

The Role of Grammar in Spelling Homophonous Regular Verbs

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Abstract

Can a lack of grammatical knowledge alone be held accountable for the spelling errors that are made for homophonous verb forms and do these errors occur because spellers do not apply their grammatical knowledge? Three experiments with secondary school pupils were conducted on Dutch weak prefix verbs. The results confirmed that pupils made many spelling errors and also have great problems identifying the verb forms' functions. Moreover, a direct correlation was revealed between a pupil's identification of the form's grammatical function and its spelling. These results indicate that many errors result from pupils' inability to determine the grammatical functions of the forms. If pupils know the form's function, they are more likely to also spell the form correctly. If they do not, they often choose the form's homophone, especially if the homophone is more frequent than the target form. Spelling education thus needs a strong grammatical basis.

Keywords: verb spelling errors, grammar, homophony, frequency effect, 11 -18 year high school pupils, Dutch

In many languages with alphabetic writing systems, like English, the spelling of spoken words represents two types of information. The first and most basic type is phonological: Spell each sound in a word by its most prototypical letter. Read (1986) demonstrated that beginning (and skilled) spellers heavily rely on this phonological principle 'spell what you hear'. The second type of information is morphological. The so-called morphological principle prescribes the spelling of a morpheme to remain constant across the words in which it occurs, despite variations in pronunciation (e.g., English *heal-health*) (e.g., Sandra, 2010). The morphological principle can thus override the phonological principle, at least for some writing systems. When learning to spell, children tend to adhere only to the phonological principle. As they become more proficient spellers, they learn to comply with the morphological principle by applying the proper ortho-morphological rules (Sandra, 2003). This study contributes to a better understanding of why it is difficult to adhere to this morphological principle.

Spelling errors violating the morphological principle are particularly prevalent in homophone verb forms, that is, for pairs of verb forms that sound identical but are spelled differently because of their grammatical function (tense, person, etc.). To give some examples, in Danish, although spelled differently, the infinitive *stirre* 'to stare' and the present tense *stirrer* are both pronounced as /stirə/. In Dutch, the first and third person singular present tense of the verb *worden* 'to become' are both pronounced as /vɔrt/, but spelled as *word* and *wordt*, respectively. In French, the first and third person singular present tense of the verb *écrire* 'to write' are both /ekʁi/, while the former is spelled as *écris* and the latter as *écrit*. Although the verb spelling in these languages is grammatically determined and as such rule-based, the homophone forms are often confused (homophone intrusion), even by highly trained spellers (e.g., Bosman, 2005; Juul, 2005; Sandra, Frisson, & Daems, 1999; van Heuven, 1978; van der Velde, 1956).

Spellers especially opt for the wrong member of a homophone verb form pair when this member has a higher frequency of occurrence (henceforth: the HF form) than the target form (the LF form, e.g., Sandra et al., 1999). This phenomenon is known as the homophone dominance effect. It has been observed in studies with error-evoking contexts as well as in studies investigating spontaneous language production (Schmitz, Chamalaun, & Ernestus, 2018).

In addition, homophone intrusions are more likely to occur when the spellers' working memory is overloaded (Sandra, 2003; Sandra, 2010; Verhaert, Danckaert, & Sandra, 2016). This is not only the case when spellers have to perform under time pressure but also when the sentence is grammatically complex (e.g., Assink, 1985). In order to spell a verb form correctly, the speller has to use the information on grammatical person from the subject. When the subject and the verb are not adjacent, as can be the case, for instance, in Dutch subordinate clauses (Subject-Object-Verb word order), it may be more difficult to determine how to spell the verb form, because the speller has to remember the grammatical person from the subject for a longer period. Research by Sandra et al. (1999) showed that more errors are made when the grammatical subject appears several words away from the verb form.

The question arises what exactly drives the spelling errors for verb forms in general and for homophone intrusions more specifically. In this study, we test the hypothesis that, as suggested by the effect of memory load, spellers producing errors cannot

determine the grammatical function of the verb form in time and consequently cannot apply the correct rules. If so, the question arises of whether the homophone intrusion also plays a role in determining a verb form's grammatical function, that is, whether spellers erroneously assign the grammatical function of the high frequency member of a homophone pair to the low frequency member. An alternative hypothesis explaining the many errors is that spellers can correctly determine the verb forms' grammatical functions but do not correctly apply the appropriate rules.

We investigated the source of the many spelling errors for homophone verb forms in three experiments. We focus on Dutch verbs with two or three homophonous forms in their inflectional paradigms. Empirical evidence shows that also in Dutch many more errors are made with homophones than with non-homophones (e.g., Assink, 1985; Sandra et al., 1999, 2004). According to a rough estimate on the basis of the verbs listed in CELEX (Baayen, Piepenbrock, & Gulikers, 1995), 10% of the Dutch verbs display homophony.

The Dutch verb spelling system

The spelling of regularly inflected verb forms in Dutch is based on a concatenative morphological system, which involves the simple addition of a suffix to a verb stem. For most verbs, a prefix is added as well in past participles. In the following, we describe the Dutch verb spelling system in more detail, focusing on the homophone forms relevant for this study. In Table 1, we schematically present the orthographic and phonological forms of regular verb paradigms in Dutch.

We distinguish two types of regular verbs in Dutch, according to their stem endings. First of all, there are verbs whose stems end in voiceless consonants before the infinitive suffix <en> /ən/ or /ə/. For example, the stem of the infinitive *beheersen* 'to control' is *beheers*, ending in /s/ <s>. Secondly, there are verbs whose stems end in voiced consonants before the infinitive suffix <en>. For instance, the stem of the infinitive *benoemen* 'to appoint' is *benoem*, ending in /m/ <m>.

The first person singular present tense of nearly all verbs is just the verbal stem while the plural present tense is the stem followed by schwa or /ən/, spelled as <en> (just like the infinitive). For instance, the first person singular present tense of *beheersen* 'to control' is *beheers* and the plural present tense is *beheersen*. The second and third person singular present tense (henceforth: third person singular present tense) of most verbs are pronounced with the suffix /t/ <t> after the stem (e.g., *beheerst* 'controls'). In spelling, the suffix <t> is also added when the stem ends in a /d/, which, due to final devoicing, is pronounced as /t/. For instance, the first and third person present tense verb forms of *vinden* are spelled as *vind* and *vindt*, respectively, but are both pronounced as /vɪnt/: Due to degemination, the second, affixal /t/ of *vindt* is not audible, and the two different spellings are thus homophones.

Whether the stems of verbs end in voiced or voiceless consonants is relevant for the spelling of past tense verb forms. Past tense verb forms are created by suffixing the allomorphs <te> /tə/ or <de> /də/. The allomorph <te> is added when the stem ends in a voiceless obstruent before the infinitive suffix <en>. The suffix <de> is used elsewhere. Plural past tense forms have an additional <n> /n/ after the allomorph <te> or <de>.

The distinction between the two types of regular verbs is also relevant for past participles. The rule for spelling regular past participles is relatively easy: simply add the prefix <ge> /yə/ or /xə/ to the verbal stem, and add the suffix <t> /t/ when the stem-final sound is voiceless before the infinitive affix <en> or add the suffix <d> /d/ when this sound is voiced. For instance, the stem of the infinitive *wandelen* ‘to walk’ is *wandel* ‘walk’, ending in <l>, which is a voiced consonant, and the past participle of this verb is spelled as *gewandeld* ‘walked’. Past participles whose stems already end in <t> or <d> do not have an extra <t> or <d>, respectively. For instance, the stem of the infinitive *feesten* ‘to party’ is *feest*, ending in <t>, and its past participle is spelled as *gefeest*, with only one <t>.

Dutch has a special class of verbs, the so-called weak prefix verbs with unstressed prefixes in the verbal stems (for instance, verbs starting with <be>, <ge>, <her>, <ont>, or <ver>). Their past participles do not have the additional prefix <ge>. For instance, the stem of the infinitive *gebeuren* ‘to happen’ is *gebeur*. A weak initial syllable <ge> is present and the past participle is spelled as *gebeurd* (i.e., *gegebeurd* does not exist). As a consequence, the paradigms of weak prefix verbs contain homophonous verb forms since the past participle and the third person singular present tense sound identical. The two forms are spelled differently for verb stems ending in voiced obstruents before the infinitive <en> (with <t> and <d>, respectively, see also Table 1). Weak prefix verbs may be confusing for spellers when they interpret the unstressed prefixes of the verbs, such as <ge>, as cues to their grammatical function and classify all forms of the verbs as past participles.

Finally, in Dutch, past participles can be used attributively, that is, adjectivally (henceforth: adjectival past participles). For a proper spelling, it suffices to append the inflectional suffix <e> to the past participles for most verbs. Thus, the adjective *verbrande* ‘burned’ is derived from the past participle *verbrand*. If the verb starts with a weak prefix, the adjectival past participle sounds identical to the past tense, which is spelled differently if the verb stem ends in /d/ or /t/ (for instance, the adjectival past participle *verbrande* versus past tense *verbrandde*).

Table 1. Overview of the Dutch conjugational system (including examples)

| | Type I Stem ending in voiced consonant | Type II Stem ending in voiceless consonant |
|--|---|--|
| 1 st person singular present tense | benoem /bənum/ | stem beheers /bəhe:rs/ |
| 2 nd , 3 rd person singular present tense | benoemt /bənumt/ | stem + <t> /t/ beheerst /bəhe:rst/ |
| Plural present tense, infinitive | benoemen /bənumən/ | stem + <en> /ən/ beheersen /bəhe:rsən/ |
| Simple past (plural) | stem + <de(n)> /də(n)/ benoemde(n) /bənumdə/ | stem + <te(n)> /tə(n)/ beheerste(n) /bəhe:rstə/ |
| Past participle | (<ge> +) stem + <d> /d/ benoemd /bənumt/ | (<ge> +) stem + <t> /t/ beheerst /bəhe:rst/ |
| Adjectival past participle | (ge) + stem + te /tə/ benoemde /bənumdə/ | (ge) + stem + de /də/ beheerste /bəhe:rstə/ |

The effects of homophone dominance are also present in the Dutch verb spelling. Assink (1985) documented effects of homophone dominance for the third persons singular present tense and the past participles of weak prefix verbs with stems ending in a consonant other than <d> or <t>. Sandra et al. (1999) reported effects for the present tense first and third persons singular of regularly inflected verbs with stem-final /d/, as well as for the third persons singular present tense and past participles of weak prefix verbs. Frisson and Sandra (2002) showed that the frequency relationship between homophonic forms not only influences adult spellers but also young spellers (i.e., 12 to 14-year olds).

