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**Reference:**

Surkyn Hanne, Vandekerckhove Reinhild, Sandra Dominiek.- From experiment to real-life data : social factors determine the rate of spelling errors on rule-governed verb homophones but not the size of the homophone dominance effect  
Mental lexicon - ISSN 1871-1340 - 15:3(2020), p. 422-463  
Full text (Publisher's DOI): <https://doi.org/10.1075/ML.20006.SUR>  
To cite this reference: <https://hdl.handle.net/10067/1748190151162165141>

# THE HOMOPHONE DOMINANCE EFFECT IN REAL-LIFE DATA

From experiment to real-life data: social factors determine the rate of spelling errors on rule-governed verb homophones but not the size of the homophone dominance effect

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## Abstract

We examine unintentional spelling errors on verb homophones in informal online chat conversations of Flemish adolescents. In experiments, these verb forms yielded an effect of homophone dominance, i.e., most errors occurred on the lower-frequency form (Sandra et al., 1999). Verb homophones are argued to require the conscious application of a spelling rule, which may cause a temporary overload of working memory resources and trigger automatic retrieval of the higher-frequency spelling from the mental lexicon. Unlike most previous research, we investigate homophone intrusions in a natural writing context. Thus, we test the ‘ecological validity’ of psycholinguistic experiments. Importantly, this study relates these psycholinguistic constructs to different social variables in social media writing to test a prediction that directly follows from Sandra et al.’s account. Whereas social factors likely affect the *error rates*, they should not affect the *error pattern*: the number of working memory failures occurs at another processing level than the homophone intrusions. Hence, the focus is on the interaction between homophone dominance and the social variables. The errors for two types of verb homophones reveal (a) an impact of all social variables, (b) an effect of homophone dominance, and (c) no interaction between this effect and the social factors.

Keywords: spelling errors, homophone dominance, mental lexicon, working memory, social media writing, gender, age, educational track

## THE HOMOPHONE DOMINANCE EFFECT IN REAL-LIFE DATA

The present study focuses on a spelling issue that has been widely investigated in Dutch psycholinguistic studies: persistent errors on regular verb homophones (see below).

These studies consistently revealed a potential clash between conscious rule application and automatic retrieval of particular forms from the mental lexicon. However, they nearly all have in common that they are based on experimental research designs.

Therefore, in the present study we want to test the ecological validity of previous findings by analyzing the production of the relevant spelling forms in a natural writing context, i.e., in informal computer-mediated communication (CMC). Moreover, a number of social variables are included in the research design. Importantly, this investigation of the interaction between mental and social processes in the production of spelling errors makes it possible to test a prediction yielded by the psycholinguistic account, i.e., social factors potentially affect the conscious computational process but not the automatic retrieval process (see below). Consequently, the existing research line is extended both by focusing on a natural writing context and by adopting an interdisciplinary (i.e., a combined psycholinguistic and sociolinguistic) approach. In the following paragraphs we first introduce the research object and previous findings and subsequently discuss the assets of working with CMC-data.

### *The paradox of persistent spelling errors on regular verb homophones.*

The cognitive processes underpinning a persistent spelling error on Dutch verb homophones constitute the research object of the present paper. These errors are interesting from a psycholinguistic perspective because they confront us with the paradox that descriptively simple spelling rules are apparently hard to apply. From a descriptive point of view, the spelling of regular verb forms in Dutch is indeed simple, reflecting the application of the two major spelling principles of the language: a

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phonological one and a morphological one. The former requires words to be spelled the way they sound. However, the latter overrides this principle to guarantee that the same spelling is maintained for the same morpheme. This so-called morphographic spelling involves both stems and inflectional endings. The spellings of the verb forms in *ik word* ('I become') and *hij wordt* ('he becomes') illustrate this. The stem *word* is spelled with a <d>, even though a [t] is heard at the end, because the morphologically related word *worden* (infinitive and plural) is pronounced with a [d]. Hence, a /d/ is considered to be the final phoneme of this verb stem. Consistent with this account, the [t] sound in *word* is explained as the result of the devoicing of the voiced consonant [d] in word-final position. Similarly, the inflectional ending *-t* in *wordt* does not reflect the word's pronunciation (i.e., the form *word* is already pronounced with a final [t] sound, and adding a *-t* does not affect this pronunciation), but is due to the fact that a [t] is heard in verb forms with the same grammatical function (e.g., *hij werkt*, 'he works'). This analogy implies that the 3<sup>rd</sup> person singular of the present tense is marked by a *-t* suffix, which is audible in some words but silent in others (due to the devoicing of stem-final /d/).

