote 106), but also go unnoticed more often during proofreading. Moreover, the detection rate on verb forms exhibiting sublexical homophony outside the verbal paradigm (i.e., rt-nt verbs) did not differ from verb forms whose erroneous orthographic pattern appeared both within and outside the verbal paradigm (i.e., st verbs). This finding confirmed our conclusion from the PDT: the familiarity of a (sublexical) orthographic pattern is determined by how often it appears across all words and not just within the verbal paradigm. As all sublexical intrusions involved an illegal combination of a non-stem and a past tense suffix, a purely decomposition-based account would predict that they should all be equally vulnerable for error detection, regardless of their orthographic familiarity.

Based on the findings of these seven perception experiments, we can draw two major conclusions. Firstly, whole-word representations for homophonous forms of stem-final d verbs are accessed not only during production but also during perception. While whole-word retrieval speeds up
processing for the HF homophone, it also triggers an unwanted side effect: intrusions involving this homophone are also accepted more often as the correct inflectional form. This makes it more likely that such intrusions go undetected in carefully re-read texts. Interestingly, the same factor (Homophone Dominance) accounts both for the emergence of homophone intrusions on regular verb forms during spelling and for the tendency to accept these intrusions during (re-)reading. In contrast, the familiarity of the HF homophone’s orthographic pattern was not responsible for the persistence of intrusion errors on weak prefix verb forms: whereas Homophone Dominance shaped the pattern of the errors during the spelling of such verb homophones, it did not affect their (re-)reading. Crucially, the absence of a Homophone Dominance effect for weak prefix verbs in the online experiments and the offline experiment on error perception was as systematic as the presence of the Homophone Dominance effect for stem-final d verbs.

Secondly, we can conclude that Homophone Dominance at the sublexical level (i.e., the sublexical error being a homophone of the correct letter string or not) is also a key determinant during the perception of past tense verb forms. Since sublexical intrusions are impossible from a morphological perspective (i.e., they consist of a non-stem and a suffix), morphological decomposition should have led to (a) a processing delay compared to correctly spelled past tenses and (b) correct error detection for all intrusion types. Nevertheless, sublexical intrusions on past tense forms were sometimes processed equally quickly as correct spellings (depending on the task, cf. above) and overlooked more often, depending on the familiarity of the orthographic pattern that straddles the morpheme boundary. When sublexical errors involved a sublexical homophonous cluster, they could lead to smaller delays and fewer error detections compared to errors involving a non-existent pattern.
CHAPTER 4

GENERAL DISCUSSION

Although the spelling rules for regularly inflected Dutch verb forms are descriptively simple, homophone intrusion errors on these rule-based forms persist in texts of even experienced Dutch spellers. This stunning paradox was the starting point of the current work. The major hypothesis behind all the experiments is that a systematic study of these errors will unravel the mental representations and the cognitive processes that inevitably lead to such errors on a number of occasions. This dissertation has contributed in two ways to our understanding of these errors by showing how the nature of the representations in the mental lexicon and the processes of lexical access are responsible for their omnipresence, both in written production and visual perception.

1. HOMOPHONE DOMINANCE: A DOUBLE TRAP

A first major insight is that the mental lexicon traps Dutch language users twice: both spellers and readers are vulnerable to frequency-induced homophone intrusions. This refers to the fact that a familiar homophone or homophonous pattern plays a preferential role, which leads to more intrusions of this homophone (string) during spelling and to more acceptances of such intrusions during reading. We will start by reviewing the results for lexical homophones, followed by a discussion of sublexical homophone intrusions.

1.1. Lexical homophone intrusions

1.1.1. Extending previous findings in spelling

The production experiments in this dissertation replicated the pattern of results found in previous spelling studies: spellers had a strong tendency to
write down the HF form of a homophonous verb pair, causing more homophone intrusions when the targeted form was the LF homophone than when it was the HF homophone (Frisson & Sandra, 2002b; Sandra, 2010; Sandra et al., 1999, 2004). This Homophone Dominance effect was observed for the two types of homophonous verbs in Dutch (i.e., stem-final d verbs and weak prefix verbs), both in an experimental and naturalistic setting. The extension of the results obtained under laboratory conditions to the context of spontaneously written messages on a social network site (Netlog) is important, as it shows that the effect of Homophone Dominance also occurs in real-life situations. While it would be difficult to understand how such an effect can arise under experimental conditions without the existence of mental processes and representations that also operate outside the laboratory, one should keep in mind that an artificial context might emphasize the importance of this infrastructure more strongly than warranted by people’s behavior in naturalistic situations. The replication of the earlier effects in the analysis of naturalistic data leads to the reassuring conclusion that the effect of Homophone Dominance also explains the persistence of homophone intrusions on regular verb forms in ordinary writing situations. Moreover, the study of weak prefix verbs in a naturalistic setting also revealed that the most frequent ending of morphological and phonological neighbors (i.e., a token count) co-determined the preferred inflectional ending of a homophonous verb form. Such an effect confirms many earlier findings that neighbors play a crucial role in processing (Bertram, Baayen, et al., 2000; Ernestus & Mak, 2005) and shows that there is more at stake than the competition between two full-form homophonous representations. The role of these neighbors in spelling homophonous verb forms also ties in with the finding that phonological neighbors affect processing of sublexical intrusions throughout the production and perception experiments (see below).

Previous research suggests that the effect of Homophone Dominance emerges because the spelling of a (homophonous) regularly inflected verb form is based on a process of morphological composition that is conscious and time-consuming. Therefore, the spelling of these inflections is sometimes
determined by the first output of an automatic (and fast) frequency-sensitive retrieval mechanism, which is the HF homophone (Sandra et al., 1999, 2004). This suggests that any factor that causes rule application to be slower than lexical retrieval will give rise to the effect of Homophone Dominance. This can be cognitive overload in working memory, caused by a secondary task (Fayol et al., 1994; Largy et al., 1996) or by a large number of intervening words between the marker and the homophone (Sandra et al., 1999). Alternatively, time limitations may impose a temporal deadline on the attentional process and thus sometimes abort this process before it can terminate. However, the theoretical framework also predicts that lack of rule knowledge (i.e., no possibility to apply the rule) and sheer negligence (i.e., no attempt to apply the rule) will cause a strong reliance on the process of whole-word retrieval and thus yield an effect of Homophone Dominance.

It is important to emphasize that, even though the frequency-sensitive process of whole-word access is a source of spelling errors, it does not always yield a homophone intrusion. When the target form is the HF homophone, frequency-based retrieval will yield the correct spelling form. As a matter of fact, this is even the case most often, as the probability that a random occurrence of the homophone is the HF spelling is (by definition) always higher than the same probability for the LF spelling. In other words, the process that is responsible for these homophone intrusions will more often yield the correct spelling than a homophone intrusion. In many circumstances in life such a probabilistic process, which is based on frequency distributions built up on the basis of past experience, guarantees relatively successful overall performance. However, this is not perceived as such when spelling verb homophones: as these spellings are determined by a set of simple but deterministic rules, the general opinion is that probabilistic spelling behavior, which unavoidably causes spelling errors, is unacceptable. The rationale behind this opinion is that the pitfalls created by verb homophones can be avoided, if spellers rely strictly on the conscious application of the spelling rules.
§ 4 General Discussion

1.1.2. From spelling to visual perception

1.1.2.1. Stem-final d verbs

This dissertation extends the findings in spelling research by showing that intrusions that are more likely to be made in production (i.e., intrusions of the HF form) are also processed more quickly during visual perception, at least for stem-final d verbs (see below, for a comparison with weak prefix verbs). We hypothesized that the Homophone Dominance effect would particularly manifest itself in the visual perception of these homophone intrusions when working memory resources were depleted by the need for a conscious and time-consuming analysis. Such an analysis checks whether the suffix spelling of the verb form, first split off by a process of morphological decomposition, matches the grammatical properties of its so-called marker, i.e., the word that determines its spelling (i.e., a process that is analogous to the composition process governing spelling). However, we found that the whole-word frequency relation between the two homophones of a stem-final d verb (i.e., their Homophone Ratio) affected the processing speed of the two homophones whether these verb forms were presented in isolation (i.e., no morphosyntactic analysis required, LDT), in a minimal grammatical context (i.e., easy analysis, either in SDT or in PDT) or in a full sentence context (i.e., time-consuming analysis, ETT, SPRT, MT, and PRT).

The interaction between Form and Homophone Ratio was significant across all experiments: faster RTs were observed to the incorrect spelling form (i.e., a homophone intrusion), when the intruding homophone was the higher-frequency one (in a PDT, SPRT and MT). The only exception was the nearly significant effect of Homophone Ratio when only dt-forms were presented as homophone intrusions in an ETT, although this effect only just missed the significance threshold ($p = .059$). The interaction between Form and Homophone Ratio was also significant when the correct spelling of the homophones was presented (in LDT, SDT and PDT), revealing the same pattern as for the intrusions errors: faster response times as the presented
spelling form increased in dominance with respect to its homophone. There
was only one situation in which increasing dominance yielded longer RTs:
when the incorrect spelling was presented in a task that required an explicit
judgment of the verb form’s spelling correctness (the SDT). As homophone
intrusions increased in dominance, RTs increased. However, even this finding
confirms the above results: whereas the quickly available dominant
homophone triggers a yes-response, a no-response is required by the task (the
intrusion being a spelling error). The more dominant the incorrect spelling,
the more difficult it is for participants to overcome this response conflict,
which gives rise to the reverse data pattern for the interaction between Form
and Homophone Ratio than in the other experiments. Hence, this finding
leads to the same conclusion as all other online perception experiments:
dominant homophones are more quickly available in visual perception
experiments and, hence, affect participants’ response speed.

As mentioned above, the evidence in favor of whole-word access to the
homophones of stem-final d verbs runs across all experiments. It was not only
obtained in the online experiments but also in the offline experiment, which
took the form of a proofreading task. Because the orthographic pattern of the
HF homophone looks more familiar than that of the LF homophone,
intrusions involving this HF form were also overlooked more often when
proofreading sentences for errors. Arguably, fast access to the orthographic
pattern of the dominant homophone makes participants feel confident that
this is likely to be the correct spelling, resulting in error detection failures. In
other words, the systematic observation across seven types of experiments that
dominant homophones from stem-final d verbs are processed/accepted more
easily during visual processing (whether they are spelled correctly or, more
importantly for the current purpose, are intrusion errors) suggests that whole-
word representations are always involved in the visual processing of these
homophones. It also shows that the whole-word retrieval of regularly inflected
verb homophones is not restricted to a cognitively demanding situation (i.e.,
intervening words between subject and homophone in sentence reading), but
is operational throughout all contexts of visual perception studied in Chapter
3. Whereas these results indicate that Homophone Dominance is at work in both spelling and reading, causing spelling errors and causing these errors to be missed during re-reading, they also suggest that the effect is even more outspoken in visual perception experiments, as the emergence of the effect does not seem to be as dependent on the cognitive overload of working memory, as is the case in spelling\textsuperscript{107}.

It is important to emphasize that the systematic evidence supporting the access to the whole-word representations of the homophones of stem-final d verbs does not imply that these forms are not also subjected to a process of morpheme-based processing. The evidence favoring the existence of whole-word representations of these homophones only indicates that the visual recognition of these forms is not always the result of a morpheme-based processing mechanism (i.e., morphological decomposition and a subsequent spelling check of the suffix spelling). It does not indicate that morpheme-based processing is totally absent. As a matter of fact, it is quite likely that whole-word access only occurs for the HF member of a d/dt-homophone pair and that even this member is sometimes recognized on the basis of morpheme-based processing. It seems a plausible assumption that all possible lexical processes are simultaneously attempted on a given verb form (as suggested by race models of word recognition, cf. Chapter 1) and that word recognition is eventually mediated by the fastest process. Obviously, such a view can easily account for the results of the perception experiments. Even when many homophones may be recognized by morpheme-based processing (the exact proportion depending on the task), the fact that whole-word processing will more often cause lexical access for HF homophones than for LF homophones, predicts faster response times for the dominant (HF) homophone. This is indeed the consistent finding in the set of visual perception experiments.

\textsuperscript{107}Note that this suggestion may be deceptive, as we never directly contrasted the effect of Homophone Dominance in conditions of low versus high cognitive overload (e.g., marker and homophone being adjacent in the sentence or being separated by intervening words). The fact that we found the effect in minimal context conditions and sentence reading does not necessarily imply that it was equally large in both experiments.
However, despite the plausibility of the above account, the online perception experiments provide less direct evidence whether morpheme-based processing was effectively used, as their design only addressed the question whether there was an effect of Homophone Dominance, i.e., focused exclusively on homophones’ access to whole-word representations. Even though it is highly likely that (homophonous) regular verb forms are often subjected to a morpheme-based processing mechanism, it still has to be proven. However, the offline experiment, i.e., the proofreading task, seems to provide undeniable and direct evidence that a morpheme-based processing mechanism was indeed often operational during the visual perception of the homophones of the stem-final d verbs. This mechanism involves two consecutive processes: (a) automatic morphological decomposition process and (b) a conscious process that checks whether the suffix spelling matches the grammatical properties of the marker. As a matter of fact, this morpheme-based checking mechanism is the implementation of the spelling rule in visual perception. Demonstrating that the PRT data reveal the existence of this mechanism during reading would constitute proof that a processing account of the visual perception of regular verb homophones involves (a) a morpheme-based mechanism (that is consciously applied and, hence, absorbs attentional resources in working memory) and (b) a whole-word retrieval process (that is unconsciously executed). Such a demonstration would be equivalent to our earlier analysis of the spelling errors on verb homophones in the corpus data (Chapter 2), which revealed that the homophone intrusions could only be explained by accepting both a mechanism implementing the spelling rule and a process that is sensitive to Homophone Dominance (in addition to a third process that is sensitive to phonological and morphological neighbors; the model incorporating these three processes providing the best fit to the data of the weak prefix verbs). Hence, demonstrating that the PRT data reveals the existence of a process that implements the spelling rules is the purpose of the following paragraphs.

Recall that participants in the PRT were confronted with 8 (critical) homophone intrusions and 8 filler homophones that were all spelled correctly
(to avoid the development of the response strategy “Each verb form with a stem-final d is a spelling error”). There was a striking difference in the percentage of correct responses on the homophones that were spelled correctly and responses on the homophones that were spelled incorrectly (i.e., homophone intrusions). Whereas participants seldom decided that the form was incorrect when it was correct (a success rate of 95.50%), participants often decided that an incorrect form was spelled correctly (a success rate of only 60.90%). In other words, there was an accuracy difference between correct and incorrect spellings of 34.60%. Such a discrepancy seems difficult to explain, as one expects the same processes to be applied to correct and incorrect spellings (i.e., it is not a priori clear whether it is a spelling error or not and, hence, the same performance level is expected).

On the one hand, a whole-word recognition mechanism would accurately accept a HF spelling and erroneously reject a LF spelling in the case of the correctly spelled filler items. On the other hand, it would erroneously accept a HF spelling and accurately reject a LF spelling in the case of the incorrectly spelled homophones. Hence, this process does not predict a different performance level for the critical verbs and the fillers. In other words, given a comparable number of HF and LF homophones in the sets of incorrect critical items and correct filler items, very similar percentages of correct decisions should have been obtained for the two item types. However, the number of HF and LF homophones in the set of fillers and the set of homophone intrusions was not matched\textsuperscript{108}. Whereas each of the three lists in the experiment contained 4 HF and 4 LF homophone intrusions ($n = 24$ for the homophone intrusions), 5 of the correct spellings of the fillers corresponded to the HF form, 2 to the LF form, and 1 had equal frequencies in both spellings. If all responses were based on the operation of a whole-word based access process, the success rate would be 50% on the homophone intrusions (half of them being the HF homophone) whereas it would be

\textsuperscript{108}This is important, as the whole-word procedure will only (occasionally) lead to the acceptance of a spelling form when it corresponds to the HF homophone. As we did not intend to use the fillers as control items, we did not anticipate this mismatch.
68.75% on the fillers\textsuperscript{109}. Note that this 18.75% difference is the maximum difference between the two spelling types that can be obtained, i.e., when the morpheme-based process never determines a response. If, however, responses are based on the output of a morpheme-based processing mechanism only, both correct and incorrect spellings would always be accurately identified, based on the check of the suffix spelling. Hence, this process does not predict a difference between the critical verbs and fillers (i.e., the difference in their success rate would be 0%).