The present study

We investigate the hypothesis that the main cause of spelling errors is that spellers do not properly determine the verb forms' grammatical functions by focusing on the spelling of homophonous regular verb forms of weak prefix verbs. More specifically, we focus on two pairs of homophones. The first pair of interest consists of the third person singular present tense and its homophone counterpart, the past participle (i.e., Homophone Type I). The second pair of interest consists of the past tense and its homophone counterpart, the adjectival past participle (i.e., Homophone Type II). Experiment 1 documents the occurrence of spelling errors in our testbed. We investigate whether spelling errors are less frequent when, given the position of the verb form in the sentence, it may be easier for the speller to determine the form's grammatical function. Experiment 2 documents how well spellers are able to determine the verb forms' grammatical function, which is necessary for the application of relevant spelling rules. We investigate whether homophone dominance also occurs when spellers have to determine verb forms' grammatical functions. In Experiment 3, we directly investigate the relationship between spelling errors and grammatical knowledge.

We tested children, varying in age between 11 and 18 years and varying in educational level. In general, a proper grammatical analysis requires great ability in abstract thinking, which may be better developed in older children and in children at higher levels of education. Studying children of various ages and educational levels enables us to study firstly how grammatical mastery improves over the years and per educational level, and secondly, how this grammatical knowledge affects verb spelling performance.

Children in Dutch primary schools are taught both the grammatical functions of verb forms (e.g., present tense, past participle) and the rules for Dutch verb spelling from around nine or ten years of age. Generally, children proceed to secondary school, or high school, at the age of twelve, where lessons in grammar and verb spelling continue. Throughout the entire school system, the same terminology for the verb forms' grammatical functions is used.

The Dutch school system has several programs in secondary school, representing different theoretical levels. First, there is a program of four-year training, which is called preparatory intermediate vocational education. This program offers practical-oriented courses as well as a more theoretical-oriented courses (henceforth referred to as *mavo*). This school program is needed for intermediate vocational education. Second,

there is a program of five-year training, called *havo*, required for higher vocational education. Third, there is a program of six-year training, called *vwo*, that gives access to university. In all programs, a substantial amount of time is invested in teaching grammar and the spelling rules.

In Experiment 1, we expect many errors, given the reported difficulties with the spelling of homophonic verb forms. We especially expect homophone intrusions, with the third person singular present tense being confused with the past participle, and the past tense with the adjectival past participle. Given the literature, the likelihood of a confusion is likely to be codetermined by the frequency of occurrence of the target form relative to its homophone, with fewer errors on HF-verb forms than on LF-verb forms (e.g., Sandra et al., 1999, 2004). We also expect that the familiarity of the verb itself instead of the specific verb form is a factor of importance. There is a possibility that especially younger pupils make more errors for low frequency verbs, which they may not know. Furthermore, we hypothesize that the grammatical function of the verb form plays an important part and that some functions are recognized more easily than others. More specifically, the past participle may be relatively easy to recognize because it is always accompanied by an auxiliary verb and, similarly, the adjectival past participle may be relatively easy to recognize because it is always followed by a noun, whose referent it modifies or restricts. We also expect that the verb's position in the sentence is important. In Dutch, past participles are usually positioned at the end of the sentence and as a result of that, we expect that spellers better recognize them when they occur in that position. Finally, we expect that verb spelling performance improves when children get older and that children at level *vwo* make fewer spelling errors than those at lower educational levels.

We did not use time pressure in Experiment 1, unlike in many experiments reported in the literature (e.g., Sandra et al., 1999), because we wished to avoid an overload in working memory. Instead, we wanted to investigate whether spellers can arrive at the correct spelling without time pressure.

1. Experiment 1

1.1 Method

1.1.1 Participants

We tested two different groups of pupils from the Netherlands, who were all native speakers of Dutch, attended the same school for secondary education, and did not suffer from dyslexia (200 pupils, 51% boys, 49% girls). The first group attended *havo* (i.e., the second highest secondary school program) (86 pupils); the second group attended *vwo* (i.e., the highest secondary school program) (114 pupils). Table 2 presents an overview of how the participants were distributed over the two programs and school years. All pupils were between the ages of 11 and 18 years. The experiment was approved by the Ethics Assessment Committee for the Humanities of Radboud University. The children's parents also approved that we tested their children.

Table 2. *Distribution of participants across the two levels and school years*

| | havo | vwo |
|-------------|----------|----------|
| school year | <i>n</i> | <i>n</i> |
| 1 | 16 | 22 |
| 2 | 16 | 21 |
| 3 | 21 | 24 |
| 4 | 15 | 17 |
| 5 | 18 | 15 |
| 6 | | 15 |

1.1.2 Materials

We selected 91 weak prefix verbs: 72 for the test sentences (see Appendix) and 19 for the filler sentences. The 72 test verbs are represented in the experiment with two verb forms that are homophonic with each other. The first homophone pair consists of third person singular present tense forms versus past participles (i.e., Homophone Type I), whereas the second homophone pair consists of past tense singular forms versus adjectival past participles (i.e., Homophone Type II).

The test verbs can be divided into two types. Half of the verbs have third person singular present tenses that are homophonic with the past participles, but are spelled differently (Homophone Type I; see also Table 1). For instance, for the verb *veranderen* 'to change', we included *verandert* /vərandərt/ 'changes' and *veranderd* /vərandərt/ 'changed'. The other half of the test verbs have past tense singulars that are homophonic with the adjectival past participles, but are spelled differently (Homophone Type II; see also Table 1). For instance, the verb *bereiden* 'to prepare' appeared as past tense singular *bereidde* /bərəidə/ 'prepared' and as the adjectival past participle *bereide* /bərəidə/ 'prepared'. Each verb occurred in both forms in the experiment; that is, the experiment contained 36 singular present tense forms, all requiring a final <t>, 36 past participle forms, all requiring a final <d>, 36 singular past tense forms, and 36 adjectival past participles.

The filler verb forms can be divided into several types. Twelve of the 19 verbs, whose stems end in /d/ or /t/, were represented by both the plural past tense and the homophonic counterpart, the infinitive. These fillers were used to bring variation in the test. The remaining seven filler verbs appeared in the experiment as two past participles, two present tense forms, one adjectival past participle, one infinitive, and one past tense plural form. These seven fillers were used as practice trials.

We embedded the verb forms into 175 compound sentences, containing subordinate clauses, as illustrated in (1).

(1) Examples of test sentences (with the target verb forms underlined)

Als je naar een spookhuis gaat, weet je dat er sowieso iets engs gebeurt.

‘When you go to a haunted house, you know that something scary will be happening.’

Hoewel je liever geen directeur wilde worden, is het nu eenmaal toch gebeurd.

‘Although you did not want to become a director, it has just happened.’

We ensured that the third person singular present tense and the past participle of the same verb were at the same place in the sentence (in the middle for half of the verbs, and at the end of the sentence for the other half), even though their grammatical functions differed. For adjectival past participles and past tense forms, the position in the sentence is less important, as their positions do not cue their grammatical functions. All adjectival past participles preceded nouns and therefore did not occur in sentence-final position. Their homophonic counterparts (i.e., their corresponding past tenses) appeared almost equally often in the middle (16 cases) as at the end of the sentence (20 cases).

We created 15 master lists containing all sentences, except the seven practice sentences. We used Mix (van Casteren & Davis, 2006) to randomize the order of the sentences, with the constraint that there should be a minimum distance of twenty sentences between a verb form and its homophone counterpart. After randomization, we mirrored these master lists replacing the sentence with one member of the homophone pair with the sentence with the other member. For example, where the master list contains the sentence with the verb form *vertelt* ‘tells’, the mirrored list has the sentence with *verteld* ‘told’, and vice versa. Eventually, we thus had thirty different tests, enabling us to give each pupil in one classroom his or her own test. Hereafter, we added the practice sentences at the top of each experimental list, for each list in the same order. Finally, we selected an additional verb form (i.e., *herkennen* ‘to recognize’) and embedded it in a sentence similar to the sentences created for the test and fillers verbs. This sentence served as an example to demonstrate the pupils the task they had to perform.

1.1.3 Procedure

The pupils performed a self-paced spelling task, using a web-based program from Radboud University. The course of a trial was as follows. A pupil was presented with a sentence with the target form replaced by a gap. Behind this gap, the infinitive of the verb form was given between brackets. The pupils’ task was to type in the correct form. Each sentence appeared centered on the screen, as did the response that the pupils typed in, a few lines below the sentence. Pupils had to answer to proceed to the next sentence. No time pressure was used. Pupils initiated the next trial by pressing *enter* or clicking the ‘next’-button. Examples are presented below.

(2) Examples of test sentences

Ik ben blij dat ik heb meegedaan aan de loterij omdat ik de _____(verloten) prijzen erg graag wilde winnen.

‘I’m glad I participated in the lottery because I really wanted to win the raffle prizes.’

Ze vertelde me dat ze haar kaartje _____(verloten) onder haar vrienden, omdat ze zelf niet meer naar het concert kon gaan.

‘She told me she _____ (to raffle) off her ticket to her friends because she could no longer go the concert herself.’

The test was conducted during a regular class of 45 minutes in a normal classroom setting. Before the actual test started, the pupils were asked to fill out personal information about age, gender, (possible) dyslexia, and mother tongue. Subsequently, we presented the example sentence, which only demonstrated what the experiment looked like. On average, it took participants 40 minutes to finish the test.

1.1.4 Analysis

We analyzed the correctness of the answers to the target verb forms by means of generalized linear mixed effects regression models with the binomial link function in R version 3.5.1 (R Core Team, 2018). We conducted separate analyses for the third person singular present tense – past participle pair (i.e., Homophone Type I) and for the past tense – adjectival past participle pair (i.e., Homophone Type II), as they constitute different types of homophony. These two analyses are conducted on all responses provided in the experiment. In addition, we conducted separate analyses on these homophone pairs exclusively focusing on the errors resulting from homophone intrusion. These analyses only include the correct responses and the homophone intrusions in the data and exclude all other error types, such as errors due to the addition of a final <n>. The results of these analyses can be found in the Appendix, Tables A and B.

In order to account for differences between participants, verbs, and individual stimuli, the model contained *Subject*, *Lemma*, and *Inflected form* as crossed random effects. Our fixed effects included *Grammatical function* of the verb (present tense versus past participle, past tense versus adjectival past participle), *Relative frequency* (log-transformed and centered) of the correct form compared to its homophone counterpart, and *Lemma frequency* (log-transformed). Results of the Kendall’s tau correlation indicated that there was a strong, positive relation between the lemma frequency and form frequency for each of the four verb forms: the present tense ($r\tau = .80, p < .05$), the past participle ($r\tau = .60, p < .05$), the past tense ($r\tau = .77, p < .05$), and the adjectival past participle ($r\tau = .56, p < .05$). Frequencies were taken from SUBTLEX-NL (Keuleers, Brysbaert, & New, 2010). We also tested for *Year* (1-6) and *Level of education* (havo or vwo). For the homophonic pair third person singular present tense – past participle, we also tested for *Sentence position* (middle or end of the sentence). Finally, we included *Presentation* (1st versus 2nd) as a predictor to the model in order to capture the effect of whether the verb form was the first or the second form of the verb in the experimental list (thus reducing the variance resulting from this variation).