Despite the simplicity of the spelling rules, errors on these forms abound, even though they are highly stigmatized. Not surprisingly, most of these errors are made on verb homophones, like *word* and *wordt*, which have the same pronunciation but a different spelling. In a series of publications Sandra and colleagues have used speeded dictation tasks to study the cognitive processes behind the persistence of these homophone intrusions (Frisson & Sandra, 2002; Sandra, 2010; Sandra, Frisson, & Daems, 1999; Sandra & Van Abbenyen, 2009). Errors typically occur when working memory runs out of resources, leaving insufficient time to apply the grammatically

based spelling rule. These errors do not reflect a preference for the spelling pattern that is associated with a particular grammatical function. Rather, most of them occur on the lower-frequency homophone, which is known as the effect of homophone dominance. This preference for the more accessible higher-frequency form is the signature of long-term memory. Hence, persistent errors on fully regular forms reflect the interplay between working memory limitations and long-term memory (i.e., orthographic representations in the mental lexicon) (Sandra et al., 1999).

This homophone dominance effect and the cognitive processes that are involved in it were not only established in experimental research on language production but also in experimental research on the perception of these spelling errors (see e.g., Verhaert, Danckaert, & Sandra, 2016). Moreover, its relevance clearly transcends the Dutch language: frequency effects in the spelling of regularly inflected word forms were also observed in other languages, e.g., in French (see e.g., Largy, Fayol, & Lemaire, 1996) and Russian (Kapatsinski, 2010).

*Chat conversations as a naturalistic testbed for validating the psycholinguistic account.*

The present study analyzes the spelling errors on regular verb homophones in informal online chat conversations of Flemish teenagers. There are several reasons for turning to informal computer-mediated communication (CMC) to study these homophone intrusions. First of all, CMC contexts offer an ideal testing-ground for testing the ‘ecological validity’ of homophone dominance, which has primarily been observed in the artificial context of spelling experiments. Whereas the latter guarantee methodological rigor, they are far removed from natural writing situations. Just like Schmitz, Chamalaun, and Ernestus (2018) we investigate this type of errors in a social

media context. However, they used Twitter data, which have a public character. Our data consist of private chat conversations produced on Facebook Messenger and WhatsApp (see Corpus). It may be assumed that public writing on Twitter implies more editing than private online writing and is therefore less spontaneous. The highly informal nature of our data increases the chance that chatters are more careless when it comes to spelling. As a result, they might not apply the spelling rules all the time, thus switching off their working memory. This gives the mental lexicon a strong opportunity to impose the higher-frequency form, which can result in more errors if the lower-frequency form needs to be spelled (Verhaert & Sandra, 2016). In addition, the conversational character of our data and the urge to guarantee smooth turn taking may create extra pressure on working memory, even when chatters attempt to observe the spelling rules.

Second, spelling has always been a major issue when studying the prototypical features of informal CMC. However, most of the linguistically oriented research on informal CMC focuses on deliberate deviations from spelling conventions, more particularly, on typical markers of informal online communication (e.g., De Decker & Vandekerckhove, 2017). Adolescents often ignore standard spelling conventions by intentionally manipulating spelling (e.g., abbreviations like *grt*, 'great') and typography (e.g., letter repetitions like *niiiiiiice!*). These spelling forms can be largely explained in terms of three pragmatic maxims that govern much of the informal CMC (e.g., Androutsopoulos, 2011): the orality maxim (i.e., mimic spoken language, e.g., vernacular forms), the economy (or speed) maxim (i.e., be as brief as possible), and the maxim of expressive compensation (i.e., compensate for the lack of face-to-face communication). However, we will not focus on the salient deviations from standard

spelling. Spelling errors on verb homophones are likely unintentional: they are no markers of the genre and, in view of their negative perception, there is no prestige to be gained by producing them. Yet, we do capitalize on the speed or economy maxim, which urges chatters to maximize their typing speed and minimize their typing efforts, since this is directly relevant to our study of verb homophone intrusions.