Obviously, it is more likely that a number of responses were determined by the whole-word process and another number by the morpheme-based process. Whatever the relation between these numbers, the difference in the success rates for the correct and incorrect spellings must be situated between 0% and 18.75%. Two remarks are in order here. Firstly, we can be certain that a morpheme-based process was involved, as much higher success rates were obtained than the ones that would be obtained if only a whole-word access process were operational: 95.50% for the correctly spelled fillers (instead of the predicted 68.75%) and 60.90% for the homophone intrusions (instead of the predicted 50%). Secondly, even though the occasional involvement of a morpheme-based process is expected to give rise to a difference in success rates that lies in-between 0% and 18.75%, the actual difference was 34.60%. This leads to a paradox: the high success rates (especially for the correctly spelled fillers) indicate a clear involvement of a morpheme-based process. At the same time, the difference in success rates is not smaller than the maximal difference of 18.75% if only whole-word based access were involved, but almost twice as large.

This paradox can be solved if assumed that participants were more confident when a stem-final d verb form was spelled correctly than when it was spelled incorrectly. At first sight, this seems a strange idea as the above analysis leads to the conclusion that the large difference in the success rates for correct and incorrect forms must be due to a morpheme-based process, i.e.,

\textsuperscript{109}Assuming that participants would randomly guess on the form with two equally frequent homophones, this would lead to 5.5/8 correct responses.
a mechanism that consists of a process that morphologically decomposes the verb homophone and a process that subsequently checks whether the decomposed suffix is spelled correctly. Why would such a mechanism make participants feel less confident when it detects an incorrect spelling? A plausible suggestion is that participants know that verb forms are a notoriously dangerous spelling domain and that, whenever they feel a form might be spelled incorrectly, doubt starts to seep in and they initiate to double-check. As they perform the PRT under time pressure, this time-consuming (morpheme-based) checking process often cannot be terminated a first time, let alone a second time. Under such circumstances, participants have only two options: either they will randomly guess whether the form is spelled correctly or they will rely on the output of the whole-word retrieval process. The latter process is likely to occur only when the HF form of a homophone is presented. This will give rise to a response conflict: the HF homophone suggests a no-response (i.e., the homophone intrusion is not a spelling error), whereas the first morpheme-based analysis suggested a yes-response (i.e., the verb form is a spelling error). However, the HF form will more often cause participants to accept the intrusion error as a correct spelling than when they make a random guess (i.e., when the LF homophone is presented). In other words, the HF form leads to a form of educated guessing (although this is entirely unconscious). To summarize, whenever the morpheme-based process signals a spelling error, participants start to doubt, initiate a double-check, which often fails as the result of time limitations, and will then randomly guess when the homophone intrusion is a LF form or occasionally accept the error when the error is the HF form.

The above account is compatible with (a) the finding that participants successfully detected the spelling error in 60.9% of the cases, which is higher than random guessing, and (b) the finding of a significant interaction between Homophone Ratio and Form. The partial effect plot of the interaction visualized in Figure 39 shows a performance of around 50% correct for dt-forms when the verb had a high dt-dominance, with an increasing performance as d-dominance increased (and vice versa for the d-form). The
account can also explain the high percentage of acceptances for correct spellings (95.50%). Such a success rate could never be obtained when participants relied exclusively on a whole-word process (an extreme and unlikely situation, which would lead to a success rate of 68.50%). Hence, they also relied on a morpheme-based mechanism. Note that, in contrast to what is the case for incorrect spellings, the outputs of this morpheme-based mechanism and that of the whole-word access process will never produce a response conflict for correct spellings. When the HF homophone is the correct spelling, both processes will suggest a no-response (i.e., “This verb form is not a spelling error”). Importantly, however, the fact that the involvement of a morpheme-based mechanism increased the success rate on correct forms to a much larger extent than the success rate on incorrect forms suggests that participants blindly trusted the output of this mechanism when it did not signal a spelling error (i.e., also in the case of LF forms), but started to doubt when it did. As will be seen below, the same account can be given to explain the results obtained for the weak prefix verbs in the PRT.

Note that the above account of participants’ responses to incorrect spellings in terms of a response conflict for HF forms is reminiscent of the account for the pattern of no-responses in the SDT, where the notion of a response conflict was also a central explanatory concept. This comparison to the SDT is not far-fetched, as the PRT can be conceived as a more naturalistic version of the SDT. In both tasks, participants are explicitly asked to decide whether words are spelled correctly or not. It is reassuring that the results for the two tasks can be explained by appealing to the same concept.

Interestingly, we arrived at a processing account for stem-final d homophones – a race between whole word-based access and morpheme-based access, with occasional response conflicts when the two processes terminate simultaneously – in an offline task. Note that this view is fully in line with what has been proposed on the basis of offline spelling experiments (e.g., Sandra et al., 1999) and on the basis of several online experiments with different materials (Baayen et al., 1997; Bertram, Schreuder, et al., 2000). Finally, even though the findings in all online experiments with the
homophones of stem-final d verbs specifically focused on the involvement of whole-word representations, they are compatible with the notion of parallel processing, i.e., the simultaneous operation of morpheme-based processing and whole-word access.

### 1.1.2.2. Weak prefix verbs

Interestingly, we did not find any evidence in favor of whole-word retrieval for weak prefix verbs in visual perception. While spellers showed a preference for the HF homophone in production, readers could not take advantage of whole-word retrieval to speed up lexical access for this HF form. Obviously, we cannot ignore the **systematic absence** of an effect of whole-word access for this verb type, which stands in sharp contrast to the **systematic presence** of an effect of Homophone Dominance in all seven visual perception experiments with stem-final d verbs. It is indeed surprising that the homophones of one verb type yield an effect of Homophone Dominance, in both spelling and reading, whereas the homophones of another verb type give rise to an effect of Homophone Dominance in spelling but fail to reveal this effect in both online and offline visual perception tasks. In principle, there seem to be only two possibilities: (a) either the homophones had whole-word representations, but were characterized by properties that made it impossible for the experimental techniques to reveal the existence of these representations or (b) the homophones (or a considerable subset of them) did not have whole-word representations. We will discuss both possibilities in this order.

A first possibility is that the absence of the Homophone Dominance effect is due to a preference for a specific inflectional form. The strong association between a weak prefix and the d-spelling of the suffix (i.e., the past participle d-form) in large text corpora and the predominance (88%) of d-dominant weak prefix verbs (cf. Section 1.2.2.3 in Chapter 2) caused a d-bias in the spelling experiments, both in the online spelling-to-dictation experiment (replicating Sandra et al., 1999) and in the corpus study. This d-bias also emerged in two online perception experiments: the LDT and the
PDT. In the LDT, where weak prefix verb forms were presented in isolation, d-forms were processed significantly faster than t-forms, regardless of their whole-word frequency. In the PDT, yes-responses to the incorrect d-spellings in a PT context (e.g., *hij beveiligd, ‘he secured’) were significantly faster than those to incorrect t-spellings in a PP context (e.g., *hij heeft beveiligd, ‘he has secured’), after controlling for the differences in letter length between the two contexts. Hence, in these two experiments (single-word recognition and word recognition in a minimal syntactic context), a d-bias may have obliterated the effect of Homophone Dominance. No direct evidence for this d-bias was found in the online sentence reading experiments (SPRT and maze task). However, it turns out that another confounding factor may have masked an effect of Homophone Dominance in these experiments.

A second factor that creates a difference between the d-form and t-form of a weak prefix verb (besides a preference for the d-form) is the difference in the homophones’ position in the verbal paradigm: both homophonous forms of stem-final d verbs are present tenses, whereas the t-form of weak prefix verbs is a present tense and the d-form a past participle. This is especially relevant for the online reading experiments in which the verb forms were embedded in a full sentence context (i.e., the SPRT and MT): the PT and PP contexts were syntactically very different, so that the integration of the verb forms is likely to have differed across the two contexts. In a PP context, the verb forms appeared at the end of a main clause. In a PT context, however, verb forms appeared at the end of a subclause with a number of intervening words between marker and verb form (i.e., an SOV word order only occurs in Dutch subclauses; cf. examples below).

PT context: "Omdat hij zijn computer tegen virussen *beveiligd, loopt hij weinig risico. ‘Because he his computer against viruses *protected, runs he little risk."
PP context: Hij heeft zijn computer tegen virussen *beveiligt om risico’s te vermijden.

‘He has his computer against viruses *protects to risks to avoid.’

This confound between the correct spelling of the homophone (t vs. d) and the syntactic context (PP vs. PT) could have led to different sentence wrap-up effects on the verb form, causing noise in the RTs. This, together with the mismatch between the two contexts with respect to the two words following the homophone, could have made it more difficult to detect an effect of Homophone Ratio in the spillover region. Moreover and possibly more importantly, the homophone spelling was unambiguous in the PP context, as the auxiliary verb appeared before the homophone (i.e., only the d-form was morphosyntactically correct). In contrast, an incorrect d-form in the PT context was potentially ambiguous: the sentence structure allowed for an auxiliary verb to follow, in which case the d-form could represent a correct spelling (e.g., Omdat hij zijn computer tegen virussen beveiligd heeft, ‘because he his computer against viruses secured has’). The only indication that an incorrect d-homophone had to be interpreted as a present tense was the comma that followed, at least in the SPRT. However, one may question to what extent participants make use of punctuation marks when reading sentences in a task that presents the words of a sentence one after the other, i.e., when participants never see more than one word at the same time. The spelling of the verb form may have been a much stronger signal for its syntactic interpretation than a comma. An extra analysis of the MT indeed showed that RTs on the word following the incorrect d-form in the PT context revealed a strong garden-path effect, i.e., longer RTs as the result of initially misinterpreting the homophone as a past participle. This may have seriously contaminated the data for the PT context, so that detecting an effect of Homophone Dominance is difficult, if not impossible, certainly in combination with the differences in wrap-up effects between PT and PP contexts.
Recall that the same sentence structures did yield a significant effect of Homophone Dominance in the offline data of the spelling-to-dictation task. Crucially, however, participants in this experiment had heard the entire sentence before writing it down, which disambiguated the PT context. Whereas the local syntactic ambiguity of the verb homophone is quite likely to emerge in a word-by-word processing task (SPRT and MT), processing the entire sentence before performing the task will remove this ambiguity (spelling-to-dictation task and PRT).

Surprisingly enough, both the Homophone Dominance effect and the lemma frequency effect were absent for the homophones of weak prefix verbs in the online sentence reading experiments. In other words, these experiments revealed no frequency effects at all. As mentioned earlier, the absence of an effect of Homophone Dominance contrasted with our hypothesis that this effect is more likely to appear when marker and verb form were separated by intervening words in a sentence context, i.e., conditions that have been shown to increase the probability of making an intrusion error in spelling tasks because the relevant grammatical information is further removed from the verb form (Sandra et al., 1999, 2004). However, the absence of an effect of lemma frequency is even more surprising, as lemma frequency effects are perhaps the most reliable signature of lexical access in online processing tasks. The results of the maze task with stem-final d verbs, a task that has been shown to produce localized effects, ruled out that this was due to spillover effects, as both frequency effects emerged on the target word itself for this verb type. Conversely, we hypothesize that the above-mentioned (considerable) differences in the PT and PP sentence contexts for weak prefix verbs masked both frequency effects. While the two sentence contexts are closely matched for stem-final d verbs (i.e., both were syntactically identical present tense contexts, whose only difference involved the choices of the personal pronoun and verb form), the syntactically different present tense and past participle contexts used for weak prefix verbs differed on both wrap-up effects and the possibility of garden-path effects (both of which considerably affect RTs).
These differences are likely to have drowned not only the effect of Homophone Dominance, but also the standard effect of lemma frequency.

Since a d-bias did not affect the results of the PRT, and since the syntactic mismatch between the two contexts is unlikely to have affected the detection rates (the full sentence context being immediately available), there must be another reason for the systematic absence of the Homophone Dominance effect in the set of weak prefix verbs. This reason might be found in the frequency characteristics of the homophones for both verb types. We ruled out that the non-significant results for weak prefix verbs are due to a mismatch between the Homophone Ratio of (a) d-dominant and t-dominant weak prefix verbs ($t = 1.63, p = .12$) or, more importantly, (b) stem-final d verbs and weak prefix verbs ($t = 1.05, p = .3$). A mismatch on the former might cause a failure to observe a dominance effect for both d-dominant and t-dominant forms, resulting in a non-significant overall effect of Homophone Dominance. A mismatch on the latter might create worse conditions for weak prefix verb forms to observe the effect of Homophone Dominance because the size of the homophone ratios was significantly smaller in this verb set, i.e., because the HF homophones were less dominant than in the case of stem-final d verbs. As these two possibilities have been ruled out, another difference also related to frequency might be the cause of the discrepancy, namely a difference involving the whole-word frequency of the verb homophones in the two verb sets. Alegre and Gordon (1999) argued that words whose frequency is lower than 6 occurrences per million do not have their own independent representation (but see, Baayen et al., 1997; Baayen et al., 2002; Baayen et al., 2007). Upon closer inspection, we found that 37 of the 48 homophones for weak prefix verbs (i.e., 24 homophone pairs) had frequencies below this threshold, whereas this was the case for only 24 verb forms in the set of stem-final d-verbs. A chi-square test with the factors Verb Type (weak prefix vs. stem-final d) and Frequency (above vs. below threshold) yielded a significant interaction effect ($\chi^2 = 7.60, p = .01$), indicating that more homophones

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110 The calculations for stem-final d verbs in this section will be based on the frequency characteristics of the basic set.
possibly have no (or at least a very weak) whole-word representation in the set of weak prefix verbs. A chi-square test with the factors Verb Type and Dominance (dominant vs. non-dominant), using the number of homophones with a frequency below 6 per million as the dependent variable, yielded no significant interaction ($\chi^2 = 2.28, p = .13$), indicating that the difference between the two verb types manifested itself in the sets of both dominant and non-dominant homophones. Finally, separate chi-square analyses on the sets of weak prefix verbs and stem-final d verbs, using the factors Dominance and Frequency yielded no significant interaction between these two factors for the set of weak prefix verbs ($\chi^2 = .12, p = .73$), but a highly significant interaction for the set of stem-final d verbs ($\chi^2 = 8.33, p = .004$). In the set of weak prefix forms, the (large) number of homophones with possibly absent/weak whole-word representations was virtually identical for the two dominance types (dominant: 75%, non-dominant: 79%). In the set of stem-final d verbs, however, this number was much smaller for the dominant homophones (dominant: 29%, non-dominant: 71%).

Together, the above analyses reveal that there were significantly more homophones with a possibly weak or absent whole-word representation in the set of weak prefix verbs. Moreover, in the set of weak prefix verbs about the same (large) percentage of homophones had an absent/weak whole-word representation in both dominance conditions (75% and 79%). In contrast, in the set of stem-final d verbs, only a relatively small percentage of verb forms had an absent/weak whole-word representation in the group of dominant homophones (29%) compared to a large percentage of such verb forms in the group of non-dominant homophones (71%). As the dominant homophones are the ones mediating the effect of Homophone Dominance, the large difference in the percentage of absent/weak whole-word representations for dominant homophones in the set of weak prefix verbs (75%) and in the set of stem-final

\footnote{Dominant: 18 vs. 7 for weak prefix verbs and stem-final d verbs, respectively. Non-dominant: 19 vs. 17 for weak prefix verbs and stem-final d verbs, respectively.}
d verbs (29%) is of crucial importance\textsuperscript{112}. This discrepancy probably explains why an effect of Homophone Dominance was observed across the perception experiments for the set of stem-final d verbs, whereas such an effect was systematically absent for the set of weak prefix verbs.

Since there are not enough weak prefix verbs that have both a pronounced frequency ratio and a high whole-word frequency (at least for the HF homophone), we preferred to work with verb pairs with the most pronounced frequency ratio. This choice was motivated by the consideration that we explicitly wanted to match weak prefix verbs with stem-final d verbs on the factor that is responsible for the effect of Homophone Dominance: the ratio between the homophone frequencies. However, it was impossible to foresee that the lower frequency range for weak prefix verbs would lead to null effects altogether. The consequence of this choice and the above analyses strongly suggest that we failed to find an effect of Homophone Dominance for weak prefix verbs (partly) because the majority of their homophones had no or only very weak whole-word representations. This was the case for even 75% of their HF forms, i.e., the ones that are responsible for the effect of Homophone Dominance.