Each predictor was added individually to the model, and only remained in the model if it was statistically significant or figured in statistically significant interactions, and improved the model’s AIC value. Furthermore, we tested for random slopes. We included slopes if they significantly improved the model fit, as revealed by likelihood ratio tests.

1.2 Results

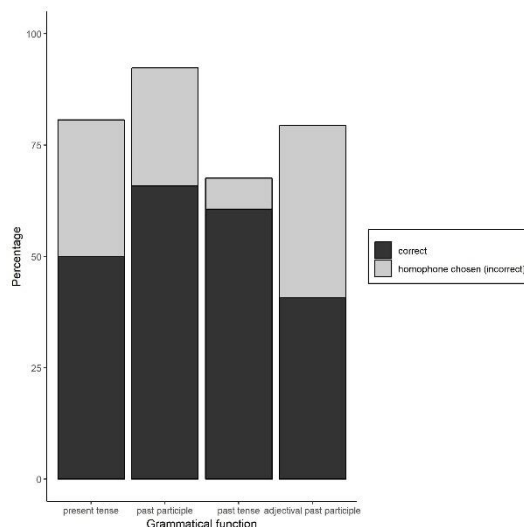


Figure 1. Scores on spelling obtained in Experiment 1

On average, 54% of all verb forms were spelled correctly (see Figure 1 for the percentage of errors per verb form). We saw various types of errors. Most importantly, spellers often wrote the homophone counterpart, but, according to Figure 1, less so when the proper verb form was singular past tense. We also found a tendency to write verb forms in the wrong tense (i.e., past tense instead of present tense or vice versa). Finally, spellers made errors by adding an extra <n> to a verb form when that was not required (i.e., using plural instead of singular).

Homophone Type I

We first performed statistical analyses on the subset of the full dataset containing the first pair of homophones, namely the present tense (requiring a final <t>) and the past participle (requiring a final <d>). Table 3 presents the final statistical model for correctness of spelling for these verb forms.

Table 3. *Experiment 1: Statistical model for predicting spelling correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents present tense, middle of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|--|---------|-------|--------|
| Intercept | -0.09 | -0.59 | 0.56 |
| Grammatical function: past participle | 0.65 | 3.42 | < .001 |
| Relative frequency | 0.87 | 3.71 | < .001 |
| Lemma frequency | 0.11 | 2.13 | < .05 |
| Sentence position: sentence-final | -0.34 | -1.86 | < .1 |
| Level of education: vwo | 0.50 | 4.75 | < .001 |
| Year | 1.53 | 10.09 | < .001 |
| Grammatical function: past participle x relative frequency | -1.46 | -4.67 | < .001 |

| | | | |
|---|-----------|------|-------|
| Grammatical function: past participle x sentence position: sentence-final | 0.77 | 2.94 | < .01 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 0.66 | | |
| Inflected form (intercept) | 0.22 | | |
| Level of education by inflected form | 0.10 | | |
| Lemma (intercept) | 0.44 | | |
| Grammatical function by lemma | 0.63 | | |

We found an effect of *Grammatical function*, as well as an interaction between *Grammatical function* and *Sentence position*, which suggests that the pupils made fewer errors for past participles than for present tense forms, especially when the form was in sentence-final position. Moreover, the model yielded a main effect of *Relative frequency* as well as an interaction between *Grammatical function* and *Relative frequency*. These effects suggest that fewer errors occurred for HF-forms on present tense forms, while more errors were made for HF-forms on past participles (as indicated by releveling of the model, see Table C in the Appendix). Furthermore, we found an effect of *Lemma frequency*, which suggests that fewer errors were made when the verb was more frequent and thus more familiar.

As predicted, *Level of education* had a significant effect on the correctness of spelling: pupils enrolled in the vwo program performed better than those enrolled in the havo program (on average 63% and 51% correct, respectively). Finally, we observed a significant linear effect of *Year*. Pupils at a higher grade made fewer mistakes than those at lower grades (45% correct in year 1, 82% correct in year 6). These results are portrayed in Figure 2. *Presentation* had no effect, suggesting that the order of presentation did not affect spelling performance.

Homophone Type II

Second, we performed statistical analyses on the second subset of the full dataset, containing our other homophonic pair of verb forms, namely the past tense (requiring <de> or <te>) and the adjectival past participle (requiring a final <e>, see also Table 1). Table 4 presents the final statistical model for correctness of spelling for these verb forms.

Table 4. *Experiment 1: Statistical model for predicting spelling correctness for the homophone pair past tense – adjectival past participle. A positive β means that pupils made fewer mistakes. The intercept represents the adjectival past participle, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | <i>z</i> | <i>p</i> |
|----------------------------------|-----------|----------|----------|
| Intercept | -0.81 | -4.62 | < .001 |
| Grammatical function: past tense | 1.12 | 6.82 | < .001 |
| Level of education: vwo | 0.94 | 5.57 | < .001 |
| Year | 1.93 | 8.09 | < .001 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 1.10 | | |
| Inflected form (intercept) | 0.67 | | |

The statistical model yielded a significant effect of *Grammatical function*, which showed that more spelling errors were made on adjectival past participles than on past tense forms. Again, pupils at level vwo made significantly fewer errors than those at level havo, and pupils at higher grades made fewer errors than those at lower grades (see also Figure 2). We also tested the role of *Relative frequency*, but we found no significant main or interaction effects with other variables of interest. Similarly, no effect of *Presentation* was found.

The results for both homophone pairs as a function of level of education and year showed that verb spelling performance between the two homophone pairs differed (see Figure 2). Both homophone pairs showed the same linear pattern of improvement as a function of year, but verb spelling performance on the homophone pair present tense – past participle (i.e., Homophone Type I) was much better than on the homophone pair past tense – adjectival past participle (i.e., Homophone Type II).

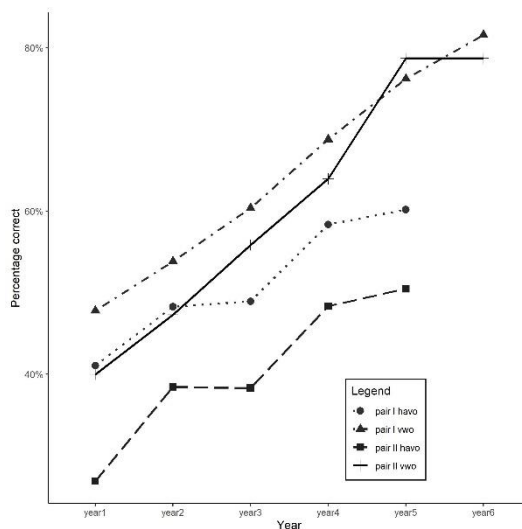


Figure 2. *Performance on spelling*

In conclusion, Experiment 1 revealed that pupils from secondary schools make many errors in spelling homophone verb forms, which warrants the research question what causes these errors. In addition, this experiment suggests that one of the causes may be that pupils have problems identifying the correct grammatical form of the verb form: Firstly, there was a simple effect of grammatical function for both homophone verb pairs; and secondly, there was an effect of the verb's position in the sentence for the homophone pair present tense – past participle.

In Experiment 2, we further investigated the hypothesis that lack of grammatical knowledge can explain the spelling performance documented in Experiment 1. We tested the same secondary school pupils and asked them to identify the grammatical functions of the target verb forms in the sentences. Given the results of Experiment 1, we expect that the type of verb form (i.e., present tense versus past participle, and past tense versus adjectival past participle) affects pupils' ability to correctly identify the

verb form's grammatical function. More specifically, we expect that pupils make fewer errors identifying the past participle than the present tense and more errors in identifying the adjectival past participle than the past tense. However, adjectival past participles usually precede nouns, which might facilitate grammatical identification. Hence, an alternative hypothesis is that, contradictory to what is suggested by our spelling results, fewer errors are made on determining the grammatical function of adjectival past participles than of past tenses.

Furthermore, we also expect an effect of the verb's position in the sentence for past participles: We hypothesize that verb forms in sentence-final position tend to be labeled as past participles. Such a result would be in line with our finding from Experiment 1 that at the end of sentences fewer errors are made for past participles compared to when they occur in mid-sentence position. Finally, we expect effects of age and level of education, expecting fewer errors as children become older or attend a higher level of education.

2. Experiment 2

2.1. Method

2.1.1 Participants

We tested the same pupils who participated in Experiment 1.

2.1.2 Materials

We used the same verb forms as in Experiment 1 and created new compound sentences for these verb forms, similar to those of Experiment 1. The new experimental lists were created following the same procedure as the lists in Experiment 1.

2.1.3 Procedure

In each trial, pupils were presented with a sentence with a gap replacing the verb form. Behind this gap, the infinitive of the verb was given between brackets. We asked the pupils to indicate the grammatical function of the missing verb form. Pupils could choose between present tense (in Dutch *persoonsvorm tegenwoordige tijd*), past tense (in Dutch *persoonsvorm verleden tijd*), past participle (in Dutch *voltooid deelwoord*), infinitive (in Dutch *infinitief*), and adjectival past participle (in Dutch *bijvoeglijk naamwoord*). Pupils are familiar with this grammatical terminology as it is part of the curriculum. The option *weet niet* ‘don’t know’ was also added.

Unlike Experiment 1, Experiment 2 was not self-paced. The rationale behind this was that we wanted to obtain the first answer that came to mind. Participants had exactly ten seconds to read each sentence and to determine the grammatical function of the verb form. Pretests showed that ten seconds is sufficiently long. We conducted the test in the same setting as in Experiment 1, and also used the same web-based program from Radboud University. It took pupils 35 minutes on average to finish the test.

2.1.4. Analysis

We analyzed the correctness of the answers to the target verb forms by means of generalized linear mixed effects regression models with the binomial link function in R version 3.5.1 (R Core Team, 2018). Again, we conducted separate analyses for the third person singular present tense – past participle pair and for the past tense – adjectival past participle pair, following the fitting procedure described for Experiment 1. We classified the answer *weet niet* ‘don’t know’ as false. Our fixed and random predictors were the same as in the analysis of Experiment 1.