Third, by focusing on classic spelling errors in CMC, we will investigate the transfer of spelling errors from formal to informal writing contexts, i.e., the opposite of what most researchers have done in the past. This shift in focus was inspired by Vandekerckhove and Sandra (2016). They found that only 5.49% of the spelling errors in a large corpus of (secondary) school tasks were CMC-based interferences. All of the other spelling errors were ‘classic’ errors, and intrusions on verb homophones were on top of the frequency list (33.69%). This made us reverse the question: is there a transfer of errors from formal writing to the informal CMC context? The ‘spontaneous’ writing context might enhance our understanding of the exact triggers of these errors.

Finally, psycholinguistic experiments on the processes and mental representations that are involved in the homophone dominance effect were mainly conducted with experienced spellers (see e.g., Largy et al., 1996; Sandra et al. 1999) or children (e.g., Sandra & Van Abbenyen, 2009). Now that it is clear that even these spellers fall into the trap that is created by their working memory and the ‘pressure’ of a higher-frequency homophone, we can move one step further and use the CMC context. This move is not only inspired by our attempt to demonstrate that the mechanisms unraveled in experiments play the same role in spontaneous writing. A second, and crucial, motivation is to test a prediction that directly follows from the psycholinguistic account of the experimental data, i.e., that there should be no interaction between



psycholinguistic and social variables. This test is obviously possible in a CMC context, as the chatters differ with respect to several social variables. The following section clarifies why the combination of social and psycholinguistic variables creates this added value.

### Research Questions and Hypotheses

In this study, we examine whether the social factors Gender, Educational Track and Age affect the error risk. As spelling errors on verb homophones are highly stigmatized in Dutch, some social groups might show a stronger tendency towards avoidance of these stigmatized forms than others, which may result in an effect of the social factors on the error rates. Note that ‘avoidance’ implies the conscious awareness of an error risk. This will turn out to be important for our first research question and our associated hypothesis (see below). Furthermore, we study the interaction between these social variables and the effect of homophone dominance. As mentioned above, the psycholinguistic account holds that spelling errors on verb homophones reflect the interplay between two memory systems: (a) working memory, which sometimes fails to apply the spelling rule in time, and (b) the mental lexicon, which in that case imposes the higher-frequency form (Sandra et al., 1999). The first cognitive process is a conscious, attentional one. The fact that this process has not become automatic, is likely due to the rare number of occasions on which spellers of Dutch are confronted with these verb homophones. Estimates reveal that only 5% of all regular verb forms in Dutch are homophones, i.e., cannot be spelled by simply listening to the form’s pronunciation (Verhaert, Danckaert, & Sandra, 2016). The second cognitive process is

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an unconscious one, as it concerns the automatic retrieval from the mental lexicon. This will be important for our second research question and our associated hypothesis.

### *Research Questions*

We addressed two research questions:

1. Do the social variables Gender, Educational Track and Age affect the *number* of verb spelling errors?
2. Do the social variables Gender, Educational Track and Age affect the *pattern* of verb spelling errors?

The term ‘pattern’ refers to the above-mentioned effect of homophone dominance.

### *Hypotheses*

We set out from the hypothesis that the social variables may affect the number of errors but are less likely to affect the pattern of these errors. This rationale is based (a) on the processing analysis of the effect of homophone dominance (i.e., the higher-frequency form causes an intrusion when the computational process in working memory cannot be terminated in time) and (b) on our hypothesis concerning the processing level at which social factors are likely to exert their effect. The psycholinguistic account makes a testable prediction: if social factors like Gender, Educational Track and Age affect spelling errors, this will be at the level of conscious processing. This can be either due to the willingness to consciously reduce the number of errors (spelling attitude) or to the ability to engage sufficiently fast in such a conscious attempt (due to good working knowledge of the rules and fast computational skills). Given the processing analysis of homophone dominance, any conscious attempt to spell correctly should only affect the process that executes the spelling rule in working memory (a conscious process), not the

(automatic) process that retrieves orthographic representations. Hence, the psycholinguistic account predicts that the social variables may affect the *number* of errors but not the *pattern* of these errors, i.e., the higher frequency of errors on the lower-frequency spelling.