Interestingly, the latter conclusion seems to confirm our above claims on the way stem-final d homophones were processed in the offline PRT. When the morpheme-based mechanism detects an error and the participant’s doubt in this notorious spelling domain initiates a second check, the whole-word access process should cause more error detection failures on intrusions of the HF form, as this form suggests the correct spelling of the verb form. However, this was not observed in the group of weak prefix verbs, which nicely converges with the above conclusion that most HF forms of these verbs had either no or a weak whole-word representation.

In sum, we conclude that we systematically failed to obtain an effect of Homophone Dominance in the perception of weak prefix verbs because 3 out

\textsuperscript{112}This conclusion is supported by the significant independent samples t-test between the (log) frequencies of the dominant homophones for stem-final d and weak prefix verbs ($t = 2.34, p = .02$).
of 4 dominant homophones of these verbs possibly had no or only a weak whole-word representation. The additional facts (a) that there was a strong d-bias in two experiments with no context or a minimal context (LDT and PDT) and (b) that considerable syntactic mismatches were inevitable in the word-for-word sentence reading experiments (SPRT and MT) are likely to have drowned all frequency effects (even an effect of lemma frequency). Clearly, the very low frequencies of the dominant homophones are primarily responsible for the series of null effects, as one cannot expect to find an effect of Homophone Dominance when whole-word representations are non-existent or only weak.

Obviously, we cannot ignore that the systematic absence of an effect of Homophone Dominance for weak prefix verbs in the visual perception experiments contrasts with the finding that Homophone Dominance affected the pattern of spelling errors both in the online spelling-to-dictation tasks and the corpus study, when using the same verb homophones. We tentatively suggest that spelling, being a relatively slow process, allows sufficient time to access even weak representations (cf. the low frequency of most dominant homophones), whereas these representations were more difficult to access during the fast process of visual perception. This is compatible with the dissociation between production and proofreading reported by Largy (2001): spelling required more cognitive effort than reading and therefore led to poorer performance on the former task. This seems to suggest that performance in spelling is more likely to be affected by whole-word representations.

1.1.2.3. Non-homophonous verb forms

The LDT also revealed that whole-word frequency affected the processing of regularly inflected homophonous and non-homophonous Dutch verb forms in a different way. While RTs to stem-final d homophones were modulated by whole-word frequency (causing an effect of Homophone Dominance), those to non-homophonous verb forms were not. This shows that whole-word
frequency is a stronger predictor of lexical decision times for Dutch verb forms that have two homophonous spelling forms within their verbal paradigm. Because their phonological representations are compatible with two spelling patterns, the orthographic lexicon needs to be accessed to successfully identify the homophonous spelling pattern, giving rise to whole-word frequency effects. Similarly, Bertram, Laine, et al. (2000) and Bertram, Schreuder, et al. (2000) argued that affixal homonymy triggers whole-word retrieval for regular Dutch and Finnish inflections. In case a suffix performs two or more frequent syntactic/semantic functions, the decomposition route is said to be very time-consuming, giving leeway to the process of whole-word retrieval. In other words, ambiguity seems to promote whole-word access (syntactic/semantic or spelling ambiguity). In contrast, the phonological representation of non-homophonous verb forms is unambiguous: as their spelling observes the phonological principle (i.e., spell what you hear), their phonological representation is linked to a single orthographic representation. Because the mapping between orthography and phonology is unambiguous for these verb forms, access to the orthographic lexicon is not necessary. Consequently, non-homophonous verb forms are more likely to be accessed through phonological recoding of the letter string and/or morphological decomposition. Our findings corroborate those obtained by Bertram, Schreuder, et al. (2000) and Baayen et al. (1997), who also failed to observe a whole-word frequency effect for non-homophonous Dutch verb forms with the regular and productive past tense suffix -te and the verb plural suffix -en in a series of LDTs.

1.2. Sublexical homophone intrusions

Next to lexical intrusions, we also studied regularly inflected verb forms whose homophonous relationship is not situated at the word level but at the sublexical level. Some past tenses in Dutch exhibit such homophony for their word-final cluster, i.e., the sequence of their stem-final consonant(s) and their suffix (a string that crosses the morphological boundary). The sound sequence [st@], for instance, can be realized orthographically as either ste (e.g., suste,
‘hushed’) or *stte (e.g., *rustte, ‘rested’). Although the rule for past tense inflection is very straightforward (i.e., add -te/-de, depending on the voicing characteristics of the stem-final phoneme), intrusions involving the substitution of a sublexical orthographic pattern by its homophonous cluster are occasionally observed. This occurs even though this pattern straddles the morpheme boundary and would not be expected to emerge either in a morpheme-based process or in a whole-word access process. As both orthographic patterns do not coincide with the morpheme boundary (e.g., neither *ste nor *stte are morphemic sequences in sus-te and rust-te), a morphological analysis should, in principle, suffice to detect sublexical intrusions. Indeed, they are true spelling errors, being morphologically impossible letter sequences, i.e., they can never arise as the result of adding the past tense suffix to a verb stem. Consequently, these errors stand in sharp contrast to lexical intrusions, which are existing but grammatically inappropriate words and can only be detected by means of a morphosyntactic analysis, i.e., a process of morphological decomposition followed by a syntactically guided check of the suffix spelling.

Although all sublexical intrusions are morphologically impossible, Homophone Dominance (i.e., the existence of a sublexical homophonous cluster) did affect the results in both spelling and visual perception experiments. In production, we found that more intrusion errors were made on past tenses whose correct spelling of the word-final orthographic pattern had a sublexical homophonous cluster that occurred in other words or word forms (e.g., *sustte in analogy with rustte) compared to past tenses lacking such sublexical homophony (e.g., *reptte). In perception, sublexical intrusions that received support from an existing sublexical homophonous pattern (i.e., a pattern occurring in phonologically similar words) affected response times differently than sublexical spelling errors that did not involve a homophonous competitor. The direction of this effect depended on task demands. In a spelling decision task and eyetracking task, the presence of two sublexical homophonous patterns caused doubt and increased reaction and reading times. When participants had to ignore spelling errors in a phonological
decision task, however, they were not delayed by the intrusion of a homophonous letter pattern (both the correct and intruding pattern being linked to the same pronunciation; e.g., *sustte, ‘hushed’ because of rustte, ‘rested’). In contrast, participants’ responses were delayed when the spelling error contained a non-existent word-final letter string (there being no existing mapping between the pronunciation [pt@] and the incorrect letter string ptte; e.g., *reptte, ‘hurried’). In the same task, RTs to intrusions on verbs exhibiting sublexical homophony within and outside the verbal paradigm (i.e., st verbs; e.g., rustte) did not differ from those to their correct spelling. The same result was obtained for verbs for which sublexical homophony was only situated outside the verbal paradigm (i.e., rt-nt verbs; e.g., printte). As RTs to these verb forms were equally sensitive to the existence of sublexical homophonous letter patterns, we concluded that the familiarity of an orthographic string is determined by all the words in which that letter string occurs. The same pattern of results for s and p verbs as in the PDT was also obtained in a self-paced reading task, in which spelling errors had to be ignored in favor of the syntactic and semantic integration of the successively presented words. Similarly, sublexical spelling errors were left undetected more often during proofreading when supported by phonological neighbors (e.g., rustte) whose word-final cluster corresponded to this incorrect spelling (i.e., s verbs, *sustte) compared to spelling errors whose incorrect spelling pattern did not occur in other words or word forms (i.e., p verbs, *reptte). This finding indicates that the presence of sublexical homophony triggered two spelling patterns and consequently yielded detection errors in a proofreading task, exactly as it increased RTs in a spelling decision task. Recall that it makes sense to consider a proofreading task as the naturalistic equivalent of a spelling decision task. It is reassuring to see that both tasks converged on the same outcome. Importantly, the results of the PRT also showed that detection rates did not differ between st and rt-nt verbs. This confirms our earlier conclusion of the PDT: the familiarity of a sublexical homophonous cluster in past tenses is not restricted to the past tense paradigm, but is determined by all phonologically similar words that exhibit that homophonous word-final cluster (i.e., also
nouns and adjectives).

To summarize, the first major conclusion of this work is that Homophone Dominance affects both production and perception, both for lexical and sublexical intrusions. The mental lexicon tricks spellers and readers into spelling and accepting homophone intrusions when these involve a HF homophonous verb form or a competing homophonous orthographic pattern at the sublexical level. Interestingly, what initially looks like a processing advantage at the lexical level (i.e., a lower error risk when spelling the HF form and faster lexical access for these forms in visual processing) has the undesirable side effect that it also leads to the persistence of homophone intrusions.

Based on these findings, one might criticize the Dutch spelling system: if these morphological spelling rules cause so many errors, why not simply apply a phonological principle for homophonous verb forms? Research by Brysbaert, Grondelaers, and Ratinckx (2000), however, showed that Dutch readers make use of the orthography of verb homophones. Although their phonology makes it impossible to distinguish between both homophones, the fact that their suffix spelling reflects their grammatical function can help disambiguate a sentence context. The authors compared three pairs of verbs, presented both in their plural present tense (i.e., stem + -en) and plural past tense forms (i.e., stem + -ten/-den). These were (a) heterophonic verb forms (e.g., harken, harkten; [hArk@n], [hArkt@n] ‘rake, raked’), (b) homophonic verb forms (e.g., wieden, wiedden; both [wid@n] ‘weed, weeded’), and (c) homographic verb forms (e.g., spitten, spitten; both [spIt@n], ‘plough, ploughed’). The verb forms of type (a) differed both phonologically and orthographically, while those of type (b) differed only orthographically (i.e., as stem-final d and weak prefix verb forms do). Finally, both forms were phonologically and orthographically identical for type (c). These verb forms were inserted in a sentence-initial subclause, while a disambiguating verb form (e.g., zitten/zaten) appeared later in the main clause:
Terwijl de moeders hark(t)en/wied(d)en/spitten in de tuin zitten/zaten de vaders op hun luie stoel.

‘While the mothers rake(d)/weed(ed)/plough(ed) in the garden sit/sat the fathers in their lazy chair’.

If the orthography of homophonic verb forms does not help in disambiguating between the two verb forms’ grammatical functions, leaving the sentence ambiguous until the appearance of the present or past tense form in the main clause, sentences containing homophonic verbs should yield similar reading times as those containing homographic verbs. The results of a non-cumulative self-paced reading task, however, indicated that RTs to the disambiguating verb form did not differ between heterophonic and homophonic verb forms, whereas RTs were delayed for homographic verb forms (Brysbaert et al., 2000). The authors concluded that purely orthographic markers of morphological structure, i.e., the different spellings of verb homophones, serve a purpose during reading, namely to correctly interpret the sentence.

This conclusion has implications for the present research: it suggests that, although verb homophones are prone to substitution errors in spelling and error identification failures in reading, their orthographic pattern has a disambiguating function in reading. Note that one finding in the present work supports this conclusion. The garden-path effect in the maze task that was created by the incorrect d-form of weak prefix verbs in the PT context also suggests that the spelling of a verb form immediately guides its grammatical interpretation (hence, that orthography matters when a verb form is homophonic). However, the findings reported by Brysbaert et al. (2000) and this garden-path effect may both be due to the fact that the spelling of the verb homophone was the only cue to distinguish between the two possible interpretations of the homophone’s pronunciation: the distinction between a present tense and a past tense in Brysbaert et al.’s (2000) experiment and the distinction between a present tense and a past participle when presenting an incorrect d-form of a weak prefix verb at a sentence position where an auxiliary verb form can still follow. When a homophone’s grammatical
function is clear from the preceding context, however, it seems reasonable that spellers and readers attach less importance to its spelling. Hence, the risk of making and not detecting a homophone intrusion might be more likely in the latter ‘redundant’ condition than in the former ‘disambiguating’ condition. However, the experiments in this work cannot elucidate this issue. At any rate, considering the fact that readers do rely on the spelling of verb homophones, at least in some circumstances, can be used as an argument against simplifying the verb spelling rules to get rid of these errors, i.e., can be used to reject the frequent suggestion to replace the morpheme-based verb spelling rules by the application of the phonological principle (e.g., wordt and word > *wort).

2. The Organization of the Mental Lexicon

A second insight gained from this dissertation concerns the organization of the mental lexicon. While a rule-based mechanism, identifying stem and affixes and their combinatorial compatibility, is the only process that guarantees a correct output in spelling and correct error identification in visual perception for homophonous verbs, our results show that other processing routes are involved. Lexical intrusions occurred more often, were processed more quickly and were overlooked more often when the HF homophone acted as an intruder for the LF one rather than vice versa. Since the pattern of results is shaped by the whole-word frequency relation between the two homophones (i.e., Homophone Dominance), this suggests that even (HF) rule-based forms have developed whole-word representations, although they are redundant (i.e., they can be computed online when needed).

However, the results are not entirely conclusive: a rule-based account enriched with a frequency-sensitive mechanism is also able to explain these results. Such a words-and-rules account (Largy et al., 1996; Pinker, 1999) posits that whole-word frequency effects are the result of a rule-based mechanism tracking how often a stem and suffix have been combined (i.e., their connection strength). In other words, the mental lexicon stores stems and affixes (rather than whole-word representations) and implements rules
that capture their combinatorial possibilities. To rule out that such a mechanism is responsible for the pattern of lexical intrusions, we also studied sublexical intrusions. This type of error poses a serious problem for such a model since they do not involve the substitution of two existing morphemes or words, but of two homophonous clusters straddling the morpheme boundary.

As with lexical intrusions, we found that the probability of making such errors depended on the frequency relation between the two orthographic alternatives. Past tenses whose word-final grapheme cluster is homophonous with an alternative spelling (s verbs) yielded more errors than past tenses whose spelling is unambiguous (i.e., p verbs). The perception experiments also revealed that the ease with which these intrusions were processed/accepted depended on the presence of a sublexical homophonous cluster. The incorrect spellings of s and p verbs were equally often (falsely) rejected as phonologically unacceptable in a PDT, because the output of the morphological decomposition process suggested a no-response (e.g., non-stem *sust/rept + past tense te-suffix) or because the whole-word route did not find a matching representation. If morphological decomposition and whole-word retrieval were the only relevant mechanisms, however, incorrect spellings should have led to a similar delay in RTs for both verb types. The PDT revealed that RTs to sublexical intrusions involving a frequently occurring homophonous cluster (*sustte) were not delayed relative to their correct spelling. In contrast, such a delay was observed for incorrectly spelled p verbs (*reptte). For s verbs, participants had to have access to the representation of the frequent sublexical letter string stte that has the same pronunciation as the correct ste-spelling. The incorrect spelling signaled by a morphological analysis therefore barely affected the processing speed for s verbs, making it (phonologically) equally acceptable as the correct spelling. In contrast, all these information sources (i.e., both the output of morphological decomposition, whole-word retrieval and the unfamiliarity of the sublexical string ptte) suggested a no-response for incorrect spellings of p verbs. Since a

113 Note that the incorrect spellings of st and rt-nt verbs did not affect RTs nor ERs in the PDT.
yes-response had to be given (i.e., these spelling errors were phonologically acceptable), the resulting response conflict caused a delay for incorrect spellings of *p* verbs. The same pattern of results was found in a SPRT. This observation regarding online processing measures was confirmed in an offline proofreading task, where sublexical errors on *s* verbs were also left undetected more often than those on *p* verbs.

To summarize, these results cannot be explained in terms of a rule-based account. Firstly, sublexical intrusions represent an illegal combination of a non-stem and a suffix (e.g., *sust* + *-te*) and are therefore impossible from a composition perspective. Likewise, a decomposition route would strip off the past tense *te*-suffix in perception and attempt to access the lexicon via the remaining non-stem. As orthographic patterns not corresponding to a stem or affix are non-existent processing units in a morpheme-based system, all types of sublexical errors should create equal processing difficulties (i.e., longer RTs) and should be identified as error in the same way. This brings us to the second argument against rule-based processing: if inflected past tenses were (de)composed, error (detection) rates and processing times should not have been sensitive to the familiarity with sublexical clusters that cross the morphemic boundary.