2.2 Results

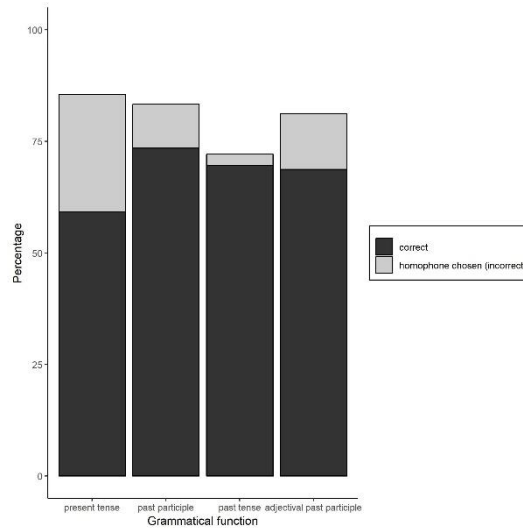


Figure 3. Scores on grammar obtained in Experiment 2

The grammatical function of 68% of all verb forms was determined correctly (58% correct at level havo, 75% correct at level vwo). As shown in Figure 3, the majority of errors were made on present tense verb forms.

Homophone Type I

Table 5 presents the final statistical model for correctness of grammar for the homophone pair present tense – past participle. We found a simple effect of *Sentence position* as well as an interaction of *Sentence position* with *Grammatical function*, while the simple effect of *Grammatical function* was not significant. Together (see also the relevant models in Tables D, E, and F in the Appendix), these effects show that past participles were more often classified correctly at the end than in the middle of the sentence while the reverse was true for the present tense verb forms. In the middle of the sentences, there is also a statically significant difference between past participles and present tense verb forms.

Table 5. Experiment 2: Statistical model for predicting grammatical correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents present tense, first presentation, middle of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.

| Fixed effects | β | z | p |
|---|---------|-------|--------|
| Intercept | 0.52 | 2.10 | < .05 |
| Grammatical function: past participle | -0.03 | -0.16 | 0.88 |
| Sentence position: sentence-final | -1.15 | -8.65 | < .001 |
| Presentation: second | 0.12 | 2.72 | < .01 |
| Lemma frequency | 0.08 | 4.25 | < .001 |
| Level of education: vwo | 1.13 | 5.67 | < .001 |
| Year | 2.99 | 9.60 | < .001 |
| Grammatical function: past participle x sentence position: sentence-final | 1.81 | 9.84 | < .001 |

| Random effects | <i>SD</i> |
|---------------------------------|-----------|
| Subject (intercept) | 1.75 |
| Grammatical function by subject | 2.29 |
| Inflected form (intercept) | 0.31 |

Furthermore, we found a significant main effect of *Level of education*. Pupils at level vwo made significantly fewer errors (on average 73% correct) than those at level havo (on average 57% correct). We also observed a significant linear effect of *Year*: Pupils at higher grades made fewer mistakes than those at lower grades (49% correct in year 1, 95% correct in year 6). Both effects are illustrated in Figure 4.

Finally, the model yielded significant effects of *Lemma frequency* and of *Presentation*. The former effect suggests that fewer errors were made in determining the proper grammatical function for verb forms with higher lemma frequencies. The latter effect suggests that pupils were more likely to correctly identify the grammatical function of the second verb form of a homophone verb in the experiment than the first one. We found no effect of *Relative frequency*, which suggests that the relative frequency of occurrence of the verb forms does not contribute much to a proper identification of their grammatical functions.

Homophone Type II

Next, we performed statistical analyses on the second subset of the full dataset, containing our second two verb forms of interest, namely the past tense and its homophonic counterpart, the adjectival past participle. Table 6 presents the final statistical model for correctness of grammar for these verb forms.

Table 6. *Experiment 2: Statistical model for predicting grammatical correctness for the homophone pair past tense – adjectival past participle. A positive β means that pupils made fewer mistakes. The intercept represents the first presentation, pupils at level havo and year 1. Estimated standard deviation is indicated by *SD*.*

| Fixed effects | <i>B</i> | <i>z</i> | <i>p</i> |
|---------------------------------|-----------|----------|----------|
| Intercept | 1.01 | 4.29 | < .001 |
| Presentation: second | 0.26 | 5.04 | < .001 |
| Level of education: vwo | 1.53 | 5.48 | < .001 |
| Year | 3.47 | 7.91 | < .001 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 2.13 | | |
| Grammatical function by subject | 2.33 | | |
| Inflected form (intercept) | 0.55 | | |

The model showed a significant simple effect of *Presentation*, suggesting better performance for the second than for the first form of a homophone verb in the experiment. More interestingly, we also found a significant effect of *Level of education*. Again, pupils at level vwo made significantly fewer errors (on average 77% correct) than those at level havo (on average 59% correct). We also found a significant linear effect of *Year*: Pupils made fewer mistakes at a higher grade (46% correct in year 1,

96% correct in year 6). These effects are illustrated in Figure 4 and resemble those for the homophone pair present tense – past participle. The figure suggests that the effect of grade is smaller for havo pupils than for vwo pupils and that, consequently, the difference between the havo and the vwo pupils grows bigger over grades. We could not test the interaction between *Level of education* and *Year* because the pertinent statistical model did not converge.

The model did not show a significant effect of *Grammatical function*, suggesting that it was equally hard to determine whether the verb form is a past tense or adjectival past participle. Furthermore, we found no effect of *Relative frequency*, or any interaction effects with *Relative frequency*.

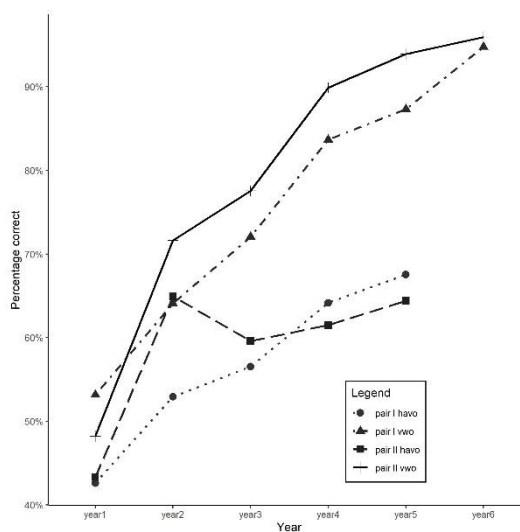


Figure 4. *Performance on grammar*

Next, we examined what pupils answered if they did not recognize the proper grammatical function of a verb form. Table 7 presents the confusion matrix.

Table 7. *Experiment 2: Overview of pupils' incorrect answers in %ages.*

| | | Correct grammatical function | | | |
|----------------------------|-----------------|------------------------------|------------|-----------------|----------------------------|
| | | Present tense | Past tense | Past participle | Adjectival past participle |
| Answer | Present tense | - | 3 | 37 | 13 |
| | Past participle | 10 | - | 29 | 40 |
| Past participle | | 65 | 64 | - | 25 |
| Adjectival past participle | | 4 | 8 | 10 | - |
| Infinitive | | 2 | 3 | 5 | 2 |

Firstly, Table 7 documents the homophone confusion. Verb forms that were used in the sentence in the present tense were often wrongly identified as past participles, and vice versa. The statistical analyses presented above showed that this confusion was not influenced by the forms' relative frequencies. Similarly, adjectival past participles were

often wrongly identified as verb forms in the past tense. Interestingly, the reverse hardly occurred, that is, verb forms in the past tense were almost never identified as adjectival past participles.

Secondly, we find errors in identifying the proper tense of the sentence. Past participles were often identified as verb forms in the past tense, and verb forms in the past tense were often identified as past participles.

Experiment 1 showed a clear effect of *Grammatical function* for spelling, suggesting that some types of verb forms are more difficult than others. Experiment 2 showed fewer grammatical errors for those verb forms of Homophone Type I that also showed fewer errors in the spelling test of Experiment 1 (past participles in sentence-final position). This suggests that there is a relation between a pupil's capability to determine the correct grammatical function of a verb form and the capability to spell this form correctly. For Homophone Type II, the results showed no clear effect of grammatical function on grammar. Spelling errors documented in Experiment 1 thus only seem to be driven by problems with identifying the verb forms' correct grammatical functions for Homophone Type I.

In Experiment 3, we directly assessed the relationship between verb spelling performance and grammatical mastery, by combining Experiment 1 and 2. This means that pupils were firstly asked to identify the grammatical function of the verb form in a sentence, and secondly to spell that verb form. We conducted this experiment at a different secondary school, to establish whether potential effects are generalizable to other schools. Moreover, this school is also attended by mavo pupils, enabling us to test pupils from three educational programs. We hypothesize that a correct identification of the grammatical function of a verb form increases the probability that the verb form is also spelled correctly.

3. Experiment 3

3.1 Method

3.1.1 Participants

We tested three different groups of pupils from the Netherlands, who were all native speakers of Dutch, and all attended the same school for secondary education, not being the school from Experiments 1 and 2, and who did not suffer from dyslexia ($n = 272$, 38% boys, 62% girls). The first group attended mavo (i.e., the lowest secondary school program) (57 pupils); the second group attended havo (i.e., the program between the lowest and the highest secondary school program) (103 pupils); the third group attended vwo (i.e., the highest secondary school program) (112 pupils). All pupils were between the ages of 12 and 18 years. This experiment was approved by the Ethics Assessment Committee for Humanities of Radboud University. The children's parents also approved that we tested their children.

3.1.2 Materials

We used the same sentences as in Experiment 1, but because pupils would perform two tasks (i.e., determine the grammatical function and spell the verb form), we divided them into two sets, to avoid that the experiment would take too long. Each set contained half of the test verbs (36 in each list). We created three master lists for each set, each containing the same 90 sentences, of which 72 contained test verb forms (i.e., a verb form and its homophone counterpart), and 18 sentences contained filler verb forms. We randomized the order of the sentences using the same procedure as in our first two experiments. After randomization, we mirrored these master lists replacing the sentence with one member of the homophone pair with the sentence with the other member. Eventually, we had thus twelve different tests.

3.1.3 Procedure

This experiment was conducted during a regular class in a normal classroom setting (50 minutes at this secondary school). We developed a new web based program which asked pupils to first identify the grammatical function by presenting a sentence with the target form replaced by a gap. Behind this gap, the infinitive of the verb was given between brackets. We asked pupils to indicate the grammatical function of the missing verb form, providing the same possible answers as in Experiment 2. After pressing <enter> or clicking the <next> button, pupils were asked to spell the correct form. Each sentence appeared centered on the screen, as did the response that the pupils typed in, a few lines below the sentence.

Pupils were obliged to answer. Both tasks were self-paced. We assumed that the task-switching might be tiring for the pupils, and we therefore built in one-minute

breaks after each set of thirty sentences. We ensured that the first two trials after each break were fillers. On average, it took the pupils 30 minutes to finish the test.