### *Gender*

As stated above, we expect teenagers' gender to affect the number of verb spelling errors in their chat conversations. In particular, we predict that girls will make fewer errors than boys. Previous sociolinguistic studies (Labov, 2001; Tagliamonte, 2011) showed that women display a stronger norm sensitivity and avoid stigmatized forms more than men. As these spelling errors on Dutch verb forms are highly stigmatized (due to the clear-cut rules), we assume that girls will allocate more attention to correct spelling and that they will consciously attempt to avoid these stigmatized errors more than boys.

Previous research on spelling errors involving verb homophones (Surkyn, Vandekerckhove, & Sandra, 2019) already demonstrated that teenagers' gender indeed affects the rate of these spelling errors: Girls performed remarkably better than boys. It did not affect the error pattern, as both boys and girls showed an effect of homophone dominance. When misspelling a verb homophone, both gender groups made more intrusions on the lower-frequency form than on the higher-frequency one, as predicted by the psycholinguistic account. Thus, we expect girls to outperform boys with regard to the number of errors, but we assume that both groups will make the same kind of errors (i.e., homophone intrusions).

### *Educational Track*

In addition to gender, we also expect an effect of teenagers' educational track on the number of spelling errors they make in CMC. In particular, we assume that students' knowledge of verb spelling rules and their ability to reflect on them will increase as educational tracks are more theory- and less practice-oriented, since the official curricula for practice-oriented educational tracks in Flanders tend to attach less importance to reflection on abstract linguistic concepts in general and spelling issues in particular than the curricula for more theory-oriented tracks (VVKSO, 2006/2014).

Studies on spelling proficiency of Dutch high school students indeed demonstrated that adolescents in the more theory-oriented tracks make fewer verb spelling errors in dictation tasks and writing assignments than their peers in the more practice-oriented tracks (Van den Bergh, Van Es, & Spijker, 2011; Van der Horst, Van den Bergh, & Evers-Vermeul, 2012). Another relevant study in this respect was conducted by Verhaert et al. (2016). It involved high school students from the three main educational tracks in Flanders (see Methodology), who participated in a speeded proofreading task. The study focused on the detection of errors on regular verb homophones and revealed that more errors went unnoticed in the groups from technical and professional education than in the group from the theory-oriented track. However, in all three groups an effect of homophone dominance was observed: participants overlooked more homophone intrusions when the intruder was more frequent than the target form.

The present study investigates whether these findings on error perception and error production in experimental tasks can be replicated in the (production) context of CMC. Just like for the social variable Gender, we expect that Educational Track will not

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modulate the effect of homophone dominance (i.e., the error pattern) but may affect the error risk (i.e., the number of errors). Given our hypothesis that these errors are probably unintentional ‘slips’, we predict fewer errors for more theory-oriented tracks.

We will study the same three educational tracks as Verhaert et al. (2016). As mentioned above, we do not expect the error patterns to differ between educational tracks. A better knowledge of the spelling rules and/or a more conscious attention for the spelling of verb forms would affect the probability that they can apply the spelling rule in working memory before the spelling of the higher-frequency homophone can ‘contaminate’ their output. However, when this rule cannot be applied fast enough, the trap created by the mental lexicon, which imposes the higher-frequency homophone, will be equally open for all three groups. Thus, if the findings by Sandra, Frisson, and Daems (1999) are transferable to natural writing contexts like social media writing, we expect an effect of homophone dominance in all educational profiles, irrespective of the (different) error rates.