Although the pattern of results for sublexical intrusions cannot be accounted for by means of a rule-based processing mechanism, a whole-word retrieval account is not able to offer a satisfactory explanation either. The whole-word retrieval route tries to access a non-word (i.e., the non-existent spelling of a past tense form) that is not stored as a full-form representation in the mental lexicon or at least with a much lower frequency of occurrence than the correct spelling, if one accepts that readers’ confrontation with incorrectly spelled verb forms leads to the development of lexical representations of these forms as well (see for example, Ernestus & Mak, 2005). If whole-word retrieval played a role, processing times should therefore have revealed a delay for the incorrect (and lower frequency) spelling of *s* verbs too. In the next section, we will discuss how the results obtained in this dissertation can be accounted for within two models of lexical processing that assign a central role to similarity.
2.1. Similarity as a single processing mechanism

It follows from the above that the influence of sublexical homophony on the processing of (in)correct past tenses, both in spelling and visual perception (online processing and offline error detection) defines an important boundary condition for any model that attempts to account for the data patterns of the behavioral experiments. So, what is lacking in a model that only relies on a whole-word process and a morpheme-based process? The best starting point is to identify the factor that distinguishes lexical from sublexical intrusions. The explanatory framework for the former relies on the existence of whole-word representations and morpheme-based representations (both being reached by processes that run in parallel), two processes that require an exact match of the letter string to stored representations in the mental lexicon (both for correct and incorrect spellings, both in production and perception). The process that is required to account for the production and perception of sublexical homophone intrusions must be sensitive to a partial match. For instance, the intrusion error *sustte is not made because it matches a homophonous form at the whole-word level or because the final letter pattern matches a homophonous morpheme, but because a letter pattern that cannot stand on its own (stte) occurs in many similar past tenses (rustte, tastte, restte, ...), i.e., appears in words whose pronunciation partially matches that of the target form.

The notion of a partial match brings us to the concept of similarity. Sublexical intrusions are made possible by the existence of a spelling pattern in phonologically similar words (being partially homophonous). Importantly, the notion of similarity can be used to define both exact and partial matches, the former instantiating maximal similarity (i.e., identity) and the latter instantiating a level that varies between 0 (no similarity at all) and 1 (identity). When adopting this perspective, whole-word based access, morpheme-based access, and access to sublexical letter strings are all driven by the same basic mechanism. This mechanism activates phonologically similar letter patterns at
different levels of description, ranging from whole words to sublexical letter patterns.\footnote{Recall that phonological neighbors also determined the spelling output for weak prefix verbs in the corpus study.} Hence, our finding that sublexical homophony affects the way words are processed both in spelling and reading strongly suggests the existence of \textit{a single processing mechanism} that is sensitive to (a) the co-occurrence frequencies between letters (forming a string that can match a whole-word form, a morpheme, or a sublexical letter string crossing a morphemic boundary), and (b) the mapping of orthographic patterns to phonological patterns (and vice versa). These mappings, involving two orthographic patterns for a single phonological pattern, are necessary to account for the effect of Homophone Dominance at the sublexical level.

Below, we will present two different implementations of this general idea of similarity-based processing: instance-based models and connectionist models. As we did not use these models to simulate our behavioral data, we will only describe how these models should \textit{in principle} be able to capture the lexical and sublexical effects of Homophone Dominance. However, it should be clear that we will adopt a neutral position as to the explanatory value of these two model types. Indeed, the only way to find out whether a model that seems \textit{conceptually} acceptable provides a valid explanatory framework is to show that this model can \textit{actually} simulate the behavioral data. In addition, such a model should also be able to make correct predictions for experiments that are yet to be performed (see Future research directions, Section 3).

\subsection*{2.1.1. Instance-based processing}

In a first model type, the similarity-based process activates whole-word and/or morphemic representations (exact matches) and co-activates all (phonological) neighbors of the target word (partial matches). The verb form \textit{suste}, for example, activates full-form representations of phonologically similar words, including words that end in the sound sequence [st@]. These phonological neighbors contain both the ste-pattern and homophonous stt-
pattern (e.g., *suste* ‘hushed’ and *rustte* ‘rested’). The presence of full-form representations of words and word forms with the same word-final phonological pattern but a different spelling can consequently affect spelling performance (for a similar conclusion, see Ernestus & Baayen, 2004). Indeed, we found that participants made more sublexical intrusions on verb forms whose correct spelling (i.e., *ste*) is homophonous with a different spelling in phonologically similar words (i.e., *stte*). In contrast, significantly fewer spelling errors were found on past tenses of verbs whose stem ends in -p: the alternative *ptte*-spelling did not receive any support from those verb forms’ phonological neighborhood, since there are no words ending in that orthographic pattern. The results obtained from the perception experiments can be explained along the same lines: the speed with which a spelling error was processed depended on the amount of support it received from phonological neighbors. Sublexical intrusions involving a homophonous pattern that occurs in phonologically similar words (i.e., *s* verbs) were processed more quickly and were overlooked more often than those that involved a non-existent pattern (i.e., *p* verbs). The former type of errors were processed more slowly in a spelling decision task for the same reason, namely due to the existence of two sublexical homophonous spelling patterns. In this task, the connection between one pronunciation and two spelling patterns created confusion and, hence, delayed responses rather than facilitated them.

This line of reasoning can be implemented in exemplar-based models, such as TiMBL (Daelemans & van den Bosch, 2005).

Although the above paragraph only focuses on explaining the pattern of results for sublexical intrusions, such a model is also capable of accounting for morpheme-based effects such as stem frequency effects (based on its ability to co-activate morphologically related words). It can also account for whole-word frequency effects (i.e., the Homophone Dominance effect at the lexical level), as full-form representations are one of the basic representational units in this type of model.
2.1.2. Connectionist processing

A second implementation of the general idea of similarity is represented by the connectionist approach. As the explanation of the observed effects in the context of a connectionist model is more intricate than in the context of an instance-based model, this section will be somewhat longer than the above. Reiterating our earlier statement, this does not reflect any preference for either model, as our explanation of the data is entirely formulated in conceptual terms and is not supported by simulation data.

In a connectionist model, both linguistic and non-linguistic (or sublexical) orthographic units (e.g., stte) are encoded in the representational structure of the mental lexicon (Daugherty & Seidenberg, 1994; MacWhinney & Leinbach, 1991; Plunkett & Marchman, 1993; Rumelhart & McClelland, 1986). These representations are not localist units, but should be considered as distributed patterns. Here, words are represented as activation patterns emerging from bi-directional meaning-to-form and form-to-form mappings, the systematicity of which is captured in connection weights between input, hidden and output layers. Through visual print exposure, these connection strengths can be fine-tuned, so that the system gradually learns the statistical regularities between these mappings.

First of all, such a system is able to account for both decomposition and whole-word frequency effects. Frequency effects in visual word processing (both in spelling and visual perception) are said to arise due to the network’s frequent exposure to particular orthographic sequences. As these recurring letter strings are mapped onto recurring phonological and semantic representations, strong connections also emerge between (a) these two types of form representations and (b) between these form representations and the meaning representation, together forming a tight connectivity pattern. This allows the network to create optimal connection strengths for these mappings and thus leads to a processing advantage for frequent letter strings.

In the light of such a mechanism, stem frequency effects do not necessarily result from an active morphological decomposition process, but
are the inevitable result of the regularities in bidirectional form-to-form or meaning-to-form mappings at the morphological level, i.e., the recurring orthographic pattern of the stem across a set of words/word forms being repeatedly mapped onto a recurring meaning representation. Such a mechanism implies that the connection strength of mappings between the different layers of the network is higher for orthographic patterns corresponding to a morphemic unit than for orthographic patterns straddling the morphemic boundary. This is due to the much lower co-occurrence frequency of the latter patterns and, hence, the considerably weaker connectivity pattern they create among the representational layers. This makes morphemes salient processing units (Seidenberg, 1987). To summarize, the overlap in meaning-to-form and form-to-meaning mappings between morphologically related words (i.e., sharing their stem) is responsible for stem frequency effects.

The same basic mechanism, i.e., strengthening both a letter string's representation within a particular layer and its connectivity pattern among the three levels of representation (orthography, phonology, and meaning) also makes whole-word forms emerge as salient processing units in a connectionist network. A full form constitutes a probabilistic sequence of letter co-occurrences. The frequency of these co-occurrences, which is encoded in the network’s connection weights between units in the orthographic layer and in the mappings between this layer and the phonological and semantic layers, can be equated with whole-word frequency. Hence, a connectionist model can easily replicate not only the lemma frequency effect caused by the recurrence of a stem across words, but also the effect of Homophone Dominance at the

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115 This formulation might suggest that a particular stem has an invariant meaning in all words and word forms in which it occurs. This is not true, as evidenced by slight differences in the meaning of the stem light in words like light, lighter, and lightning. Such semantic variability in the face of a constant orthographic pattern for the stem gives rise to graded morphological effects in some experiments (Plaut & Gonnerman, 2000). However, such gradations in meaning are generally the province of derivational morphology, while the meaning of a stem remains constant in all inflectional variants of a verb.
lexical level, which depends on the existence of frequency-sensitive whole-word representations for regular (homophonous) verb forms.

A similar line of reasoning can be applied to the effect of Homophone Dominance\textsuperscript{116} at the sublexical level. As is the case for morphologically related words with respect to form-to-meaning mappings, the phoneme-to-grapheme mappings (in spelling) and grapheme-to-phoneme mappings (in visual perception) of phonologically similar words partially overlap with those activated for the target word. Taking into account that a connectionist network will simultaneously activate mappings between a single phonological representation and slightly different orthographic representations (i.e., both being encoded in the model’s pattern of connections), a correct phoneme-to-grapheme mapping (e.g., \([\text{st@]} = \text{ste}\) in \(\text{sustte}\)) can be overridden by an incorrect one (e.g., \([\text{st@]} = \text{stte}\) in \(\text{rustte}\), yielding \(\text{*sustte}\)). In other words, if the network misapplies the mappings between sound and spelling from co-activated representations to the target word, irrelevant mappings may determine the spelling output and thus give rise to sublexical homophone intrusions.

Our findings with respect to the past tenses of \(s\) and \(p\) verbs both in the spelling and visual perception experiments are compatible with such an account. Firstly, the existence of a sublexical homophonous cluster indeed determined the error risk in production. Intrusions were observed more often for past tenses with a competing phoneme-to-grapheme mapping for the word-final sublexical sequence than for past tenses with only a single possible spelling. Secondly, in the visual perception experiments, we observed a facilitatory effect on processing speed for sublexical intrusions involving a homophonous grapheme-to-phoneme mapping in contrast to sublexical errors involving a non-existent (hence, not encoded) grapheme-to-phoneme mapping.

\textsuperscript{116}The term Homophone Dominance may not be the ideal choice for the phenomenon at the sublexical level, as we did not demonstrate that homophone intrusions at this level depend on the frequency relation between two homophonous letter strings; only that they are mediated by the existence vs. non-existence of a homophonous string. Whereas the term ‘Sublexical Homophony’ would be more appropriate, we prefer a single term for referring to the cause of homophone intrusions at the lexical and sublexical levels.
(e.g., the \textit{ptte} cluster in \textit{*reptte}).\footnote{The only experiments in which an inhibition effect was found for sublexical homophone intrusions was the SDT and the ETT. As we argued, the same representational structure that yields facilitation in other tasks gives rise to inhibition in these two tasks, as the existence of two orthographic patterns for a single pronunciation creates doubt as to which one is the correct spelling pattern.} This facilitation is due to the simultaneous activation between the mappings for the target (e.g., \textit{suste}) and those for phonologically similar words (e.g., \textit{rustte}, \textit{testte}, ...).\footnote{Note that this is surprising given that the \textit{stte}-pattern has a lower frequency than the correct \textit{ste}-pattern, which suggests that the presence vs. absence of a homophonous orthographic pattern is the crucial factor, not so much the frequency relation between the two (but see, Sandra \& van Abbenyen, 2009).}

Sections 2.1.1 and 2.1.2 demonstrate that our findings of an effect of Homophone Dominance at the lexical and sublexical levels, both in spelling and reading, can in principle be modeled in two model types that are built around the central concept of similarity-based processing. Both model types rely on their possibility of the basic representational and processing aspects (a) to map orthographic representations onto phonological ones (and vice versa) and (b) to make use of mappings that represent exact or partial matches to the target output (spelling) or input (reading).

In the above interpretations of the data (and in all accounts throughout this work), we have restricted our attention to the orthography-phonology interface and have never mentioned the possible involvement of semantics. Still, it should be pointed out that, in some experiments, mappings involving semantics are likely to have played a role as well. Indeed, in addition to the existence of mappings between two orthographic and one phonological representation, another factor may have contributed to the fast acceptance of incorrect spellings like \textit{*sustte} in visual perception and to the occurrence of these homophone intrusions in spelling. The word-final letter sequence \textit{tte} is restricted to past tenses in Dutch spelling and is, hence, a highly valid orthographic cue for the past tense meaning of a word form. Even though this orthographic ending is not a \textit{linguistic} marker for a past tense form (the suffix \textit{-te} is), it is a fully reliable \textit{orthographic} marker, there being a 100\%
correlation between the word-final orthographic sequence *tte and the past tense meaning\textsuperscript{119}. This strong mapping between the orthographic sequence *tte and the meaning 'past tense' is likely to have been an additional factor that caused readers to accept incorrect past tenses like *sustte and caused spellers to make such spelling errors.

Note, however, that this bidirectional form-to-meaning mapping must operate in interaction with the mappings between orthography and phonology. More particularly, its influence depends on the existence of a sublexical homophonous orthographic sequence. Indeed, we observed fewer spelling errors when such a sublexical homophonous pattern was absent (e.g., *reptte), despite this strong form-to-meaning mapping. Similarly, when such spelling errors were presented in visual perception experiments, they caused a strong 'surprise effect' (leading to slower RTs in online experiments and more correct error detections in an offline proofreading task than those for errors involving a sublexical homophonous pattern).

In short, two types of mappings in similarity-based models can account for spellers' tendency to make homophone intrusion errors like *sustte when spelling past tenses and readers' fast acceptance of these spelling errors, both in online tasks (in the PDT and SPRT) and offline tasks (PRT): bi-directional mappings between orthography and phonology and bi-directional mappings between semantics and orthography (the orthographic sequence *tte being a reliable indicator of the meaning 'past tense'). The impact of the latter mapping is conditional on the presence of the former. Note that each model type that makes use of a central similarity-based process and has a way of representing semantics should, in principle, also be able to represent such mappings and, hence, simulate spellers' and readers' performance on homophone intrusions like *sustte, by appealing to both bidirectional mappings between orthography and phonology as well as between orthography and semantics.

\textsuperscript{119}The sequence *tte results from the concatenation of a stem-final t and the spelling of the past tense suffix -te.
Interestingly, other studies have also shown that the mental lexicon is not organized in terms of linguistic units such as morphemes and affixes, whose combinatorial possibilities are governed by a set of rules. A study by Bowers, Davis, and Hanley (2005) found that frequent sublexical patterns are automatically activated, whether matching a true morpheme or not. When presented with a word such as *hatch* in which the sublexical unit *hat* is embedded, questions such as “*Does hatch refer to a piece of clothing?*” were more difficult to answer (i.e., longer RTs/higher ERs) than questions that did not make any reference to that substring’s meaning, as in “*Does hatch refer to a human body part?*” Crucially, the inability to suppress this letter pattern, matching the form of a morpheme but not having the function of a morpheme in the word, was only found when its frequency exceeded that of the entire word. This goes to show that lexical processing is driven by the retrieval of frequently occurring letter strings, whether they are morphemes or not.