3.1.4 Analysis

We analyzed the correctness of the spelling of the verb form by means of generalized linear mixed effects regression models with the binomial link function in R version 3.5.1 (R Core Team, 2018). As for Experiments 1 and 2, we conducted separate analyses for the third person singular present tense – past participle pair and for the past tense – adjectival past participle pair. For the grammar task, we classified the answer *weet niet* ‘don’t know’ as false. Our fixed and random predictors were also the same as in the analyses of Experiments 1 and 2. Importantly, we included whether the participants had correctly identified the grammatical function of the verb form (henceforth referred to as *Correctness of grammar*) as an additional predictor for the correctness of spelling. We also conducted separate analyses on both homophone pairs, including only the correct responses and the homophone intrusions in the data and excluding all other error types, just like we did in Experiment 1 (see the Appendix, Tables G and H).

3.2 Results

Overall, 61% of all verb forms were spelled correctly, whether the form’s grammatical function was identified properly or not: 51% of all verb forms were spelled correctly if the grammatical function was identified correctly as well. An additional 10% of the verb forms was correctly spelled, even when spellers failed to correctly identify the grammatical function. As for the grammatical task, the results show that overall 63% of all verbs forms were identified correctly. If the grammatical function was not identified correctly and the verb form was incorrectly spelled, pupils chose the spelling of the verb form’s homophone in 40% of the cases, while homophone confusion only occurred in 13% of the cases when they had properly identified the verb form’s grammatical function. There are great differences, however, between the verb forms, depending on their grammatical function. Figure 5 shows the relationship between participants’ knowledge of the grammatical function of the verb form and whether they spelled the verb form correctly.

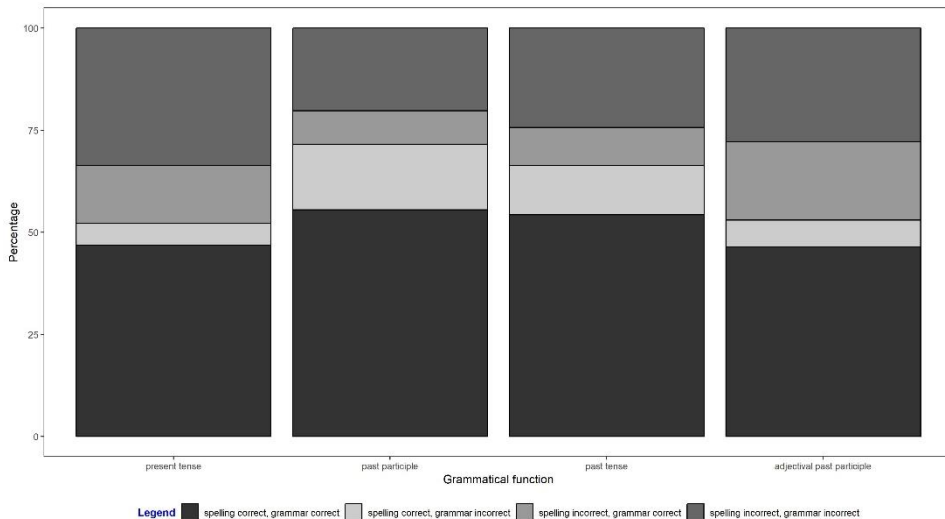


Figure 5. Scores on grammar and spelling obtained in Experiment 3

There are large differences between the levels of education with regard to spelling as well as grammar. These differences are portrayed in Figure 6. It is noteworthy that the lines show a perfect parallel development of grammar and spelling.

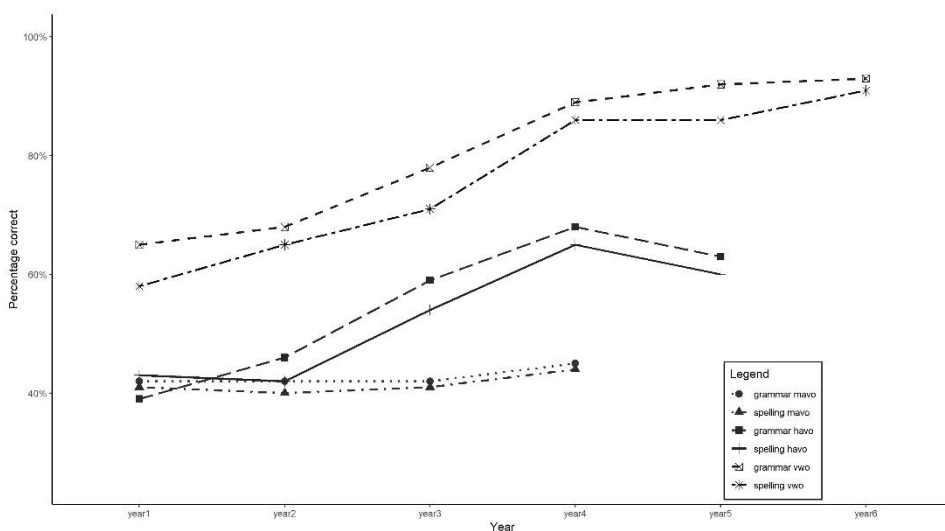


Figure 6. Performance on grammar and spelling by level of education and year

Homophone Type I

First, we performed statistical analyses on the subset of the full dataset containing the first pair of homophones, namely the present tense (requiring a final <t>) and the past participle (requiring a final <d>). Table 8 presents the final statistical model for correctness of spelling for these particular verb forms.

Table 8. Experiment 3: Statistical model for predicting spelling correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents present tense, first presentation, incorrect

identification of the grammatical function, pupils at level havo, and year 1. Estimated standard deviation is indicated by *SD*.

| Fixed effects | β | z | p |
|--|-----------|-------|--------|
| Intercept | 2.09 | -9.25 | < .001 |
| Correctness of grammar: correct | 2.27 | 37.12 | < .001 |
| Grammatical function: past participle | 2.32 | 7.95 | < .001 |
| Relative frequency | 0.83 | 3.92 | < .001 |
| Presentation: second | -0.13 | -2.31 | < .05 |
| Level of education: mavo | -0.28 | -2.18 | < .05 |
| Level of education: vwo | 0.85 | 7.78 | < .001 |
| Year | 1.23 | 7.36 | < .001 |
| Grammatical function: past participle x relative frequency | -1.24 | -4.16 | < .001 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 0.40 | | |
| Relative frequency by subject | 0.20 | | |
| Inflected form (intercept) | 0.56 | | |
| Level of education (mavo) by inflected form | 0.38 | | |
| Level of education (vwo) by inflected form | 0.11 | | |

As predicted, the model yielded a significant effect of *Correctness of grammar*, confirming our hypothesis that proper identification of the grammatical function of a verb form increases the chance that the verb form is properly spelled. On top of this, we still found an effect of *Grammatical function*: More spelling errors were made on present tense verb forms as opposed to past participles.

The model also yielded an effect of *Relative frequency*, as well as an interaction between *Grammatical function* and *Relative frequency*. These effects suggest that fewer errors occurred for HF present tense forms than for LF present tense forms, whereas the past participle did not show a similar relative frequency effect as indicated by releveling of the model, see Table I in the Appendix. In contrast to Experiment 1, *Presentation* showed an effect on spelling correctness, which suggests that the correctness of the spelling of a verb form was affected by whether the pupil had already encountered the form's homophone in the experiment. We tested for *Lemma frequency*, but no effects were found.

Again, we found statistically significant effects of *Level of education*: pupils at level havo made significantly fewer errors than those at level mavo, but more errors than those at level vwo. Moreover, we observed a significant linear effect of *Year*: Pupils at a higher grade made fewer mistakes than those at lower grades. Both effects were also found in Experiments 1 and 2. Again, we could not test the interaction between *Level of education* and *Year* because the pertinent statistical model did not converge. These effects are illustrated in Figure 6.

In contrast to Experiment 1 (see Table 3), the predictor *Sentence position* did not show a simple effect or an interaction with *Grammatical function*. Similarly, it did not interact with *Correctness of grammar*. The absence of these effects on spelling in this experiment, whereas the effects were present in Experiment 1, may be due to the

smaller statistical power of Experiment 3 versus Experiment 1 (since each pupil only spelled half of the verb forms in Experiment 3). However, it may also be the case that sentence position only affects spelling indirectly, by hindering or facilitating the identification of the verb form's grammatical function (which was only a predictor in Experiment 3). Analysis of the grammatical identifications of Experiment 3 (see Table 9) indeed showed a statistically significant effect of *Sentence position* on grammatical correctness. There was also an interaction between *Sentence position* and *Relative frequency*, and between *Sentence position*, *Relative frequency*, and *Grammatical function* on grammatical correctness, which together (see the relevelled model in Table J in the Appendix) indicate that fewer errors were made for HF present tense forms and HF past participles that appear in sentence-final position than on LF forms. This shows that the verb's position in the sentence indirectly affects verb spelling performance.

Table 9. *Experiment 3: Statistical model for predicting grammatical correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents present tense, first presentation, middle of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|--|-----------|-------|--------|
| Intercept | 1.08 | 5.02 | < .001 |
| Grammatical function: past participle | -0.74 | -2.76 | < .01 |
| Sentence position: sentence-final | -1.14 | -4.99 | < .001 |
| Relative frequency | 1.67 | 3.43 | < .001 |
| Presentation: second | -0.21 | -3.60 | < .001 |
| Level of education: mavo | -0.58 | -2.90 | < .01 |
| Level of education: vwo | 1.48 | 8.45 | < .001 |
| Year | 1.96 | 7.43 | < .001 |
| Grammatical function: past participle x sentence-final | 2.03 | 6.31 | < .001 |
| Grammatical function: past participle x relative frequency | -1.86 | -2.72 | < .01 |
| Sentence position: sentence-final x relative frequency | -1.30 | -2.27 | < .05 |
| Grammatical function: past participle x sentence position: sentence-final x relative frequency | 1.72 | 2.12 | < .05 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 1.55 | | |
| Grammatical function (past participle) by subject | 2.51 | | |
| Inflected form (intercept) | 0.56 | | |

Homophone Type II

Second, statistical analyses on the second subset of the full dataset was conducted, containing the other homophonic pair of verb forms, namely the past tense and the adjectival past participle. Table 10 presents the final statistical model for correctness of spelling for these verb forms.

Table 10. *Experiment 3: Statistical model for predicting spelling correctness for the homophone pair past tense – adjectival past participle. A positive β means that pupils made fewer errors. The intercept represents adjectival past participle, incorrect*

identification of the grammatical function, pupils at level havo, and year 1. Estimated standard deviation is indicated by *SD*.

| Fixed effects | β | z | p |
|--|-----------|-------|--------|
| Intercept | -1.18 | -8.26 | < .001 |
| Correctness of grammar: correct | 1.84 | 20.20 | < .001 |
| Grammatical function: past tense | 0.74 | 3.97 | < .001 |
| Level of education: mavo | -0.48 | -2.83 | < .01 |
| Level of education: vwo | 0.92 | 6.17 | < .001 |
| Year | 1.19 | 5.41 | < .001 |
| Grammatical function: past tense x correctness of grammar: correct | 0.35 | 2.87 | < .01 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 0.91 | | |
| Inflected form (intercept) | 0.25 | | |
| Lemma | 0.27 | | |
| Grammatical function (past tense) by lemma | 0.90 | | |

The model showed a significant effect of *Correctness of grammar*. Moreover, the interaction between *Correctness of grammar* and *Grammatical function* reached significance, which suggests that the effect of proper identification of the grammatical function has more impact on a proper spelling of past tense verb forms than on adjectival past participles. Furthermore, the simple effect of *Grammatical function* was also significant, indicating that overall more spelling errors are made on adjectival past participles as opposed to past tense verb forms.