### *Age*

Besides the teenagers’ gender and educational track, we also expect their age to affect the number of verb spelling errors. A first possibility is that younger chatters make more errors because they intentionally deviate from the spelling conventions. It is generally assumed that nonconformist linguistic behavior is at its highest in adolescents but decreases as adolescents approach adulthood (although the latter might apply to a greater extent to girls than to boys, e.g., Eisikovits, 2006). In view of this so-called adolescent peak principle (see e.g., Coates, 1993; Tagliamonte, 2016), one might expect older adolescents to make fewer errors than younger adolescents. However, this

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theoretical possibility is at odds with our assumption that these errors are unlikely to be used by teenagers to consciously deviate from spelling conventions in chat messages, as one of their most salient features is that many spellers (and readers) fail to notice them. This inconspicuous nature of the errors is obviously the consequence of the cognitive mechanisms that make them so persistent. This does not make verb homophones good candidates for intentional misspellings, even though youngsters like to consciously deviate from spellings that would be sanctioned by their teachers (e.g., cluster reductions like *egt* for *echt*, ‘real’, De Decker & Vandekerckhove, 2017).

Still, the fact that verb spelling errors often go unnoticed does not preclude that spellers attempt to avoid them by monitoring their written output. Such attempts are likely to be more successful with increasing age. This may be due to the fact that young teenagers have a general indifference to writing and spelling conventions or to the fact that they are less likely to have sufficient metalinguistic awareness to apply the verb spelling rules in time.

Alternatively, Age might not affect these errors at all. In a study of Bosman (2005) for example, the younger high school students (14-year-olds and 15-year-olds) did not show significantly lower scores on a verb spelling test than the older high school students (16- and 17-year-olds).

As in the case of Gender and Educational Track we do not expect the error pattern to differ as a function of age. Different age groups might differ in their error rates, but the effect of homophone dominance is expected to emerge in all groups. Our line of reasoning is the same as for the variables Gender and Educational Track: if older adolescents attempt to be more alert to verb spelling, this will only result in fewer errors. On occasions when working memory fails to apply the spelling rule in time, the

psycholinguistic model proposed by Sandra and coworkers predicts that most intrusion errors will be on the account of the higher-frequency homophone, whose orthographic representation is more accessible in the mental lexicon.

### Methodology

#### *Corpus*

Our corpus consists of private informal online conversations produced on Facebook Messenger and WhatsApp in 2015 and 2016. All 403,491 posts (2,360,117 tokens) were written by Flemish teenagers aged between 15 and 20 years old<sup>1</sup>. Table 1 shows the distribution of the data over the three social factors. We signal that the girls and students from technical education (see Independent variables) are somewhat overrepresented in the database (in terms of posts, tokens and target forms). However, even for the smallest group (professional education students) there are almost 1,700 target homophones. Moreover, the statistical analysis takes this discrepancy into account.

INSERT TABLE 1 ABOUT HERE

#### *Research Variables and Their Operationalization*

##### *Dependent Variable*

Spelling performance on Dutch homophonous verb forms is the dependent variable. We focus on two types of homophones. The first type (Study 1) concerns verbs whose stem

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<sup>1</sup> The original corpus, as described in e.g., Hilte (2019, p. 17), also included messages of 13- and 14-year-olds. We excluded the messages of these youngest participants because they contained very few target forms.

ends in /d/ (stem-final /d/ verbs) that are homophonous in the first and second + third person singular present tense. The first person is spelled as the stem of the verb (e.g., *word*, ‘become’), the rule for the third (and second) person is to add a *-t* to the stem (e.g., *wordt*, ‘becomes’)<sup>2</sup>. The second type of homophones (Study 2) are prefixed verb forms that give rise to homophones in the second and third person singular present tense (spelled as stem + *-t*, e.g., *bedoelt*, ‘means’) and the past participle (stem + *-d*, e.g., *bedoeld*, ‘meant’). We will refer to the first homophone type as <d>/<dt> homophones and to the second type as <t>/<d> homophones.

The spelling of all theoretically relevant verb forms in the corpus was manually encoded as correct or incorrect, in order to determine the error risk for a particular ending, i.e., the probability of making an error or not. Only the <d>, <t> or <dt> ending of the verb was taken into account when encoding for the correctness of the verbs. This means we did not consider typos or other spelling errors.

Finally, it is important to note that autocorrection cannot affect the production of spelling errors on verb homophones, and, hence, cannot have affected our data. Autocorrection for Dutch on Facebook Messenger and WhatsApp only corrects non-existing words, without taking their grammatical context into account. Since both homophones of the investigated verb types are existing forms, autocorrection cannot detect spelling errors on these forms.