Similarly, Davis, van Casteren, and Marslen-Wilson (2003) propose a different interpretation of the results obtained by Baayen et al. (1997). In a series of LDTs, these authors found that lemma frequency modulated RTs to singular Dutch nouns, whereas whole-word frequency affected RTs to plural nouns with the plural en-suffix. Baayen et al. (1997) took these findings as evidence for a dual-route morphological race model in which both full forms and morphemic units are stored in the mental lexicon (Schreuder & Baayen, 1995). While such a model assumes two different processing mechanisms (whole-word retrieval vs. decomposition), Davis et al. (2003) showed that a single distributed connectionist mechanism that does not make any reference to linguistic units such as morphemes or full forms (being morpheme combinations) can also simulate the pattern of results for regularly inflected nouns found by Baayen et al. (1997). We also refer to Moscoso del Prado Martín et al. (2004) for a connectionist model of type- and token-based frequency effects with Dutch past tenses. These simulations within the context of a connectionist framework are less important to us than the demonstration that a similarity-based approach can account for these data.
2.2. Summary

To summarize, we found that the frequency of regularly inflected homophonous verb forms and the familiarity of sublexical homophonous letter strings straddling a morpheme boundary affected production and perception (see Bowers et al., 2005; Davis et al., 2003 for similar findings with sublexical letter strings matching a morphemic form but lacking a morphemic function). Importantly, the findings for sublexical homophone intrusions reject an account of homophone intrusions at the lexical level in which whole-word representations are claimed to be absent. In such an account the effect of Homophone Dominance is explained in terms of (a) a purely morpheme-based decomposition process that is (b) enriched with a frequency-sensitive mechanism encoding the co-occurrence frequency of a particular stem-suffix pairing. Such an account would naturally give rise to whole-word frequency effects and could, hence, also account for the effect of Homophone Dominance at the lexical level (Fayol et al., 1994; Largy et al., 1996). However, an account in which morphemes are the basic representational units can never account (a) for homophone intrusions at the sublexical level involving letter patterns that run across a morpheme boundary and (b) for the way in which such homophone intrusions are processed in visual perception (i.e., depending on the frequency of the sublexical letter string). Hence, any model that makes use of morphemes and combinatorial rules will fail to account for the entire data pattern.

In contrast, a model that takes recourse to three qualitatively different processing mechanisms (i.e., morphological decomposition and whole-word retrieval and a process that co-activates sublexical homophonous letter strings) can explain the data. However, it is more parsimonious to account for lexical and sublexical homophone intrusions by assuming a single underlying processing mechanism: similarity-based processing. Any model that incorporates such a mechanism should in principle be able to account for homophone intrusions involving an exact or partial match to one or more
existing lexical representations (i.e., lexical and sublexical intrusions, respectively).

The fact that both types of intrusions involve the co-occurrence frequencies of letter patterns, stretching either across the whole word, across a morpheme, or across a sublexical string (i.e., a pattern consisting of the stem-final letter and the suffix), suggests that these intrusions reflect statistical patterns in the mental lexicon. The exact way in which these statistical patterns and the similarity-based processing mechanism for accessing these patterns is implemented differs between these two possible instantiations of this concept. In a connectionist implementation, the statistical structure of the lexicon is encoded in the connection weights between the units in the same or across different representational layers. Although whole-word, morphemic and sublexical units are not explicitly represented in such a model, they are emergent properties of its representational structure. Hence, this structure is able to capture rule-like behavior and statistical regularities, like the effect of Homophone Dominance. In an instance-based model, the statistical structure is not directly encoded in the representational structure itself. Rather, it emerges as the result of its basic similarity-driven process, which retrieves both exact and partial matches. The set of thus retrieved representations reflects statistical tendencies (e.g., more tokens of HF verb forms or of representations containing the alternative orthographic pattern of a homophonous substring). The statistical tendencies in this set will directly determine the output of the selection mechanism, which is based on the frequency distribution of the possible output patterns. Hence, any model where similarity is a central process should in principle be able to simulate the three frequency effects found in our experiments, namely whole-word, morphemic and sublexical frequency, as these are all examples of statistical tendencies.

When spelling and reading regular verb homophones (at the lexical level) or inflected verb forms containing a sublexical homophonous letter string in word-final position (crossing the morpheme boundary), language users rely on the conscious application of explicitly trained abstract mental
rules represented in a *declarative knowledge base* (reflecting the spelling rules). However, at the same time they make use of an *implicit knowledge base* that captures the recurrence of orthographic patterns that are systematically mapped onto phonological patterns, whether they match morphemes, full forms or sublexical patterns. They also rely on form-meaning mappings in the case of morphemes, full forms and sometimes even sublexical patterns (the word-final letter string *tte* being an orthographic marker of the past tense meaning).\(^\text{120}\)

### 3. Future Research Directions

Our findings also offer several opportunities for future research. Firstly, the experiments in the sublexical domain focused on the opposition between past tenses with and without a competing homophonous cluster. To further confirm the probabilistic nature of lexical processing, one might examine whether the frequency relation between two existing homophonous orthographic clusters serves as an explanatory factor in the perception of Dutch past tenses (as has been found for homophone intrusions at the whole-word, i.e., lexical level). A Google corpus study on past tenses (Sandra, 2010) already showed that spellers made fewer errors (i.e., substituting the correct *tte*-spelling by the incorrect *te*-spelling) for *cht* verbs (e.g., *wachtte* ‘waited’), whose correct *chtte*-spelling is more frequent than its homophonous cluster *cht* (e.g., *lachte* ‘laughed’), compared to *st* verbs. For the latter verbs, the frequency of the homophonous cluster *ste* (e.g., *suste*) is much higher than that of the correct *stte*-pattern (e.g., *rstette*). It would be interesting to examine whether errors on *st* verbs would also be processed more quickly and, hence, go undetected more often compared to errors on *cht* verbs, considering that the orthographic frequency of the competing *chtte*-pattern (i.e., *ch* verbs) is lower (hence, less familiar) than the correct *chtte*-pattern, whereas the

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\(^{120}\) The above implementations of similarity-based models obviously only capture language users’ implicit knowledge, but are not intended to encode their declarative knowledge.
homophonous ste-pattern (i.e., s verbs) is higher than that of the correct stte-pattern.

Intrinsically linked to this issue, a future challenge might be to implement an instance-based and a connectionist model and compare their performance with respect to their actual ability to simulate our experimental data. Importantly, a model that is able to simulate the behavioral data should also be able to predict the outcome of an experimental manipulation that has not been tested yet, such as (the processing speed of) other error types. On the one hand, it should predict the pattern/processing speed of intrusions involving other sublexical homophonous clusters (i.e., of the type proposed above; e.g., *wachte vs. *ruste), depending on their frequency relation. In the case of ‘homophonous mappings’, frequent mappings should more often override infrequent mappings than vice versa. On the other hand, a valid model should also be able to predict intrusions involving homophonous clusters from different inflectional types. An example of the latter intrusion type is *gevormdt (instead of gevormd ‘formed’; both pronounced as [x@vOrmt]). This type of intrusion combines the past participle ge-prefix and the sublexical (i.e., non-morphemic) cluster dt that is a reliable orthographic marker for 3rd person present tenses of stem-final d verbs (e.g., meld-t ‘report-s’). Such errors are commonly observed in, for instance, student writings (although not so frequently as the errors studied in this work) and raise the question which factors account for their existence. In comparison to the errors studied in the present work, these are ‘strange’ errors, as the incorrect form is homophonous to the correct form, but is a non-existent stem-suffix combination because the suffix belongs to a different inflectional type (i.e., is not allowed to occur in the past participle, unlike the errors on past participles of weak prefix verbs, which are existing forms).

An additional benefit of such simulations might be a better characterization of the phonological neighbors that actually influence processing. As mentioned before, not only the phoneme-to-grapheme mappings between [st@] and ste vs. stte might be relevant, but also those between other letter patterns and their pronunciation (e.g., (t)te, us(t)te,
vowel+s(t)te, vowel+fricative+(t)te). In other words, it is not clear how far into the word form the relevant sublexical pattern reaches, nor how specific the representation of the pattern should be (i.e., in terms of specific phonemes or in terms of abstract phoneme categories like ‘vowel’ and ‘fricative’?). Such a simulation might redefine which words are to be considered as phonological neighbors.

A third prospect for future research concerns an attempt to link behavioral to neurological measures. Event-related brain potential (ERP) and brain imaging studies might offer a complementary view on how homophone intrusions are processed. ERP studies (e.g., EEG, MEG), investigating the differences in latencies and amplitudes of specific components (e.g., N400, P600), are able to shed light on participants’ sensitivity to homophone intrusions and the timing of such component processes. Harris, Perfetti, and Rickles (2014), for instance, examined the amplitude of the error-related negativity (ERN), defined as “a response-locked, negative-going component that has been associated with error detection in decision-making” (p. 112). One possible interpretation of their findings in a spelling decision task is that the amplitude of the ERN was smaller when there was no response conflict compared to when there was. Similarly, one could examine whether the amplitude of the ERN is smaller in a spelling decision task for intrusions involving an infrequent homophonous orthographic pattern (i.e., causing a small response conflict) compared to intrusions of the higher frequency form (i.e., causing a large response conflict). Additionally, brain imaging techniques (e.g., fMRI, PET) can reveal which neural regions are activated when processing homophonous verb forms (i.e., in contrast to, for instance, non-homophonous forms). An fMRI study by Newman and Joanisse (2011) showed that the frequency of a homophone (in this case semantically unrelated homophones such as maid and made) affected the size of the activation in the left inferior frontal gyrus (IFG) and left middle temporal gyrus (MTG), with an increased activation in these regions for LF homophones. Similarly, brain imaging might be able to provide an answer to the question whether homophone intrusions of regular verb forms cause a different pattern of brain
activation compared to the correctly spelled verb forms (because the relevant brain region(s) signal a spelling error) and, if so, whether such differences are affected by the frequency of the homophone intrusion.
CONCLUSION

In this dissertation, we aimed to provide an answer to the question why Dutch texts are plagued by homophone intrusions, despite the straightforward rules that govern the spelling of these regularly inflected verb forms. We studied two types of intrusion: (a) lexical intrusions (i.e., verb forms are substituted by homophonous full-forms from the same verbal paradigm; e.g., *hij meld ‘he report’) and (b) sublexical intrusions (i.e., non-morphemic orthographic patterns straddling the stem-suffix boundary are substituted by homophonous spelling patterns; e.g., *hij sustte ‘he hushed’). The experiments, targeting both written production (Chapter 2) and visual perception (Chapter 3) converge on the same conclusion: Dutch language users do not deterministically apply spelling rules by appealing to an explicit and consciously accessible knowledge base and by implementing the stored rules in working memory. Rather, both careful spellers and readers occasionally run into the trap set up by our cognitive infrastructure, causing them to produce and overlook intrusions involving a frequent homophonous spelling pattern, as a result of access to an implicit and unconsciously accessible knowledge base. At the end of this work, we can be rather confident in claiming that the persistence of these homophone intrusions is due to the impact of Homophone Dominance in both spelling and reading (at both the lexical and sublexical level). In other words, our cognitive infrastructure underlying lexical processing creates a double trap, which explains why these errors are so difficult to eradicate.

This dissertation also reveals an important aspect about the organization of the mental lexicon. The pattern of results for lexical intrusions was determined by the whole-word frequency ratio between the two homophonous forms. Homophone intrusions involving the HF form were made more often, processed more quickly and overlooked more often than the LF form121, suggesting that processing cannot be exclusively morpheme-based.

121 Note that the Homophone Dominance effect in visual perception was restricted to homophones forms of stem-final d verbs, but was not found for weak prefix verbs.
In contrast, these findings indicate that whole-word representations are accessed for regularly inflected verb forms (at least for HF ones), although such a process is logically superfluous given the rule-based nature of these inflections. Sublexical intrusions involving an illegal combination of a non-stem and the past tense suffix also confirm the conclusion that processing is not purely morpheme-based (i.e., they are morphologically impossible forms). The finding that the familiarity of sublexical homophonous clusters (neither functioning as morphemes, nor corresponding to morphemic forms) co-determined the error risk in production and the processing times and error detection rates in visual perception also indicates that not all sublexical strings that influence lexical processing are morphemes. These sublexical intrusions, however, also question the involvement of a whole-word retrieval route, since such spelling errors cannot be caused by the intrusion of an existing homophonous word form. Therefore, the pattern of results is more consistent with a similarity-based mechanism that assigns a central role to each sufficiently frequent co-occurrence of letters whether these orthographic patterns coincide with morphemic, full-form or sublexical units that straddle the stem-suffix boundary. In such a view, a homophonous letter string is mapped onto its phonological representation, which in turn is mapped onto all corresponding orthographic realizations, thus co-activating those of its morphological and phonological neighbors. These form representations are also mapped onto a semantic representation (sometimes even in the case of non-morphemic patterns, the final cluster *tte* being a reliable orthographic cue for the past tense meaning). These mappings cause (lexical or sublexical) homophone intrusions in spelling and detection failures in visual perception. Moreover, such a similarity-based model predicts that the risk of making homophone intrusions as well as overlooking them is higher when the intruder corresponds to the HF homophone or a familiar sublexical homophonous pattern. This prediction matches the findings reported in this work.

In sum, homophone intrusions are the inevitable by-products of the workings of our lexical architecture and its concomitant processes, which tricks Dutch language users into making these errors in spelling and accepting
them in reading, at least when their spelling corresponds to the most frequent homophone or to a familiar orthographic homophonous pattern.


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## APPENDIX

<table>
<thead>
<tr>
<th>Verb</th>
<th>Translation</th>
<th>Homophoneous Forms</th>
<th>WWF D-form</th>
<th>WWF DT-form</th>
<th>Homophone Ratio</th>
<th>Dominance</th>
<th>LF</th>
</tr>
</thead>
<tbody>
<tr>
<td>duiden</td>
<td>to interpret, explain</td>
<td>duid(t)</td>
<td>7</td>
<td>147</td>
<td>-1.32</td>
<td>DT-dominant</td>
<td>244</td>
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<tr>
<td>schaden</td>
<td>to damage</td>
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<td>77</td>
<td>-0.98</td>
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<td>272</td>
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<td>uibradden</td>
<td>to expand</td>
<td>uibrad(t)</td>
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<td>15</td>
<td>-0.88</td>
<td>DT-dominant</td>
<td>195</td>
</tr>
<tr>
<td>overschrijden</td>
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Table 1: Characteristics of stem-final d verbs. WWF = raw Whole-Word Frequency; LF = raw Lemma Frequency
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Table 2: Characteristics of past tense verb forms whose stem end in -s or -p. WWF = raw Whole-Word Frequency; LF = raw Lemma Frequency.
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Table 3: Characteristics of weak prefix verbs. WWF = raw Whole-Word Frequency; LF = raw Lemma Frequency.
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Table 4: Characteristics of non-homophonous verb forms. WWF = raw Whole-Word Frequency; LF = raw Lemma Frequency, * = weak prefix verbs deleted from the analysis in Section 2.1.3 of Chapter 3.

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Table 4: Characteristics of non-homophonous verb forms. WWF = raw Whole-Word Frequency; LF = raw Lemma Frequency, * = weak prefix verbs deleted from the analysis in Section 2.1.3 of Chapter 3.
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<th>LF</th>
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Table 5: Characteristics of past tense verb forms whose stem end in -st, -rt or -nt. WWF = raw Whole-Word Frequency; LF = raw Lemma Frequency.
De spelling van regelmatige werkwoordvormen in het Nederlands wordt gekenmerkt door een opmerkelijke paradox. De spellingsregels zijn vanuit descriptief standpunt erg eenvoudig en worden bovendien expliciet aangeleerd in het onderwijs. Toch zondigen zowel onervaren als ervaren spellers verrassend vaak tegen deze schijnbaar eenvoudige regels. Het is dan ook niet verwonderlijk dat fouten tegen dergelijke regelwoorden (e.g., hij *meld) minder aanvaardbaar zijn dan fouten tegen weetwoorden zoals *onmiddelijk. Hoewel het in eerste instantie moeilijk te begrijpen lijkt waarom zoveel fouten in (zelfs zorgvuldig nagelezen) teksten blijven staan, zijn er drie factoren die de systematiek achter het foutenpatroon blootleggen en aantonen dat de hardnekkigheid ervan te wijten is aan meer dan enkel een nonchalante houding.