Main effects of *Level of education* and *Year* were also found. These confirm our previous findings in this experiment, and in Experiments 1: There is a strong relationship between the year and level of education on the one hand, and the performance on spelling on the other (see Figure 6). Furthermore, there are great differences between the three educational levels (see Table 11).

Table 11. *Experiment 3: Overview of pupils' performance in % across levels and school years.*

| Level | <i>Mavo</i> | | <i>havo</i> | | <i>vwo</i> | |
|--------|-------------|----------|-------------|----------|------------|----------|
| | grammar | spelling | grammar | spelling | grammar | spelling |
| Year 2 | 42 | 41 | 39 | 43 | 65 | 58 |
| 3 | 42 | 40 | 46 | 42 | 68 | 65 |
| 4 | 42 | 41 | 59 | 54 | 78 | 71 |
| 5 | 45 | 44 | 68 | 65 | 89 | 86 |
| 6 | | | 63 | 60 | 92 | 86 |
| | | | | | 93 | 91 |

As portrayed in Table 11, the results on spelling and grammar of pupils in grade 1 at levels mavo and havo are similar. They start to diverge in grade 3: while the third

grade pupils at level mavo hardly show any improvement compared to grade 1, the scores for the pupils at level havo seem to be higher.

The role of *Relative frequency* was also tested, but neither a significant simple effect nor significant interactions with other variables of interest were found. This suggests that the effect of *Relative frequency* only holds for the other homophone pair. The same holds for the predictor *Presentation*: unlike for the first homophone pair, we found no effect of *Presentation* for the second homophone pair. Finally, we tested whether we could predict grammatical correctness for this homophone pair, but no effects were found.

Next, we took a more detailed look at the relationship between spelling and grammatical identification. Firstly, despite proper grammatical identification, pupils made many errors. These errors were similar to the spelling errors that were found in Experiment 1: Pupils opted for the homophone counterparts or erroneously added an extra <n> to a verb form. No spelling errors occurred related to the tense, which makes sense, considering the fact that the grammatical identification was correct.

Secondly, if pupils failed to correctly identify the grammatical function, they used the proper spelling in 10% of the cases. In all other cases, they made the same spelling errors as pupils did in Experiment 1. Pupils mostly opted for the homophone counterparts, which is in line with the results obtained by our final statistical model as presented in Table 3. In general, the results confirmed the findings of Experiment 1.

4. General discussion

This study investigated whether a lack of grammatical knowledge can be held accountable for the many spelling errors pupils make for homophone verb forms, or whether these errors occur because spellers simply do not (correctly) apply their grammatical knowledge. This main question was investigated in three experiments. Experiment 1 tested how well homophonous verb forms are spelled and what this tells us about the participants' (application of) grammatical knowledge. Experiment 2 studied how well spellers are able to determine the grammatical functions of the relevant verb forms. Experiment 3 directly addressed the relationship between verb spelling performance and grammatical mastery.

In all three experiments, the focus was on weak prefix verbs with two or three homophonous forms in their inflectional paradigms. The results showed that many verb spelling errors are made (i.e., 46% and 39% incorrect in Experiments 1 and 3, respectively) as well as grammatical errors (i.e., 32% and 37% incorrect in Experiments 2 and 3, respectively). Because the participants made many errors on both tasks, our results are in line with the hypothesis that spellers make spelling errors, among other reasons, because they cannot identify the forms' functions.

The results also showed that spellers have more difficulties spelling some verb forms than others depending on the forms' grammatical function: Experiments 1 and 3 showed that spellers made more spelling errors on present tense verb forms than on past participles, and more errors on adjectival past participles than on past tense verb forms. Experiment 1 revealed that the verb's position in the sentence is a predictor for spelling errors. Past participles were more often correctly spelled with final <d> instead of incorrect <t> when they were in sentence-final position than when they were in sentence-medial position, possibly because past participles usually occur in sentence-final position. The results of Experiment 2 confirm this: Fewer errors were made in the identification of the grammatical functions of past participles at sentence-final position.

The clearest support for our hypothesis that spellers make many errors in the spelling of verb forms because they have difficulties identifying the verb forms' grammatical functions, comes from Experiment 3, which shows that whether the participant has correctly identified the form's grammatical function is an important predictor for whether the verb form is spelled correctly. When the participants correctly identified the forms' grammatical functions, they correctly spelled the forms in 51% of the cases, whereas in only 10% of the cases, spellers were able to spell the verb form properly, when the grammatical identification was wrong. This supports our claim that grammatical mastery is important for spelling success.

Furthermore, Experiment 3 shows that when pupils did not correctly identify the verb form's grammatical function, more homophone intrusions occurred. When the pupils did not correctly identify the verb form's grammatical function, they incorrectly chose the spelling of the verb form's homophone in 40% of the cases, while homophone confusion only occurred in 13% of trials where they had properly identified the verb form's correct grammatical function.

Importantly, the results also show that grammatical mastery offers no guarantee that verb forms are spelled correctly, because the pupils misspelled 49% of the verb forms whose grammatical functions they had identified correctly. Pupils were not always capable of applying the spelling rules correctly after they had correctly identified the verb form's grammatical function. This, in combination with systematic lower performance on the spelling task than on the grammatical task, shows that applying the spelling rules is more difficult than identifying a verb form's grammatical function.

Experiment 3 replicated the relevance of the form's position in the sentence for past participles. While this experiment did not show a direct effect of sentence position on spelling, there is an effect of sentence position on grammatical correctness, which was a good predictor of spelling success. More errors were made on HF past participles in sentence-medial position than in sentence-final position, which is typically the position of past participles. Experiment 2 showed an effect of sentence position for past participles as well. Fewer errors were made in determining past participles at sentence-final position. These results suggest that position affects spelling performance indirectly, that is, spellers use the verb's position to determine whether a verb form is a past participle or present tense, and, subsequently, a proper identification of the grammatical function favors fewer spelling errors.

There may be several reasons for why participants made errors identifying the grammatical functions of the verb forms. One is that it requires abstract thinking, which the participants in our experiment were still developing. A second reason is that for the identification of the correct grammatical function of a verb form, working memory has to be available. This was especially necessary in our experiments because the verb forms were separated from the clause's grammatical subject by several words.

Third, it appears that participants based their choices for a grammatical function on the forms' semantics. Pupils confused verb forms in the past tense with past participles and vice versa (20% versus 8%, and 18% versus 8%, in Experiments 2 and 3, respectively). Both verb forms indicate that an event has occurred in the past. Thus, it is likely that pupils have recognized that the sentence was about the past and randomly picked one of the two grammatical functions referring to the past. This result is in line with previous evidence that people use several skills in reading and spelling, including semantic skills (e.g., Browne Rego & Bryant, 1993; Juul, 2005).

Finally, participants confused homophones in the grammatical task. They probably tried to identify the verb form out of its context, picking one of its possible grammatical functions. Experiment 3 suggests that participants preferred the grammatical function of the most frequent member of the homophone pair. The homophone dominance effect thus appears not to be restricted to spelling, as documented by Sandra (2010) amongst others, but may also surface in grammatical tasks. The homophone dominance effect leads to the proper grammatical identification of the verb form's function when the HF-form is the intended verb form, but to grammatical, and thus spelling, errors when the LF-form is the intended verb form.

However, an alternative explanation for why the homophone dominance effect in grammatical identification only occurs in Experiment 3, and not in Experiment 2 is that the participants knew that they had to spell the verb forms after they had identified the grammatical functions of the verb forms and sometimes generated the spelling before

they determined the grammatical function. If so, our finding of homophone intrusion in the grammatical task would in fact be driven by spelling processes. The explanation based on the assumption that the grammatical task in Experiment 3 was ‘contaminated’ by the following spelling task may be supported by one other difference in the results between the two experiments: The analysis of the grammatical correctness scores in Experiment 2 does not reveal a simple effect of grammatical function in sentence-medial position, whereas the analysis of these score in Experiment 3 does yield such an effect. Future research has to investigate what the effect is of combining the spelling task and the grammatical task.

We did not find the homophone dominance effect for Homophone Type II in Experiment 1. This may be due to pupils’ strong bias to spell the past tense forms instead of the adjectival past participles (in 39% of the trials where they had to spell the adjectival past participle, they spelled the past tense, whereas the reverse only occurred in 7% of the trials). This strong bias likely makes it difficult to measure any effect of relative frequency.

In Experiment 1, the effect of homophone dominance for past participles was reversed from what is typically found: pupils more often spelled past participles correctly when these forms were less frequent than the corresponding homophonous third person singular present tense forms. We speculate that this unexpected reversed effect results from hypercorrection. In general, pupils may be aware that they make more errors for the third person singular than for the past participle (in this experiment: 34% errors for past participles and 50% errors for the third person singular present tense) and may especially become insecure when the past participle is highly familiar. Another explanation for the reversed effect of homophone dominance is the set of verbs we used in our experiments. A recent paper by Surkyn, Vandekerckhove, and Sandra (in press) showed a regular effect of homophone dominance. One specific verb in their dataset (i.e., *bedoelen* ‘to mean’) was responsible for the majority of the homophone intrusions. This specific verb did not occur in our dataset, which might explain the difference between our two studies.

Our spelling results also suggest spellers’ use of analogy. Sometimes pupils added a final <n>, which resulted in spellings ending in <en> rather than <e>. In many regions of the Netherlands, word-final <en> is generally pronounced identically to <e> (i.e., as schwa). The orthographic sequence <en> is much more frequent than <e>, especially in verbal paradigms. The pupils appear to have spelled in analogy with these more frequent orthographic sequences. This supports earlier findings that analogy may play an important role in the spelling of Dutch verbal forms (e.g., Ernestus & Baayen, 2004; Ernestus & Mak, 2005). The preference for letter sequences with higher frequencies than the sequence in the correct spelling has also been documented by Sandra and van Abbenyen (2009).

In all experiments, we presented participants with both homophones of each verb. We analyzed whether the likelihood of a correct answer varied with whether the verb form was the first or the second form of the verb presented in the experiment. It did for the grammatical test of Experiment 2 for both homophone pairs, and for the spelling test of Experiment 3 for the first homophone pair. This suggests that the pupils’ answers to the first member of a homophone pair may have affected their answers to the second.