### *Independent Variables*

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<sup>2</sup> If the verb precedes the subject (inversion, e.g., in question forms), the second person singular is formed in the same way as the first person singular (i.e., the stem of the verb, e.g., *Word je moe?*, ‘Are you getting tired?’).



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There are two types of independent variables: the three social variables and the two variables that together define the effect of homophone dominance.

The social factor Gender is the first independent variable. This variable was operationalized as a binary one: students identified themselves as boys or girls. Consequently, it can be assumed that gender largely (but not necessarily completely) coincides with biological sex.

The social factor Educational Track is the second independent variable. All participants are enrolled in Flemish secondary school education. We distinguish between writers on the basis of their educational profile, which corresponds to one of the three main educational tracks in Flanders: *aso*, *tso* and *bso*. *Aso* (*algemeen secundair onderwijs*) refers to general secondary education (GE): it has a strong theoretical orientation and prepares for higher (university) education. *Bso* (*beroepssecundair onderwijs*) is professional secondary education (PE): it prepares for direct access to the job market, mainly for manual labor. *Tso* (*technisch secundair onderwijs*) represents technical secondary education (TE), occupying an intermediate position between *aso* and *bso*. It is less theoretical than the former but more than the latter. Students from technical education proceed to higher education, but generally much less to university than their *aso*-peers. In view of the orientation and learning contents, these tracks can be assumed to differ considerably with respect to the focus on metalinguistic skills in general and spelling skills in particular.

The age of the participants functions as the third independent variable. We made a distinction between younger (15-and 16-year-old) and older (17-20-year-old) adolescents. For this subdivision we set out from the grade structure in Flemish secondary education (first graders: mainly 13-and 14-year-olds; second graders:

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primarily 15-16 year olds and third graders: mainly 17-to 18-year olds). Henceforth, we will use the terms Grade 2 and Grade 3.

The fourth independent variable is the Correct Ending of the verb homophones. For the <d>/<dt> homophones, this psycholinguistic variable includes two conditions: the <d> spelling (i.e., stem-final /d/) in the 1<sup>st</sup> person singular present tense form and the <dt> spelling in the 2<sup>nd</sup> and 3<sup>rd</sup> person singular present tense forms. For the <t>/<d> homophones, this variable also includes two conditions: the <t> spelling in the 2<sup>nd</sup> and 3<sup>rd</sup> person singular present tense forms and the <d> spelling in the past participle.

The fifth variable is the psycholinguistic variable Dominance Type, which involves the relationship between the homophones' frequencies. This variable is based on the ratio between the log10 frequencies of the <d> and <dt> form (Study 1) or the <d> and <t> form (Study 2). These frequencies were extracted from SUBTLEX-NL, a database of Dutch word frequencies based on more than 40 million words from television and film subtitles (Keuleers, Brysbaert, & New, 2010). On the basis of these ratios, every target form was encoded as a <d> dominant or <dt> dominant verb (Study 1), or as a <t> dominant or a <d> dominant verb form (Study 2). This variable was operationalized as a binary one to guarantee maximum comparability with previous experimental studies, in which this was also a dichotomous factor (which proved sufficient to find and replicate a robust effect of homophone dominance).

### *Data Processing*

In an automated prefiltering process all potentially relevant verb forms were extracted from the corpus by selecting all tokens ending with <d> or <t>. Thus we achieved maximum coverage in terms of recall, so there were no false negatives. Next, in a post

processing phase all false positives were removed manually. Most of these false positives concerned tokens that, without context, could actually be homophonous verb forms. For example, the token *antwoord* ('answer') can either function as a noun or as a first person singular present tense. Furthermore, we excluded standard messages generated by Facebook Messenger and WhatsApp as they were not produced by participants. This led to a final corpus of 8,640 target forms.

Each target form was not only encoded for correctness but also for the social and psycholinguistic independent factors mentioned above. The two homophone types were analyzed separately in Studies 1 and 2, as the homophones involve different grammatical functions for the two types. The main analyses concern: (a) the effect of the social variables, (b) the effect of homophone dominance, and (c) the interaction between this effect and the social factors. The latter analysis addresses the question whether the social factors affect the error pattern, more particularly, the effect of homophone dominance.