Eerst en vooral, doen deze fouten zich bijna uitsluitend voor op werkwoordvormen met dezelfde uitspraak (voortaan: homofonen), die bij een spelfout worden omgewisseld (bv., hij *meld i.p.v. hij meldt, beide uitgesproken als [mElt]). We kunnen twee types werkwoorden onderscheiden waarvoor dergelijke homofonintrusies een probleem vormen. Enerzijds zijn er stam-finale d werkwoorden, waarbij er concurrentie bestaat tussen het spellingpatroon van de d- en dt-vorm (e.g., meld vs. meldt). Hiervoor zijn de twee homofonen werkwoordvormen in de onvoltooid tegenwoordige tijd (OTT): de d-vorm (stam + -Ø) wordt gebruikt voor de 1e persoon enkelvoud, 2e persoon enkelvoud (met inversie) en de imperatief, terwijl de dt-vorm (stam + -t) de correcte vorm is voor de 2e persoon enkelvoud (zonder inversie) en de 3e persoon enkelvoud. Anderzijds zijn er zwakke-prefixwerkwoorden, waarbij er verwarring ontstaat tussen de t-vorm (stam + -t) die gebruikt wordt voor de 2e en 3e persoon enkelvoud van de OTT en de d-vorm (stam + -d) die gebruikt wordt als voltooid deelwoord (e.g., bestelt vs. besteld). In tegenstelling tot het eerste type overschrijdt de homofone relatie voor dit tweede type homofone werkwoordvormen dus een belangrijk grammaticaal onderscheid (OTT-
voltooid deelwoord).

Ten tweede, kan men voor de correcte spelling van niet-homofone werkwoordvormen (de meerderheid van alle werkwoordvormen; ruwweg 80%, rekening houdend met hun frequentie) simpelweg neerschrijven wat men hoort (bv., *bel-belt*), terwijl de spelling van homofone werkwoordvormen de bewuste toepassing van een grammaticale analyse vergt, die moet worden uitgevoerd door het werkgeheugen. De spelling van regelmatige homofone werkwoordvormen verloopt volgens een compositioneel proces, waarbij spellers gebruik maken van de syntactische informatie van de marker (d.w.z., het woord in de zin dat de suffixspelling bepaalt; bv., het onderwerp is een 3e persoon enkelvoud) om de juiste uitgang van de werkwoordvorm te selecteren (bv., voeg het suffix -t toe aan de stam). Aangezien een dergelijk bewust proces tijdrovend is, slinkt de kans op de tijdige uitvoering van de grammaticale analyse wanneer het werkgeheugen onder druk komt te staan (bv., door tijdsbeperkingen). Als het compositionele proces niet tijdig de spelling van de uitgang kan bepalen, ontstaat bij de spelling van een homofone werkwoordvorm een groter foutrisico.

Onder deze omstandigheden, dringt zich een derde proces op dat het foutenpatroon mee bepaalt: het mentale lexicon (een onderdeel van het langetermijngeheugen) haalt de meest frequente van de twee spellingpatronen van een homofone werkwoordvorm op. In tegenstelling tot het tijdrovende en bewuste proces dat nodig is om de spellingsregel toe te passen, is dit frequentiegevoelige mechanisme een onbewust, geautomatiseerd en daarom snel proces. Wanneer spellers (onbewust) een beroep doen op de output van dit proces omdat het compositionele proces te traag is (d.w.z., snelle activatie van de frequentste vorm), leidt dit tot meer fouten tegen de laagfrequente (LF) werkwoordvorm dan tegen de hoogfrequente (HF) vorm. Wanneer het werkgeheugen overbelast is en de bewuste toepassing van de regel dus vaak te traag is, leidt deze probabilistische strategie niet enkel tot fouten; ze minimaliseert tevens het foutenaantal (i.e., de HF vorm heeft immers de grootste kans om de correcte spelling te zijn). Dit frequentie-effect wordt het effect van *Homofoondominantie* genoemd (d.w.z., de dominante of meest
frequente homofoon zorgt voor de meeste intrusiefouten). Het effect werd herhaaldelijk aangetoond in spellingexperimenten (Assink, 1985; Bosman, 2005; Frisson & Sandra, 2002b; Sandra, 2010; Sandra, Frisson, & Daems, 1999).

Dit effect heeft een verstrekende implicatie: het suggereert immers dat regelmatig gespelde werkwoordvormen worden opgeslagen in het mentale lexicon, hoewel dit strikt gesproken overbodig is. Er is immers geen noodzaak om de spelling van werkwoordvormen op te slaan als die afgeleid kunnen worden aan de hand van regels. Er bestaat echter een alternatieve verklaring die het bestaan van representaties voor regelmatige homofone werkwoordvormen ontkent. Een regelgebaseerd systeem, bestaande uit stammen, suffixen en stam-suffixcombinatieregels die uitgerust zijn met een tellertje dat bijhoudt hoe vaak elke stam met elk suffix werd gecombineerd, kan het effect van Homofoondominantie ook verklaren.

Een tweede soort homofoonintrusie kan deze verklaring echter weerleggen, namelijk sublexicale intrusies. In tegenstelling tot lexicale intrusies, waarbij twee bestaande homofone vormen worden omgewisseld, worden er bij dergelijke fouten twee homofone letterpatronen omgewisseld. Sublexicale homofonie ontstaat bijvoorbeeld voor de klankreeks [st@] wanneer deze in woordfinale positie verschijnt, zoals in de onvoltooid verleden tijden (OVT) suste en rustte. Hoewel de vorming van de OVT ook aan een simpele spellingsregel onderhevig is (nl. voeg -te toe aan de stam na een stemloos foneem en -de in alle andere gevallen > suste en rust-te), worden de twee alternatieve spelwijzen (ste en stte) soms verwisseld (bv., *sustte en *rustte). Terwijl lexicale intrusies grammaticaal onmogelijk zijn (bv. de dt-vorm van een werkwoord met stam-finale d is een grammaticaal fout als de d-vorm de doelvorm is), vormen sublexicale intrusies non-woorden die grammaticaal niet fout zijn (bv., non-stam *sust + -te). Vanuit het perspectief van een regelmodel (of dat nu gevoelig is voor de frequentie waarmee morfemen worden gecombineerd of niet) zijn sublexicale intrusies dus onmogelijk. Ze kunnen immers niet door een morfologische combinatieregel gegenereerd worden. Bovendien kan een dergelijk mechanisme niet verklaren

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waarom bepaalde sublexicale intrusies vaker voorkomen dan andere, omdat die intrusies berusten op de vertrouwdheid met een homofoon letterpatroon dat niet correspondeert met een morfeem maar met een letterreeks die de morfeemgrens overschrijdt (bv. *ste* en *stte*). Een systematische studie van lexicale en sublexicale homofoonintrusies laat ons daarom toe om een centrale vraag in de psycholinguïstiek te beantwoorden: doen taalgebruikers in het geval van de spelling van regelmatige werkwoordvormen uitsluitend een beroep op bewuste regeltoepassing over stam- en suffixmorfemen of ook op statistische wetmatigheden (nl., de frequentie van woordvormen of letterpatronen)?

Dit proefschrift had twee grote doelen. Enerzijds, wilden we nagaan of Homofoondominantie zowel het spelproces als het leesproces beïnvloedt. Anderzijds, wilden we nagaan of Homofoondominantie niet enkel een rol speelt voor lexicale maar ook voor sublexicale intrusies. Voor het spelproces onderzochten we daarom of intrusies vaker gemaakt werden (a) wanneer de LF homofoon gespeld moest worden dan wanneer de HF homofoon de doelvorm was en (b) wanneer een OVT gespeld moest worden met een homofoon (concurrerend) letterpatroon aan het woordeinde (dat de morfeemgrens overschrijdt) in vergelijking met een OVT waarvan de uitspraak van het overeenstemmende woordeinde maar één spelling mogelijk maakt. Voor het leesproces onderzochten we of de intrusies die vaker voorkwamen tijdens het spellen ook sneller verwerkt werden tijdens hun visuele perceptie en daarom ook eerder (ten onrechte) geaccepteerd werden als de correcte spelling. In dat geval zou Homofoondominantie zowel het leesproces als het spellingproces beïnvloeden.

### 1. Spellingsproces

Het effect van Homofoondominantie op het spellingproces werd onderzocht aan de hand van drie experimenten: een offline dictee, een online dictee en een corpusanalyse.
1.1. Offline dictee

In het eerste experiment – een offline dictee – vroegen we participanten om gedicteerde zinnetjes neer te schrijven. Die bevatten twee kritische werkwoordtypes, namelijk tegenwoordige tijdsvormen van stam-finale d-werkwoorden (type *melden*) en verleden tijdsvormen (type *suste, repte*). Voor het eerste werkwoordtype moesten de deelnemers zinnen noteren waarin ofwel de 1e persoon enkelvoud (bv., *ik … meld* ofwel de 3e persoon enkelvoud (bv., *hij … meldt*) voorkwam. Conform onze hypothese stelden we vast dat er een voorkeur was om de HF homofoon neer te schrijven, wat tot meer fouten leidde wanneer de doelvorm de LF vorm was dan de HF vorm. Naarmate werkwoorden d-dominanter werden (d.w.z., naarmate de frequentie van de d-vorm toenam t.o.v. de frequentie van de dt-vorm, met heel d-dominante werkwoorden aan het eind van het continuüm), werden er meer d-intrusies in de 3e persoon geobserveerd (bv., *hij meld* dan dt-intrusies in de 1e persoon (bv., *ik meldt*). Het omgekeerde patroon werd zichtbaar voor dt-dominante werkwoorden (dt-intrusies kwamen meer voor dan d-intrusies). Deze bevindingen repliceren de resultaten van vorige spellingonderzoeken (Frisson & Sandra, 2002b; Sandra, 2010; Sandra et al., 1999, 2004).

Onze hypothese m.b.t. de OVT-vormen werd ook ondersteund: verleden tijdsvormen waarvan de correcte spelling concurrentie ondervindt van een homofoon orthografisch patroon aan het woordeinde (s-werkwoorden; bv., *suste naar analogie met *rustte*) veroorzaakten meer fouten dan werkwoorden waarvoor dergelijke sublexicale homofonie afwezig is (p-werkwoorden; e.g., *reptte*). Voor s-werkwoorden is het correcte stt-patroon homofoon met het stte-patroon, dat voorkomt in andere OVT’s, meer bepaald OVT’s van werkwoorden waarvan de stam eindigt op st (st-werkwoorden; bv., *rustte*). Voor p-werkwoorden, daarentegen, bestaat er geen enkel woord dat de incorrecte spelling met het ptte-patroon ondersteunt.
1.2. Online dictee

Een online dictee liet ons toe na te gaan of het effect van Homofoondominantie zich ook voordoet voor het tweede type werkwoordhomofonen op lexicaal niveau, namelijk de homofone vormen van zwakke-prefixwerkwoorden (bv. bestellen). Bij zulke werkwoorden zijn de 3e persoon enkelvoud van de onvoltooid tegenwoordige tijd en het voltooid deelwoord homofoon (bv. bestelt-besteld). Opnieuw moesten proefpersonen gedicteerde zinnetjes neerschrijven maar dit keer door ze in te typen in een Word-document. Door gebruik te maken van een dergelijke techniek kunnen we niet enkel het foutenpatroon maar ook de pauzetijden tussen toetsaanslagen onderzoeken. Opnieuw correspondeerde de fout het vaakst met de meest frequente homofoon: naarmate werkwoorden d-dominator werden, werden er minder fouten gemaakt in de voltooid deelwoord (VD) context, die een d-vorm vraagt, maar meer in de onvoltooid tegenwoordige tijd (OTT) context, waar de t-vorm de correcte spelling is. Voor t-dominante werkwoorden, zag het patroon er net omgekeerd uit. Belangrijk om op te merken is dat er een uitgesproken voorkeur voor was de d-vorm, mogelijk het gevolg van een sterke associatie tussen de prefixen ver-/be- en de voltooid deelwoord d-spelling voor dit type homofone werkwoorden (Bosman, 2005; Frisson & Sandra, 2002). De analyse van de pauzetijden bevestigden onze hypothese echter niet: de pauzes tussen toetsaanslagen waren niet korter wanneer de HF vorm correct gespeld werd dan wanneer de LF vorm correct gespeld werd.

Het pauzepatroon voor de OVT’s werd wel beïnvloed door het effect van Homofoondominantie: OVT’s waarvan het t-foneem op slechts één manier gespeld kon worden (p-werkwoorden, enkel het eindcluster pte bestaat) lieten significant kortere pauzetijden opmeten in vergelijking met de OVT’s van s-werkwoorden. Dit is het gevolg van de tijdelijke verwarring tussen het correcte ste-patroon en het bestaan van een homofone spelling (stte) voor het woordfinale cluster in andere OVT’s. Dit effect werd gemeten op de morfo-
syllabische grens (bv., sus_te), waar spellers moeten beslissen of het /t/-foneem met een enkele of dubbele t wordt gespeld.

1.3. Corpusstudie

Om uit te sluiten dat het effect van Homofoondominantie enkel kan worden uitgelokt onder experimentele condities, analyseerden we lexicale intrusies in een grootschalig corpus van teksten op de sociale netwerksite Netlog. We focusten op de homofone spellingvormen van zowel stam-finale d werkwoorden als zwakke-prefixwerkwoorden. Het eerste doel van deze studie was het uitbreiden van het Homofoondominantie-effect naar spontane schrijfoutput. De resultaten beantwoordden aan onze verwachtingen: naarmate de d-vorm de meest frequente homofoon werd, verkozen spellers vaker deze HF d-vorm, terwijl er een voorkeur voor de (d)t-vorm werd geobserveerd wanneer die (d)t-vorm de dominante spelling van een werkwoord vertegenwoordigde. Dit was het geval voor zowel stam-finale d als zwakke-prefixwerkwoorden.

Het tweede doel was aan te tonen dat, onafhankelijk van het effect van Homofoondominantie, morfologische en fonologische buren mee bepalen welke homofone vorm werd neergeschreven. De resultaten voor zwakke-prefixwerkwoorden bevestigden onze voorspelling: naarmate de d-spelling frequenter werd bij de morfologische buren (d.w.z., woorden met dezelfde stam; bv., meld(t) > vermeld(t), gemeld, aangemeld, ...) en fonologische buren (d.w.z., woorden waarvan de stam rijmt met die van het doelwoord; bv., meld(t) > belt, gebeld, bestelt/d, telt, ...), ontstond er een sterke voorkeur voor de d-spelling van het homofone werkwoord, terwijl het omgekeerde patroon zichtbaar werd wanneer de t-spelling de frequentste was. Ook bij de spelling van lexicale homofonen blijkt de frequentie van sublexicale patronen dus een rol te spelen, naast de frequentierelatie tussen de twee homofonen zelf.
1.4. Conclusie spellingproces

De resultaten van de drie productietaken hebben laten zien dat regelmatige werkwoordvormen niet (altijd) volgens strikte spellingsregels worden gevormd, maar dat spellers in de val lopen tijdens het spellen van (gedeeltelijk) homofone werkwoordvormen. Homofoonintrusies zijn het gevolg van de snelle activatie van HF homofone woordvormen (lexicale intrusies) of concurrerende homofone orthografische patronen (sublexicale intrusies).

2. Leesproces

Op basis van de resultaten in de productie-experimenten, stelden we ons de vraag of eenzelfde risicofactor een dubbele val creëert: veroorzaakt Homoofoondominantie niet enkel fouten tijdens het spellen, maar zorgt die factor er ook voor dat lezers eerder over deze fouten heen lezen? Omwille van de vertrouwdheid met het spellingpatroon van een HF homofoon of een bestaand homofoon lettercluster zullen homofoonintrusies van die vertrouwde patronen mogelijk sneller verwerkt worden dan intrusies van een LF homofoonvorm of van een gelijkklinkend maar niet-bestaand cluster. Als gevolg hiervan zullen dergelijke fouten er mogelijk niet ‘verdacht’ uitzien en daardoor minder vaak opgemerkt worden als fout. Indien deze hypothese klopt, zou het bestaan van die dubbele val een sterke verklaring bieden voor de hardnekkigheid van homofoonintrusies.