Whereas in Experiment 2 participants performed better in identifying the grammatical function of the second form of a verb than its first form, in Experiment 3, participants were better in correctly spelling the first rather than the second form of a verb. The direction of the effect possibly relates to the difficulty of the task: while pupils may learn during simple tasks (only grammatical identification), they may easily become tired during more complex tasks (grammatical identification combined with spelling).

Interestingly, in the analyses of homophone intrusions only, Experiment 1 showed simple effects of the order in which the verb forms were presented and sentence position for the present tense, whereas these effects were absent in the models that contained all errors. A possible explanation is that non-intrusion errors (e.g., wrong tense, wrong number) result in verb forms that are not homophonic with the other form of the same verb in the experiment. As a result the priming effect is much smaller. With respect to the position of the verb form in the sentence, we especially expected an effect for past participles, but the non-intrusion errors mostly resulted in non-past participles (e.g., past tense verb forms).

In contrast to many previous studies, this study focused on school children from three different education levels and ranging in age between 11 and 18 years. As expected, this revealed that both spelling performance and grammatical mastery depend on the level of education and on age. Children at level havo make more errors than those at level vwo, but fewer than children at level mavo, and younger children perform worse than older children from the same education level. This might be explained by the fact that a proper grammatical analysis requires great ability in abstract thinking. Although there is no hard empirical evidence, our intuition says that pupils at level vwo are better in abstract thinking than those at level havo, who in turn are better in abstract thinking than those at level mavo, generally speaking. Moreover, older children may be better in abstract thinking than younger children. Our findings match results by Juul and Ebro (2004), who have shown that knowledge of the links between grammar and spelling are not very well established in Danish students below the high school level, whereas high school students, 16-17 years old, used grammatically defined spellings more consistently.

Interestingly, pupils' spelling performance at mavo grade 4 matches pupils' performance at havo grade 2 (i.e., 44% and 42% correct, respectively), while pupils' performance at havo grade 5 matches pupils' performance at vwo between grades 2 and 3 for Experiment 1 (i.e., 55% correct at havo grade 5, 51% and 58% correct at vwo grades 2 and 3, respectively), and between grade 1 and 2 for Experiment 3 (i.e., 60% correct at havo grade 5, versus 58% and 65% correct at vwo grades 1 and 2, respectively). The same pattern shows for grammatical mastery. This is unexpected because Dutch pupils who finished mavo can proceed to havo 4, and pupils who finished havo can proceed to vwo 5. Our results show that, while these promotions may work fine for other study subjects, they may be problematic for verbal spelling: For pupils with average spelling abilities, the promotion brings them to grades that do not match their spelling capabilities. With respect to verbal spelling, they should rather promote to grades 2. This suggests that the differences between education levels is larger for spelling performance than for other school subjects.

The past decades, there is a strong focus on communicative language teaching that does not always make the connection between a verb form's grammatical function and its spelling explicit. Our results indicating that a proper grammatical identification increases the likelihood of a correct spelling calls this teaching method into question.

In conclusion, our experiments indicate that a lack of grammatical knowledge can be held accountable for the many spelling errors pupils make for homophone verb forms. When pupils properly identify a verb form's grammatical function, they are more likely to spell the verb form correctly . Thus, teaching spelling appears to necessarily imply increasing spellers' grammatical awareness.

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Appendix

Homophone Type I (present tense – past participle; 36 verbs)

| Lemma | Present tense | Past participle |
|--|--------------------|-------------------|
| Verbs with stems ending in other than <i>t</i> or <i>d</i> | | |
| <i>behandelen</i> ‘to treat’ | <i>behandelt</i> | <i>behandeld</i> |
| <i>behoren</i> ‘to be part of’ | <i>behoort</i> | <i>behoord</i> |
| <i>bekennen</i> ‘to confess’ | <i>bekent</i> | <i>bekend</i> |
| <i>benoemen</i> ‘to appoint’ | <i>benoemt</i> | <i>benoemd</i> |
| <i>bepalen</i> ‘to determine’ | <i>bepaalt</i> | <i>bepaald</i> |
| <i>besparen</i> ‘to save’ | <i>bespaart</i> | <i>bespaard</i> |
| <i>besturen</i> ‘to drive’ | <i>bestuurt</i> | <i>bestuurd</i> |
| <i>betekenen</i> ‘to mean’ | <i>betekent</i> | <i>betekend</i> |
| <i>beveiligen</i> ‘to secure’ | <i>beveiligt</i> | <i>beveiligd</i> |
| <i>bevestigen</i> ‘to confirm’ | <i>bevestigt</i> | <i>bevestigd</i> |
| <i>gebeuren</i> ‘to happen’ | <i>gebeurt</i> | <i>gebeurd</i> |
| <i>geloven</i> ‘to believe’ | <i>gelooft</i> | <i>geloofd</i> |
| <i>herinneren</i> ‘to remember’ | <i>herinnert</i> | <i>herinnerd</i> |
| <i>herkennen</i> ‘to recognize’ | <i>herkent</i> | <i>herkend</i> |
| <i>herhalen</i> ‘to repeat’ | <i>herhaalt</i> | <i>herhaald</i> |
| <i>herstellen</i> ‘to recover’ | <i>herstelt</i> | <i>hersteld</i> |
| <i>verbazen</i> ‘to amaze’ | <i>verbaast</i> | <i>verbaasd</i> |
| <i>verdedigen</i> ‘to defend’ | <i>verdedigt</i> | <i>verdedigd</i> |
| <i>verdelen</i> ‘to divide’ | <i>verdeelt</i> | <i>verdeeld</i> |
| <i>verdienen</i> ‘to earn’ | <i>verdient</i> | <i>verdiend</i> |
| <i>verklaren</i> ‘to declare’ | <i>verklaart</i> | <i>verklaard</i> |
| <i>vertellen</i> ‘to tell’ | <i>vertelt</i> | <i>verteld</i> |
| <i>vervolgen</i> ‘to continue’ | <i>vervolgt</i> | <i>vervolgd</i> |
| <i>verwijderen</i> ‘to delete’ | <i>verwijdert</i> | <i>verwijderd</i> |
| Verbs with stems ending in <i>d</i> | | |
| <i>beantwoorden</i> ‘to answer’ | <i>beantwoordt</i> | <i>beantwoord</i> |
| <i>beraden</i> ‘to deliberate’ | <i>beraadt</i> | <i>beraad</i> |
| <i>bespieden</i> ‘to spy on’ | <i>bespiedt</i> | <i>bespied</i> |
| <i>bevreemden</i> ‘to strange’ | <i>bevreemdt</i> | <i>bevreemd</i> |
| <i>ontaarden</i> ‘to degenerate’ | <i>ontaardt</i> | <i>ontaard</i> |
| <i>ontharden</i> ‘to soften’ | <i>onthardt</i> | <i>onthard</i> |
| <i>onthoofden</i> ‘to behead’ | <i>onthoofdt</i> | <i>onthoofd</i> |
| <i>ontbranden</i> ‘to ignite’ | <i>ontbrandt</i> | <i>ontbrand</i> |
| <i>vergoeden</i> ‘to reimburse’ | <i>vergoedt</i> | <i>vergoed</i> |
| <i>verleiden</i> ‘to seduce’ | <i>verleidt</i> | <i>verleid</i> |
| <i>vermoeden</i> ‘to suspect’ | <i>vermoedt</i> | <i>vermoed</i> |
| <i>vermoorden</i> ‘to kill’ | <i>vermoordt</i> | <i>vermoord</i> |

Homophone Type II (past tense – adjectival past participle; 36 verbs)

| Lemma | Past tense | Adjectival past participle |
|-------------------------------------|---------------------|----------------------------|
| Verbs with stems ending in <i>t</i> | | |
| <i>beboeten</i> ‘to fine’ | <i>beboette</i> | <i>beboete</i> |
| <i>begroeten</i> ‘to greet’ | <i>begroette</i> | <i>begroete</i> |
| <i>begroten</i> ‘to estimate’ | <i>begrootte</i> | <i>begrote</i> |
| <i>belasten</i> ‘to tax’ | <i>belastte</i> | <i>belaste</i> |
| <i>beplemen</i> ‘to advocate’ | <i>bepleette</i> | <i>bepelite</i> |
| <i>berechten</i> ‘to trial’ | <i>berechtte</i> | <i>berechte</i> |
| <i>bestraten</i> ‘to pave’ | <i>bestraatte</i> | <i>bestrate</i> |
| <i>ontbloten</i> ‘to uncover’ | <i>ontblootte</i> | <i>ontblote</i> |
| <i>ontkrachten</i> ‘to invalidate’ | <i>ontkrachtte</i> | <i>ontkrachte</i> |
| <i>ontluchten</i> ‘to vent’ | <i>ontluchtte</i> | <i>ontluchte</i> |
| <i>ontmoeten</i> ‘to encounter’ | <i>ontmoette</i> | <i>ontmoete</i> |
| <i>vergrotten</i> ‘to enlarge’ | <i>vergrootte</i> | <i>vergroete</i> |
| <i>verloten</i> ‘to raffle’ | <i>verlootte</i> | <i>verlote</i> |
| <i>verontrusten</i> ‘to trouble’ | <i>verontrustte</i> | <i>verontrustte</i> |
| <i>verpesten</i> ‘to screw up | <i>verpestte</i> | <i>verpeste</i> |
| <i>verplichten</i> ‘to oblige’ | <i>verplichtte</i> | <i>verplichtte</i> |
| <i>verroesten</i> ‘to rust’ | <i>verroestte</i> | <i>verroeste</i> |
| <i>verwachten</i> ‘to expect’ | <i>verwachtte</i> | <i>verwachte</i> |
| <i>verwoesten</i> ‘to destroy’ | <i>verwoestte</i> | <i>verwoeste</i> |
| Verbs with stems ending in <i>d</i> | | |
| <i>begeleiden</i> ‘to accompany’ | <i>begeleidde</i> | <i>begeleide</i> |
| <i>beïnvloeden</i> ‘to influence’ | <i>beïnvloedde</i> | <i>beïnvloede</i> |
| <i>bekleden</i> ‘to dress’ | <i>bekleedde</i> | <i>beklede</i> |
| <i>bereiden</i> ‘to prepare’ | <i>bereidde</i> | <i>bereide</i> |
| <i>besteden</i> ‘to spend’ | <i>besteedde</i> | <i>bestede</i> |
| <i>bevoorraden</i> ‘to supply’ | <i>bevoorraadde</i> | <i>bevoorrade</i> |
| <i>bevrijden</i> ‘to free’ | <i>bevrijdde</i> | <i>bevrijde</i> |
| <i>ontleden</i> ‘to dissect’ | <i>ontleedde</i> | <i>ontlede</i> |
| <i>verafgoden</i> ‘to idolize’ | <i>verafgoedde</i> | <i>verafgode</i> |
| <i>verblijden</i> ‘to rejoice’ | <i>verblijdde</i> | <i>verblijde</i> |
| <i>verblinden</i> ‘to dazzle’ | <i>verblindde</i> | <i>verblinde</i> |
| <i>verbranden</i> ‘to burn’ | <i>verbrandde</i> | <i>verbrande</i> |
| <i>verbreden</i> ‘to broaden’ | <i>verbreedde</i> | <i>verbrede</i> |
| <i>verharden</i> ‘to harden’ | <i>verhardde</i> | <i>verharde</i> |
| <i>verkleeden</i> ‘to disguise’ | <i>verkleedde</i> | <i>verklede</i> |
| <i>vermelden</i> ‘to mention’ | <i>vermeldde</i> | <i>vermelde</i> |
| <i>verspreiden</i> ‘to spread’ | <i>verspreidde</i> | <i>verspreide</i> |