### Results

#### *Model Building Procedure*

For each homophone type, we built a single model, in which the effects of the two random factors (i.e., Chatter and Lemma<sup>3</sup>), the social variables, their interactions, the factors determining the effect of Homophone Dominance, and their interaction with the social variables were sequentially added (in that order). A single model avoids the

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<sup>3</sup> Lemma was used as a random variable to capture the fact that each pair of verb homophones represents a different level of the same (random) variable.

inflation of Type I errors<sup>4</sup> and, moreover, avoids the danger that, for instance, a social factor is significant when estimating its effect in a different model than the psycholinguistic factors, whereas it is non-significant in a model that encompasses all factors under study. This decision was obviously also inspired by our major goal, which was to find out whether the effect of Homophone Dominance interacts with the social variables.

We analyzed the data with a generalized linear mixed effects model, using the `glmer` function from the `lme4` package (Bates, Maechler, Bolker, & Walker, 2015) in the R statistical software package (R Core Team, 2014). We set out from a model in which Chatter was the only (random) variable and followed a stepwise forward procedure, in which one extra factor is added at each step<sup>5</sup>. We first introduced Lemma as the second random factor, then each of the social variables, followed by their pairwise interactions. Next, we added the linguistic and psycholinguistic factors: Correct Ending, Dominance Type, and their interaction (the latter defines the effect of Homophone Dominance). Finally, we added each interaction between a social variable and the psycholinguistic

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<sup>4</sup> When  $\alpha = .05$ , i.e., accepting one Type I error per 20 contrasts on average, implies a probability of .36 that not a single false positive is observed, ( $0.95^{20} = .36$ ). This means that there is a 64% chance that at least one false positive is found. This high risk makes it crucial to take precautions against Type I errors.

<sup>5</sup> There is no consensus about the best model-building procedure. Both stepwise forward, stepwise backward, and automated procedures have been advanced. Baayen (2014) advises a hypothesis-driven approach, which is the one taken here. Moreover, Hastie, Tibshirani, and Tibshirani (2017) conclude from their simulation data that “forward stepwise selection and best subset selection perform similarly throughout” (p. 17).

variables. We used a likelihood ratio test to decide whether adding an extra factor accounted for significantly more variance in the data ( $\alpha = .05$ ).

Once the final model was derived, we further analyzed the interaction effects by performing contrasts on the different levels of each factor involved in the interaction, using the function ‘relevel’ from the ‘stats’ package in R<sup>6</sup>. As this increased the number of contrasts (hence, the risk for Type I errors) we used Benjamini and Hochberg's (1995) step-down procedure to determine (more stringent) cut-off values for significance for each of these contrasts<sup>7</sup>. This procedure addresses the problem of multiple testing by controlling the False Discovery Rate (FDR), i.e., the rate of false positives. Even though the FDR does not require the same alpha level as the overall analysis (here: .05), we set it at the same value. This is rather conservative, but we wanted to minimize the risk for Type I errors as much as possible. Benjamini and Hochberg's procedure rank-orders the effects from smallest to largest and then determines the cut-off value for each effect by dividing the alpha level by the number of remaining comparisons, i.e., arriving at .05 for the last comparison. When ‘stepping down’ from the strongest effect, the first  $p$ -value that exceeds the cut-off value sets the

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<sup>6</sup> The same contrast can be extracted from the model without changing the intercept, by using the appropriate set of coefficients in a general linear hypothesis test (the ‘glht’ function in the ‘multcomp’ package in R accomplishes this), i.e., the choice of another reference level for the intercept does not amount to a novel statistical model.

<sup>7</sup> The Benjamini and Hochberg procedure is considered a very powerful technique to control for the false discovery rate. The method is superior to the conservative Bonferroni correction, which risks to yield too many false negatives, i.e., failures to reject a wrong null hypothesis. The impact of the procedure is indicated by the high citation rate of the paper: it was ranked as the 7<sup>th</sup> most cited paper in statistics in the period between 1993 and 2003 (in a 2005 publication by Ryan & Woodall).

boundary between significant and non-significant effects: all preceding effects are treated as significant and all following ones are non-significant.