Deze twee hypotheses werden getest aan de hand van zeven experimenten: (1) een lexicale-decisietaak, waarin de werkwoordvormen in isolatie werden aangeboden; (2) een spellingdecisietaak en (3) een fonologische-decisietaak, waarin de werkwoordvormen in een minimale grammaticale context verschenen; en vier taken waarin de werkwoordvormen in een volledige zinscontext werden aangeboden: (4) een oogbewegingstaak, (5) een self-paced reading taak, (6) een maze taak en (7) een naleestaak.
Om de correcte spelling van een homofone werkwoordvorm te achterhalen, moet een bewuste en tijdrovende grammaticale analyse uitgevoerd worden. Hierbij moet het werkgeheugen de grammaticale kenmerken van de marker identificeren (d.w.z., het woord dat de spelling van de uitgang bepaalt; bv., het onderwerp) en die laten congrueren met de spelling van de uitgang, die tijdens de visuele perceptie wordt losgemaakt van de stam door een morfologisch decompositieproces. Wanneer woorden in isolatie worden aangeboden is een dergelijke tijdrovende grammaticale analyse uiteraard overbodig aangezien er geen marker aanwezig is en proefpersonen enkel moeten nagaan of de werkwoordvorm een bestaande woordvorm is, m.a.w. een homofone werkwoordvorm kan in isolatie per definitie niet fout gespeld worden. Wanneer marker en werkwoord naast elkaar staan (m.a.w., in een minimale grammaticale context) is die analyse relatief makkelijk en snel uit te voeren. Spellingonderzoek heeft inderdaad aangetoond dat het foutenrisico stijgt naarmate er meer woorden de marker en de werkwoordvorm van elkaar scheiden, zoals in bepaalde zinscontexten (Fayol, Largy, & Lemaire, 1994; Largy, Fayol, & Lemaire, 1996; Sandra, Frisson, & Daems, 1999). Aangezien het afronden van de grammaticale analyse tijdsintensiever wordt naarmate marker en homofone werkwoordvorm verder uiteen staan, was onze predictie dat proefpersonen onder dergelijke omstandigheden niet altijd wachten op de output van dit trage proces en dat de kans bijgevolg groter wordt dat ze gebruik maken van de output van de niet grammaticaal gestuurde snelle helewoordroute (m.a.w., het proces dat de HF vorm snel activeert). Daarom schatten we de kans op een effect van Homofoondominantie op het lexicale niveau kleiner in voor de taken met een minimale grammaticale context (Experimenten 2 en 3) dan voor de taken met een zinscontext (Experimenten 4, 5, 6 en 7). In de geïsoleerde herkenningstaak (Experiment 1) zal een effect van Homofoondominantie uiteraard geen betrekking hebben op de verwerkingsnelheid van intrusies aangezien werkwoordvormen buiten een grammaticale context per definitie geen intrusies zijn. Het effect zou reflecteren dat de dominante vorm sneller herkend wordt, voor de twee homofone spellingpatronen (d vs dt of d vs t) en
daarom ook in het mentale lexicon is opgeslagen. Het optreden van dit effect is zelfs een noodzakelijke voorwaarde om bij de studie van intrusies een effect van Homofoondominantie te vinden omdat dit effect volledig afhankelijk is van de opslag van (minstens) de HF vorm en (mogelijk ook) de LF vorm van een homofonenpaar (maar zie de commentaar bij de resultaten voor de zwakke-prefix werkwoorden).

2.1. Lexicale decisietaak

In de lexicale decisietaak (LDT) moesten proefpersonen zo snel mogelijk beslissen of de gepresenteerde letterreeks een bestaand Nederlands woord was of niet. Voor stam-finale d werkwoorden, was de snelheid waarmee er een ja-respons gegeven werd afhankelijk was van de frequentierelatie tussen de twee werkwoordvormen: naarmate werkwoorden d-dominanter werden, daalden de reactietijden voor d-vormen en stegen ze voor dt-vormen (en vice versa wanneer werkwoorden dt-dominanter werden).\textsuperscript{122} De bevinding dat de HF vorm werd geactiveerd is een eerste sterke indicatie dat de hele-woordroute een rol speelt tijdens de visuele perceptie van regelmatige (homofone) werkwoordvormen. Aangezien er geen grammaticale context aanwezig was en er dus ook geen grammaticale analyse nodig was, suggereert dit dat een regelmatige homofone werkwoordvorm in de visuele perceptie niet enkel via morfologische decompositie wordt herkend maar ook via toegang tot hele-woordrepresentaties. Dat bevestigt de conclusies van de spellingexperimenten en maakt het mogelijk om met syntactische contexten (zowel minimale contexten als zinscontexten) het effect van Homofoondominantie te bestuderen.

In tegenstelling tot stam-finale d werkwoorden, werd er geen effect van Homofoondominantie gevonden voor het tweede type van homofone werkwoorden, namelijk zwakke-prefixwerkwoorden: LF vormen werden niet

\textsuperscript{122} Een opvallende observatie was dat proefpersonen in deze LDT in mindere mate een beroep deden op hele-woordrepresentaties voor niet-homofone werkwoordvormen, die men kan spellen op basis van hun uitspraak (bv., bel-belt).
trager verwerkt dan HF vormen. Het effect werd echter mogelijk gemaskeerd door een globale d-bias (cf. de productie-experimenten), waardoor d-vormen steeds sneller verwerkt werden dan t-vormen, ongeacht de dominantie van de vorm. Binnen de set homofoonparen van zwakke-prefixwerkwoorden is er in een tokenantelling (die rekening houdt met de frequentie van elke vorm) immers een heel sterke associatie tussen zwakke prefixen en de d-spelling. We verwachtten dat het effect zich voor zwakke-prefixwerkwoorden wel zou manifesteren wanneer deze vormen worden aangeboden in een minimale grammaticale context, die een grammaticale analyse vereist via de trage regelroute (bv. de fonologische decisietaak), waardoor de spelling van de HF vorm via activatie van zijn hele woordrepresentatie het snelst beschikbaar zou kunnen zijn.

### 2.2. Spellingdecisietaak

In de spellingdecisietaak (SDT) werden stam-finale d werkwoordvormen in een minimale grammaticale context aangeboden, die bestond uit het voornaamwoord *ik* of *hij* gevolgd door een correct of foutief gespelde werkwoordvorm (bv., *ik meld* vs. *hij *meld*). Het was de taak van de deelnemers om te beslissen of deze tweewoordcombinaties correct gespeld waren. De proefpersonen focusten dus expliciet op de spelling van de homofoonvormen. Hoewel de grammaticale analyse die nodig is om de correctheid van de spelling te achterhalen relatief makkelijk is (immers, het onderwerp en de werkwoordvorm verschenen naast elkaar) werd er toch ook een beroep gedaan op de hele-woordroute: voor correcte spellingen (ja-responsen) werd er sneller gereageerd op de HF dan op de LF homofoon. Wanneer de HF homofoon echter verworpen moest worden als een incorrecte spelling (nee-responsen) waren de reactietijden (RT) juist sneller voor de LF homofoon. Die vertraging is het gevolg van een responsconflict: de initiële neiging om een ja-respons te geven op basis van de orthografische vertrouwdheid met de HF homofoon moest worden onderdrukt om een nee-respons te geven op basis van de grammaticaal foutieve spelling. Als gevolg
van de snelle activatie van de HF homofoon werd deze spelling sneller geaccepteerd dan die van de LF homofoon wanneer het een correcte spelling was, maar moeilijker verworpen wanneer het een foutieve spelling was. Beide effecten verwijzen echter naar de snelle activatie van een opgeslagen orthografische representatie van de HF vorm.

Voor de OVT’s moesten de deelnemers ook beslissen of de letterreeks correct gespeld was (hij suste/repte vs. hij *sustte/*reptte). In tegenstelling tot lexicale intrusies, waar beide spellingen bestaande vormen zijn en een grammaticale analyse nodig is om een fout te detecteren, kunnen sublexicale intrusies gedetecteerd worden louter aan de hand van een morfologische analyse en speelt de syntactische context geen rol. Wanneer het verleden tijdsuffix -te wordt weggehaald, blijft er bij een incorrecte vorm immers een niet-bestaande werkwoordstam over (e.g., *sustte > *sust + -te), zowel voor p- als voor s-werkwoorden. In tegenstelling tot wat voorspeld zou worden door een model waarin morfologische decompositie centraal staat, werden zowel ja- als nee-responsen vertraagd voor s-werkwoorden ten opzichte van p-werkwoorden. Voor deze laatste groep kan het eindcluster slechts op één manier gespeld worden (pte en niet *ptte), terwijl het eindcluster bij de OVT van s-werkwoorden (ste) homofoon is en dus in de OVT’s van andere werkwoorden anders gespeld wordt (m.a.w., ook het eindcluster stte bestaat). Dit demonstreren dat de herkenning van werkwoordvormen in een taak met een sterke focus op spelling vertraagd wordt wanneer er twee orthografische patronen met één enkele uitspraak verbonden zijn. Het bestaan van een sublexicaal homofoon letterpatroon dat de morfeemgrens overschrijdt, creëert verwarring tijdens de visuele perceptie van zowel correct als incorrect gespelde werkwoordvormen.

2.3. Fonologische-decisietaak

Om het responsconflict dat ontstond voor stam-finale d werkwoorden in de SDT weg te werken, voerden we een fonologische-decisietaak (FDT) uit met dezelfde tweewoodcombinaaties. Deelnemers moesten nu beslissen of de
uitspraak ervan als correct Nederlands zou klinken (d.w.z. dat ze spelfouten moesten negeren en een correcte ja-respons geven voor zowel correcte als incorrecte spellingen, bv., ‘ja’ voor *ik vind en *ik vindt). Proefpersonen reageerden steeds sneller op de HF vorm van een homofonenpaar, ongeacht of die vorm een spelfout was of niet. Die spelfouten werden nochtans opgemerkt, wat bleek uit de tragere responsen op incorrect gespelde vormen. Dit bevestigt onze conclusie uit de SDT: ondanks het feit dat het onderwerp en het werkwoord naast elkaar verschijnen en de kans dus groot is dat men gebruik maakt van de spellingsregel om een respons te geven, werd de helewoordroute toch (ook) aangesproken, wat blijkt uit de hele snelle activatie van de HF vorm van het homofonenpaar.

In de FDT moesten deelnemers ook beslissen of correct en incorrect gespelde homofone vormen van zwakke-prefixwerkwoorden fonologisch acceptabel waren wanneer ze in een minimale context aangeboden werden (bv., *hij bestelt/d vs. *hij heeft besteld/t). In het experiment werd de HF homofoon echter niet sneller verwerkt dan de LF vorm, maar ook hier kan een d-bias het Homofoondominatie-effect gemaskeerd hebben (cf. de LDT). Hierdoor moeten we concluderen dat de hele-woordroute geen faciliterende rol speelt wanneer zwakke-prefixwerkwoorden in een minimale grammaticale context verschijnen. Dat betekent niet dat die route niet actief is maar dat het effect ervan mogelijk overschaduwd wordt door een sterkere factor (in casu: de d-bias).

De FDT onderzocht ook het Homofoondominantie-effect op het sublexicale niveau: proefpersonen moesten een ja-respons geven voor zowel correcte als foutieve spellingen van OVT’s (bv., een ja-respons voor *hij suste en *hij *sustte). Een theoretisch kader waarin morfemen als basisrepresentaties worden beschouwd voorspelt dat sublexicale intrusies tot een gelijkaardige vertraging moeten leiden t.o.v. correcte spellingen voor p- en s-werkwoorden (als gevolg van een onmogelijke stam-suffix combinatie). Het feit dat werkwoorden van het eerste type geen homofone tegenhanger *ptte kennen maar die van het tweede type wel de homofone tegenhanger stte kennen zou dus geen rol mogen spelen. Toch werden spelfouten voor beide types
werkwoorden niet even snel aanvaard als fonologisch correct. De reactietijden voor correcte en incorrecte vormen verschillen niet wanneer het indringende orthografische patroon ondersteund werd door een homofoon cluster in andere OVT’s (s-werkwoorden; *sustte < rustte) terwijl spelfouten waarvan het orthografisch cluster niet werd ondersteund (p-werkwoorden; e.g., *reptte) minder snel herkend werden.

Ten slotte gingen we in de FDT na of de vertrouwdheid met een orthografisch (homofoon) patroon voor OVT’s beperkt blijft tot het werkwoordelijk paradigma of uitgebreid kan worden naar alle woorden die dat patroon bevatten. De resultaten gaven aan dat het laatste het geval is. Sublexicale intrusies leverden geen vertraging op t.o.v. correcte spellingvormen, noch voor werkwoorden met een homofoon patroon zowel binnen als buiten het werkwoordelijk paradigma (st-werkwoorden; bv., testte > suste, activiste) noch voor werkwoorden met een homofoon patroon dat enkel buiten het werkwoordelijk paradigma voorkwam (rt/nt-werkwoorden; bv., startte of plantte > zwarte, lente). Dit wijst erop dat werkwoordvormen met sublexicale fouten – hoewel ze onmogelijk zijn vanuit morfologisch standpunt – sneller worden verwerkt van zodra ze een bestaand homofoon orthografisch patroon bevatten (s-, st- en rt/nt-werkwoorden), onafhankelijk van de lexicale categorieën waarbinnen dit patroon voorkomt, dan wanneer ze een niet-bestaand patroon bevatten (p-werkwoorden). Uit al deze observaties concluderen we dat de mate van vertrouwdheid met een orthografisch patroon ongevoelig is voor (a) morfeemgrenzen (de homofone clusters overschreden immers de stam-suffixgrens) en (b) woordsoortcategorieën (het gaat om een puur vormeffect van homofone patronen).

Hoewel deze reeks perceptie-experimenten bewijs leveren dat Homofoondominantie de visuele herkenning van stam-finale d werkwoorden (lexicaal niveau) en OVT’s (sublexicaal niveau) mee bepaalt, volgt hier niet noodzakelijk uit dat men ook gebruik gaat maken van HF vormen of frequente orthografische patronen tijdens het lezen van werkwoordvormen in zinnen. Om na te gaan of Homofoondominantie de verwerkingsnelheid ook
beïnvloedt tijdens het leesproces voerden we vier leestaken uit waarbij de werkwoordvormen in een zinscontext werden aangeboden.

### 2.4. Oogbewegingsexperiment

In de meest natuurlijke leestaak – het oogbewegingsexperiment (waar proefpersonen enkel zinnen moeten lezen en niet tegelijkertijd een experimentele taak moeten uitvoeren) – bestudeerden we hoe lang er werd gekeken naar incorrect gespelde homofone werkwoordvormen, waarbij de duurtijd van een fixatie sterk correleert met de verwerkingsmoeilijkheid ervan. Voor stam-finale d werkwoorden, observeerden we een niet-significante maar zeer sterke trend van Homofoondominantie in de spillover regio, de regio van woorden die onmiddellijk op de werkwoordvorm volgen. Naarmate de dt-vorm de meest frequente homfooon van een werkwoordpaar werd, werd er minder lang gefixeerd op dt-intrusies.

Het fixatiepatroon voor de OVT’s was vergelijkbaar met de resultaten voor de SDT: de totale fixatietijden op die vormen werden vertraagd door een sublexicale intrusie (m.a.w., een spelfout viel op), en dit zowel voor s- als voor p-werkwoorden. Bovendien werd er langer gefixeerd op werkwoordvormen met een homofoon cluster op het sublexicale niveau (s-werkwoorden) dan op werkwoordvormen zonder sublexicale homofonie (p-werkwoorden), zowel voor de correcte spellingen als voor de homofoonintrusies. Net zoals in de SDT werden proefpersonen ook hier gehinderd door de ambiguïteit dat er twee spellingswijzes waren (ste en stte) voor eenzelfde klankreeks.

### 2.5. Self-paced reading taak

Om de hoge skipping rate (d.w.z., het overslaan van woorden zonder deze te fixeren) in het oogbewegingsexperiment te vermijden, voerden we een tweede leestaak uit, namelijk een zgn. self-paced reading taak (SPRT). Hierbij lezen proefpersonen zinnen woord per woord, nl. door telkens op een knop te drukken om het volgende woord te laten verschijnen (alle letters in de andere
woorden zijn door x-tekens vervangen) en bepalen ze op die manier zelf het leestempo. Aangezien woorden overslaan niet mogelijk is, kan er voor elk woord een reactietijd gemeten worden. Voor stam-finale d werkwoorden, werden homofoonintrusies sneller verwerkt naarmate de gepresenteerde homofoon de dominante vorm binnen een homofonenpaar werd. Belangrijk om op te merken is dat het Homofoondominantie-effect zich enkel manifesteerde in de spillover regio, namelijk op het tweede woord na de werkwoordvorm. Dit komt vaker voor in een SPRT omdat de verwerking van een woord vaak niet voltooid is als de proefpersoon al naar de volgende woorden doorklikt (die om methodologische redenen vaak korte woorden zijn).