Table A. *Experiment 1: Statistical model for predicting spelling correctness for the homophone pair present tense – past participle (only homophone intrusions included). A positive β means that pupils made fewer mistakes. The intercept represents present tense, first presentation, middle of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|---|-----------|-------|--------|
| Intercept | 0.67 | 4.90 | < .001 |
| Grammatical function: past participle | 0.31 | 2.24 | < .05 |
| Relative frequency | 0.87 | 5.16 | < .001 |
| Presentation: second | -0.12 | -2.76 | < .01 |
| Sentence position: sentence-final | -0.51 | -3.77 | < .001 |
| Level of education: vwo | 0.48 | 4.04 | < .001 |
| Year | 1.62 | 9.30 | < .001 |
| Grammatical function: past participle x relative frequency | -1.39 | -5.89 | < .001 |
| Grammatical function: past participle x sentence position: sentence-final | 0.83 | 4.35 | < .001 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 0.74 | | |
| Inflected form (intercept) | 0.35 | | |

Table B. *Experiment 1: Statistical model for predicting spelling correctness for the homophone pair past tense – adjectival past participle (only homophone intrusions included). A positive β means that pupils made fewer mistakes. The intercept represents the adjectival past participle, first presentation, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | <i>B</i> | <i>z</i> | <i>p</i> |
|----------------------------------|-----------|----------|----------|
| Intercept | -0.26 | -1.26 | 0.21 |
| Grammatical function: past tense | 2.72 | 15.69 | < .001 |
| Level of education: vwo | 0.96 | 4.42 | < .001 |
| Year | 2.16 | 6.98 | < .001 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 1.39 | | |
| Inflected form (intercept) | 0.68 | | |

Table C. *Experiment 1: Relevelled statistical model for predicting spelling correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents past participle, middle of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|---|---------|-------|--------|
| Intercept | 0.46 | 3.66 | < .001 |
| Grammatical function: present tense | -0.40 | -2.01 | < .05 |
| Relative frequency | -0.24 | -3.39 | < .001 |
| Lemma frequency | 0.11 | 2.13 | < .05 |
| Sentence position: sentence-final | 0.43 | 3.25 | < .01 |
| Level of education: vwo | 0.50 | 4.75 | < .001 |
| Year | 1.53 | 10.09 | < .001 |
| Grammatical function: present tense x relative frequency | 0.60 | 4.67 | < .001 |
| Grammatical function: present tense x sentence position: sentence-final | -0.77 | -2.94 | < .01 |
| Random effects | SD | | |
| Subject (intercept) | 0.66 | | |
| Inflected form (intercept) | 0.11 | | |
| Level of education by inflected form | 0.10 | | |
| Lemma (intercept) | 0.30 | | |
| Grammatical function by lemma | 0.68 | | |

Table D. *Experiment 2: Relevelled statistical model for predicting grammatical correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents past participle, first presentation, middle of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|---|---------|-------|--------|
| Intercept | 0.48 | 1.98 | < .05 |
| Grammatical function: present tense | 0.03 | 0.16 | 0.88 |
| Sentence position: sentence-final | 0.66 | 5.25 | < .001 |
| Presentation: second | 0.12 | 2.72 | < .01 |
| Lemma frequency | 0.08 | 4.26 | < .001 |
| Level of education: vwo | 1.13 | 5.67 | < .001 |
| Year | 2.99 | 9.61 | < .001 |
| Grammatical function: present tense x sentence position: sentence-final | -1.81 | -9.84 | < .001 |
| Random effects | SD | | |
| Subject (intercept) | 1.68 | | |
| Grammatical function by subject | 2.29 | | |
| Inflected form (intercept) | 0.31 | | |

Table E. *Experiment 2: Relevelled statistical model for predicting grammatical correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents past participle, first presentation, end of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|---|---------|-------|--------|
| Intercept | 1.14 | 4.90 | < .001 |
| Grammatical function: present tense | -1.78 | -8.67 | < .001 |
| Sentence position: mid-sentence | -0.66 | -5.25 | < .001 |
| Presentation: second | 0.12 | 2.72 | < .01 |
| Lemma frequency | 0.08 | 4.26 | < .001 |
| Level of education: vwo | 1.13 | 5.67 | < .001 |
| Year | 2.99 | 9.60 | < .001 |
| Grammatical function: present tense x sentence position: mid-sentence | 1.81 | 9.84 | < .001 |
| Random effects | SD | | |
| Subject (intercept) | 1.68 | | |
| Grammatical function by subject | 2.29 | | |
| Inflected form (intercept) | 0.31 | | |

Table F. *Experiment 2: Relevelled statistical model for predicting grammatical correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents present tense, first presentation, end of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|---|---------|-------|--------|
| Intercept | -0.63 | -2.70 | < .01 |
| Grammatical function: past participle | 1.78 | 8.67 | < .001 |
| Sentence position: mid-sentence | 1.15 | 8.65 | < .001 |
| Presentation: second | 0.12 | 2.72 | < .01 |
| Lemma frequency | 0.08 | 4.26 | < .001 |
| Level of education: vwo | 1.13 | 5.67 | < .001 |
| Year | 2.99 | 9.61 | < .001 |
| Grammatical function: past participle x sentence position: mid-sentence | -1.81 | -9.84 | < .001 |
| Random effects | SD | | |
| Subject (intercept) | 1.75 | | |
| Grammatical function by subject | 2.29 | | |
| Inflected form (intercept) | 0.31 | | |

Table G. *Experiment 3: Statistical model for predicting spelling correctness for the homophone pair present tense – past participle (only homophone intrusions included). A positive β means that pupils made fewer mistakes. The intercept represents present tense, incorrect identification of the grammatical function, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|--|---------|-------|--------|
| Intercept | -1.06 | -7.86 | < .001 |
| Correctness of grammar: correct | 2.30 | 33.39 | < .001 |
| Grammatical function: past participle | 1.33 | 9.07 | < .001 |
| Relative frequency | 0.57 | 2.88 | < .01 |
| Level of education: mavo | -0.34 | -2.54 | < .05 |
| Level of education: vwo | 0.71 | 6.11 | < .001 |
| Year | 1.00 | 5.99 | < .001 |
| Grammatical function: past participle x relative frequency | -1.12 | -4.01 | < .001 |
| Random effects | SD | | |
| Subject (intercept) | 0.59 | | |
| Inflected form (intercept) | 0.47 | | |
| Level of education (mavo) by inflected form | 0.35 | | |
| Level of education (vwo) by inflected form | 0.22 | | |

Table H. *Experiment 3: Statistical model for predicting spelling correctness for the homophone pair past tense – adjectival past participle (only homophone intrusions included). A positive β means that pupils made fewer mistakes. The intercept represents the adjectival past participle, incorrect identification of the grammatical function, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|--|-----------|-------|--------|
| Intercept | -0.61 | -3.28 | < .01 |
| Correctness of grammar: correct | 1.82 | 17.02 | < .001 |
| Grammatical function: past tense | 2.11 | 10.77 | < .001 |
| Level of education: mavo | -0.32 | -1.59 | 0.11 |
| Level of education: vwo | 1.08 | 6.06 | < .001 |
| Year | 1.16 | 4.27 | < .001 |
| Grammatical function: past tense x correctness of grammar: correct | -0.61 | -3.86 | < .001 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 1.03 | | |
| Inflected form (intercept) | 0.65 | | |

Table I. *Experiment 3: Relevelled statistical model for predicting spelling correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents past participle, first presentation, incorrect identification of the grammatical function, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|--|-----------|-------|--------|
| Intercept | 0.23 | 1.03 | 0.30 |
| Correctness of grammar: correct | 2.27 | 37.12 | < .001 |
| Grammatical function: present tense | -2.32 | -7.95 | < .001 |
| Relative frequency | -0.42 | -1.94 | < .1 |
| Presentation: second | -0.13 | -2.31 | < .05 |
| Level of education: mavo | -0.28 | -2.18 | < .05 |
| Level of education: vwo | 0.85 | 7.78 | < .001 |
| Year | 1.23 | 7.36 | < .001 |
| Grammatical function: present tense x relative frequency | 1.24 | 4.16 | < .001 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 0.40 | | |
| Relative frequency by subject | 0.20 | | |
| Inflected form (intercept) | 0.56 | | |
| Level of education (mavo) by inflected form | 0.38 | | |
| Level of education (vwo) by inflected form | 0.11 | | |

Table J. *Experiment 3: Relevelled statistical model for predicting grammatical correctness for the homophone pair present tense – past participle. A positive β means that pupils made fewer mistakes. The intercept represents past participle, first presentation, middle of the sentence, pupils at level havo, and year 1. Estimated standard deviation is indicated by SD.*

| Fixed effects | β | z | p |
|--|-----------|-------|--------|
| Intercept | 0.34 | 1.54 | 0.12 |
| Grammatical function: present tense | 0.74 | 2.76 | < .01 |
| Sentence position: sentence-final | 0.89 | 3.94 | < .001 |
| Relative frequency | -.019 | -0.39 | 0.69 |
| Presentation: second | -0.21 | -3.60 | < .001 |
| Level of education: mavo | -0.58 | -2.90 | < .01 |
| Level of education: vwo | 1.48 | 8.45 | < .001 |
| Year | 1.96 | 7.43 | < .001 |
| Grammatical function: present tense x sentence-final | -2.03 | -6.31 | < .001 |
| Grammatical function: present tense x relative frequency | 1.86 | 2.72 | < .01 |
| Sentence position: sentence-final x relative frequency | 0.41 | 0.73 | 0.47 |
| Grammatical function: present tense x sentence position: sentence-final x relative frequency | -1.72 | -2.13 | < .05 |
| Random effects | <i>SD</i> | | |
| Subject (intercept) | 1.76 | | |
| Grammatical function (present tense) by subject | 2.51 | | |
| Inflected form (intercept) | 0.57 | | |