Hoewel we geen effect van Homofoondominantie vonden voor zwakke-prefixwerkwoorden in de vorige perceptie-experimenten, waar een grammaticale analyse overbodig of relatief makkelijk uit te voeren was, redeneerden we dat het effect zich waarschijnlijk wel zou manifesteren in een zinscontext waar er verscheidene woorden tussen marker en werkwoord werden geplaatst. Deze manipulatie vergrootte immers aanzienlijk de kans op intrusies in spellingexperimenten (Sandra et al., 1999). Dit is het gevolg van de beperkte capaciteit van het werkgeheugen, dat instaat voor de uitvoering van de grammaticale analyse: de ophaling van de marker en de daarop volgende selectie van de spelling van het suffix. In tegenstelling tot wat onze hypothese voorspelde, was er echter ook hier geen indicatie dat intrusies sneller werden verwerkt als ze met de HF vorm correspondeerden. Belangrijk hierbij is dat het effect van lemmafrequentie van deze homofonen (een indicator dat het lemma van de stam geactiveerd werd) ook niet significant was. Omdat dit een zeer stabiel effect is, kunnen we geen conclusies trekken over de verwerking van homofonen van zwakke-prefixwerkwoorden in een SPRT.

Ten slotte bevestigden de resultaten voor de OVT’s dat Homofoondominantie de verwerkingsnoodheid van sublexicale intrusies bepaalt. Hoewel een morfologisch decompositiemechanisme voorspelt dat incorrecte spellingen van OVT’s aanleiding zullen geven tot (eenzelfde) vertraging voor beide werkwoordtypes werd er (net zoals in de FDT) geen
vertraging opgemeten voor intrusies op de vormen van s-werkwoorden, waarvoor het incorrecte spellingpatroon ondersteund wordt door een homofoon cluster in andere OVT’s. Sublexicale intrusies vertraagden de reactietijden daarentegen wel op de vormen van p-werkwoorden, waar de incorrecte spelling niet werd ondersteund door een dergelijk sublexicaal homofoon cluster. Het effect manifesteerde zich niet in de spillover-regio (zoals bij stam-finale d werkwoorden) maar werd gemeten op de kritische werkwoordvorm zelf.

2.6. Maze taak

Als gevolg van de verschillende grammaticale contexten (nl., OTT- vs. VD-context) waarin de twee vormen van zwakke-prefixwerkwoorden werden gepresenteerd, was het mogelijk dat beide contexten tot verschillende spillover-effecten leidden en zo het Homofoondominantie-effect maskeerden. De homofoonintrusies in de OTT-context bevinden zich immers aan het einde van een bijzin terwijl die in de VD-context zich midden in een hoofdzin bevinden. Die grote syntactische verschillen kunnen de responstijden op de werkwoordvorm aanzienlijk beïnvloed hebben, zodat de syntactische context een belangrijke storende variabele was. Daarom voerden we een maze taak (MT) uit, een taak waarbij zinnen ook woord voor woord worden gelezen maar waarvoor men heeft aangetoond dat de gezocht effecten zich op het gemanipuleerde woord zelf manifesteren eerder dan in de spillover-regio. Proefpersonen moeten de zin woord per woord opbouwen door op elke woordpositie te kiezen tussen twee woorden, waarvan slechts één in de voorgaande context past (het andere woord is een afleider). Om het juiste woord te kiezen, moeten ze dat woord zowel lexicaal, syntactisch als semantisch verwerken en integreren in de zin. Daarom zouden de syntactische

123 Voorbeelden van deze contexten zijn:
OTT: Omdat hij zijn computer tegen virussen *beveiligd, loopt hij Weinig risico.
VD: Hij heeft zijn computer tegen virussen *beveiligd om risico’s te vermijden.
verschillen tussen de OTT- en VD-context in deze taak geen rol mogen spelen en dus ook het effect van Homofoondominantie niet kunnen maskeren.

Om de taak te valideren m.b.t. het meten van het Homofoondominantie-effect, voerden we dit experiment eerst uit met stam-finale d werkwoorden. Wanneer de deelnemers een keuze moesten maken tussen een homofoonintrusie en een afleider, waren de reactietijden inderdaad sneller voor intrusies van de HF vorm - en deze keer manifesteerde het effect zich op het woord zelf. Verrassend genoeg was het effect van Homofoondominantie opnieuw afwezig voor zwakke-prefixwerkwoorden, evenals dat van lemmafrequentie. Het garden-path effect dat gevonden werd in deze taak is mogelijk verantwoordelijk voor de afwezigheid van beide effecten. Het garden-path effect ontstond doordat de d-intrusie in de OTT-context initieel als een correct gespelde VD-vorm geïnterpreteerd werd, een foute interpretatie die later bijgesteld moest worden. Aangezien voor zwakke-prefixwerkwoorden noch de SPRT noch de MT evidentie opleverden voor de betrokkenheid van deze leestaken ons niet toelaten om conclusies te trekken m.b.t. het Homofoondominantie-effect voor deze werkwoorden.

2.7. Naleestaak

De vorige zes perceptie-experimenten laten zien dat homofoonintrusies sneller verwerkt worden wanneer ze corresponderen met de HF homofoon (voor stam-finale d werkwoorden) of wanneer ze een sublexicaal homofoon lettercluster bevatten (voor OVT’s) dan wanneer ze corresponderen met de LF homofoon of een niet-bestaand lettercluster bevatten. Toch mag men hier niet rechtstreeks uit afleiden dat deze fouten door hun orthografische vertrouwdheid ook minder opgemerkt zullen worden bij het nalezen van een tekst. Om na te gaan of de snellere verwerking van vertrouwde homofone

124 Merk op dat het Homofoondominantie-effect de reactietijden niet moduleerde voor d-vormen, mogelijk als gevolg van een dt-bias, die veroorzaakt werd door de frequentie aanwezigheid van een enkelvoudig nomen (een woord dat de kenmerken van een 3e persoon oproept) tussen onderwerp en werkwoord.
patronen ook leidt tot het sneller accepteren van die patronen als ze incorrect zijn voerden we een naleestaak uit waarin proefpersonen onder tijdsdruk alle spelfouten moesten aanduiden: spelfouten tegen werkwoordvormen maar ook spelfouten tegen andere moeilijke woorden zoals onmiddellijk.

Voor stam-finale d werkwoorden vonden we dat naarmate werkwoorden d-dominator werden d-intrusies vaker over het hoofd gezien werden dan dt-intrusies, en vice versa wanneer werkwoorden dt-dominator werden. De vertrouwdheid met het orthografische patroon van de HF vorm zorgt ervoor dat homofoonintrusies van die vorm minder saillant zijn en dat er bijgevolg vaker overheen gelezen wordt in vergelijking met intrusies van de LF vorm. Homofoondominantie beïnvloedde het aantal gedetecteerde intrusies echter niet voor zwakke-prefixwerkwoorden: zowel d- als t-intrusies bleven onopgemerkt in ongeveer 50% van de gevallen.

De resultaten voor sublexicale intrusies toonden aan dat het aantal detecties afhankelijk was van Homofoondominantie, hoewel al deze spelfouten een illegale stam-suffixcombinatie vormden. Een morfologisch decompositiemechanisme zou alle intrusies, ongeacht de frequentie van het incorrecte sublexicaal orthografisch patroon, moeten opmerken. Sublexicale intrusies met een orthografisch patroon dat voorkomt in gelijkklinkende OVT’s (s-werkwoorden) vielen echter minder op als fout tijdens het nalezen dan intrusies met een niet-bestaand letterpatroon (p-werkwoorden). Bovendien was er geen verschil tussen het aantal detecties van foutief gespelde OVT’s met sublexicale homofonie buiten het werkwoordelijk paradigma (rt/nt-werkwoorden) en het aantal detecties van foutief gespelde OVT’s met een foutief spellingpatroon dat zowel binnen als buiten het werkwoordelijk paradigma bestaat (st-werkwoorden). Dit bevestigt onze eerdere conclusie uit de FDT: de vertrouwdheid met een homofoon orthografisch patroon wordt bepaald door de frequentie waarmee het voorkomt in alle woorden (ook nomina en adjectieven) en niet enkel door zijn frequentie binnen het werkwoordelijk paradigma.
3. Conclusie

Op basis van deze resultaten kunnen we twee grote conclusies trekken. Eerst en vooral is de hardnekkigheid van spelfouten tegen regelmatige homofone werkwoordvormen, niettegenstaande de simpele spelregels, te wijten aan een stoorzender die zowel tijdens het spellen en lezen een rol speelt, namelijk Homofoondominantie. Op het lexicaal niveau zorgt de snelle beschikbaarheid van de HF vorm voor (a) meer intrusies tijdens het spellen wanneer de LF homofoon de doelvorm is en (b) snellere verwerkingstijden van HF homofonen tijdens het lezen, los van het feit of die vorm correct of incorrect is in de syntactische context. Die snellere visuele verwerking leidt echter ook tot een ongewenst neveneffect: de vertrouwdeheid met het HF patroon zorgt er ook voor dat homofoonintrusies gemakkelijker geaccepteerd worden als een correcte vorm wanneer zij corresponderen met de HF vorm, waardoor deze intrusies het vaakst onopgemerkt blijven in zorgvuldig nagelezen teksten.125

Hoewel die conclusie van toepassing is op stam-finale d werkwoorden werd er voor zwakke-prefixwerkwoorden enkel een effect van Homofoondominantie gevonden in de spellingexperimenten. Een mogelijk verklaring kan gevonden worden in de frequenties van de werkwoordvormen. Alegre en Gordon (1999) beargumenteren dat woorden met een erg lage frequentie geen eigen lexicaal representatie hebben. Concreet zou dit betekenen dat woorden die minder dan 6 keer per miljoen woorden voorkomen niet in het mentale lexicon zijn opgeslagen. We stelden vast dat 75% van de dominante vormen bij zwakke-prefixwerkwoorden onder deze grens zaten, terwijl dit enkel voor 25% van de stam-finale d werkwoorden het geval was. De afwezigheid van representaties of de zeer zwakke representaties voor de dominante homofoonvormen in die eerste groep is hoogstwaarschijnlijk de verklarende factor voor de afwezigheid van het effect

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125 Hoewel alle experimenten bewijs hebben geleverd dat de hele-woordroute een rol speelt tijdens het spellen en lezen van homofone werkwoordvormen sluit dit geenszins uit dat deze werkwoordvormen ook door een morfologisch proces (gevolgd door een grammaticale analyse) worden verwerkt.
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(in combinatie met een d-bias en een mismatch in syntactische context; cf. supra). We suggereren dat het effect van Homofoondominantie wel in onze spellingexperimenten (en corpusonderzoek) gevonden werd omdat spellen een relatief traag proces is in vergelijking met lezen, zodat het voldoende tijd biedt om zelfs zwakke representaties op te halen. Visuele perceptie is daarentegen een snel proces, waardoor deze zwakke representaties minder kans krijgen om een rol te spelen tijdens het herkenningsproces en trager opgehaald worden dan de tijd die nodig is om de homofone vorm morfologisch te decomponeren en te checken of de suffixspelling door de grammaticale relaties gelegitimeerd is.

Ook op het sublexicaal niveau creëert Homofoondominantie een dubbele val. Tijdens het spellen werden er meer sublexicale intrusies gemaakt op OVT’s waarvan het woordfinale cluster homofoon is met een alternatieve spelling dan op OVT’s waarvan het woordfinale cluster maar op één manier gespeld kan worden. Tijdens het lezen zorgde de ondersteuning van het incorrecte homofone cluster door zijn voorkomen in andere OVT’s en niet-werkwoordelijke vormen (nomina en adjectieven) er ook voor dat zulke sublexicale intrusies sneller verwerkt werden (althans in de FDT en SPRT) en vaker onopgemerkt bleven.

Een tweede conclusie heeft betrekking op de werking van het mentale lexicon. Een regelgebaseerd mechanisme, dat de stam en uitgang van een werkwoordvorm identificeert en hun compatibiliteit in de syntactische context controleert, is het enige proces dat met 100% zekerheid tot een foutloze spelling leidt (althans voor homofone werkwoorden). Toch suggereren de resultaten voor lexicale intrusies dat de expliciete instructie van de spellingsregel de succesvolle toepassing ervan geenszins garandeert. De resultaten tonen aan dat de verwerking van homofone werkwoordvormen ook gestuurd wordt door impliciete (en dus onbewuste) processen, die niets met regels te maken hebben. Aangezien de resultaten voor lexicale intrusies, zowel in de spelling- als in de leesexperimenten, bepaald werden door de frequentieverhouding tussen de twee homofone werkwoordvormen (waarbij de dominante vorm het snelst actief wordt), suggereert dit dat deze
regelmatige werkwoordvormen (op zijn minst de HF vormen) een eigen representatie hebben in het mentale lexicon, hoewel dat logisch overbodig is. De opslag en activatie van frequente vormen zijn automatische (en snelle) processen waar men geen bewuste controle over heeft en die de toepassing van expliciet aangeleerde regels in het gedrang brengen.

De resultaten voor de sublexicale intrusies bevestigen dat de verwerking van reguliere werkwoordvormen in het Nederlands niet (enkel) via morfeemgebaseerde spellingregels verloopt. Eerst en vooral zijn dergelijke fouten onmogelijk vanuit een (de)compositieperspectief. Het zijn namelijk non-woorden die bestaan uit een niet-werkwoordelijke stam en het OVT te-suffix. Toch vonden we in de productie-experimenten dat er zich dergelijke sublexicale intrusies voordoen. Een tweede argument is dat een decompositieproces voorspelt dat alle sublexicale intrusies voor vergelijkbare verwerkingsproblemen zouden moeten zorgen. We stelden echter vast dat de vertrouwdheid met een sublexicaal homofoon patroon dat noch met een woord noch met een morfeem overeenstemt (en dus een onmogelijke verwerkingseenheid is in een morfeemgebaseerd systeem) beïnvloedde hoe vaak sublexicale intrusies werden gemaakt, hoe snel ze werden herkend en hoe vaak ze werden gemist als fout. Belangrijk om op te merken is dat sublexicale intrusies niet alleen uitsluiten dat regelmatige werkwoordvormen enkel via morfemen worden verwerkt maar ook de hele-woordroute in vraag stellen. Deze fouten kunnen immers niet veroorzaakt worden door de verwisseling van twee bestaande homofonen in het mentale lexicon (de intrusie is een non-woord en heeft dus geen eigen representatie).

Om die reden suggereren de resultaten het beeld van een mentaal lexicon waarin een similariteitsgedreven mechanisme een centrale rol toedeelelt aan elk frequent letterpatroon, of dat nu overeenstemt met een woord, een morfeem of een sublexicaal cluster dat de morfeemgrens overschrijdt. Volgens een dergelijke visie is een fonologische representatie verbonden met alle overeenstemmende orthografische realisaties (m.a.w., meer dan één in het geval van homofonen). De frequentieverhouding tussen die orthografische patronen bepaalt welk patroon zich zal opdringen tijdens
het spellen, welk patroon het snelst herkend zal worden tijdens het lezen en welk patroon het vaakst als een correcte spelling zal worden geaccepteerd als zijn spelling incorrect is (hetzij omwille van de syntactische context, hetzij omdat het een onbestaande spelling van de morfologische constructie is), d.w.z. gemist zal worden als spelfout.

Samengevat tonen de resultaten aan dat Nederlandse taalgebruikers niet altijd een beroep doen op bewust aangeleerde en glasheldere spellingsregels. Op een onbewust niveau zijn zij ook gevoelig voor statistische wetmatigheden in de geschreven taal. Hierdoor zijn homofoonintrusies het onvermijdelijke neveneffect van onze cognitieve infrastructuur, die taalgebruikers in de val lokt om dergelijke fouten te maken tijdens het spelproces en eroverheen te lezen tijdens het leesproces, tenminste wanneer die spelfouten overeenstemmen met de meest frequente homofoonspelling of met een vertrouwd orthografisch homofoon patroon op sublexicaal niveau.