### *Study 1: <d>/<dt> homophones*

Recall that the stem of all verbs in this set ends in the letter <d> and is pronounced as [t]. The dataset contained 5,804 such homophones: 2,989 that required the <d> spelling (51.50%) and 2,815 that required the <dt> spelling (48.50%). The number of tokens for the <d> dominant verbs, i.e., 3,910 (67.37%), exceeded that for <dt> dominant verbs, i.e., 1,894 (32.63%), which closely reflects the distribution of these two dominance types in what people encounter in subtitles<sup>8</sup>. As we focused on homophone intrusions, our data set only included <d> spellings and <dt> spellings (applied correctly or incorrectly). Phonetic spellings, like *vint*, where the final stem /d/ was spelled as <t>, were omitted from the dataset. The latter subset was almost non-existent: 14 forms, i.e., 0.24%.

### *Preliminary Analyses*

#### *Collinearity between social variables.*

In contrast to the typical situation in an experiment, the tokens produced by the teenagers were not evenly distributed across the cells of the matrix defined by the social variables. To ensure that an effect of one social variable was not due to its collinearity

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<sup>8</sup> There are 83 homophones in SUBTLEX-NL (Keuleers, Brysbaert, & New, 2010) that occur at least once per million in the 44 million words corpus. In a type count, 51 verbs are <d> dominant (61.45%) and 32 are <dt> dominant (38.55%). In a token count 4,667 (69.35%) are <d> dominant and 2,063 (30.65%) are <dt> dominant.

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with another one (e.g., in an extreme example, all boys would be in Grade 2 and all girls in Grade 3), the collinearity of each pair of social variables was determined. We calculated Cramér's  $v$  or the equivalent phi coefficient for a  $2 \times 2$  table (i.e., for Gender and Grade) to measure the association strength between the two variables. A negligible relationship was found for all three variable pairs, in the counts by token (number of homophones) and by type (number of chatters): Educational Track and Gender ( $v = .04$  and  $v = .02$ , respectively), Educational Track and Grade ( $v = .10$  and  $v = .09$ ), Gender and Grade ( $\Phi = .14$  and  $\Phi = .08$ ). Five of these six values fall below the cut-off value for a small association in  $2 \times 3$  and  $2 \times 2$  contingency tables (.07 and .10, respectively) and one value falls far below the cut-off for a medium association in a  $2 \times 2$  table (.30, Kim, 2017, Table 2). Hence, the collinearity between the social variables is no cause for concern.<sup>9</sup>

### *Homophones' distribution in corpus versus other text types.*

The frequency distribution of the verb homophones in a chat corpus might not reflect their occurrence frequencies in other text types, due to medium-specific differences.

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<sup>9</sup> We also calculated the Variance Inflation Factor (VIF) to check whether the data met the assumption of collinearity. We conducted a GVIF test, the generalized version of VIF introduced by Fox and Monette (1992), based on a generalized linear mixed model in which the dependent variable was predicted by our social variables (Gender, Grade, Educational Track) and the two (psycho)linguistic factors (Correct Ending and Dominance Type). The random factors (Chatter and Lemma) were also included in the model. The GVIF test indicated that multicollinearity was no cause for concern, as all squared generalized VIF scores were smaller than 1.03, i.e., well below the conventional threshold of 4 above which collinearity between the predictors is a source of concern. The GVIF values were squared, as these values are computed as the square root of the VIF.

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This could have an impact on the effect of Homophone Dominance, as this effect hinges on the frequency relationship between the two homophone spellings. A chi-square analysis of the numbers of homophones in the corpus, as a function of their Correct Ending and Dominance Type, revealed that the distribution of these verb homophones followed the same pattern as in other text types: 2,662 <d> spellings, 68.08%, for <d> dominant verbs; 1,480 <dt> spellings, 78.14%, for <dt> dominant verbs. The highly significant interaction effect was associated with a strong effect size, i.e., a high associative strength between the two factors ( $\Phi = .43$ ). This result did not change when only the correct spellings of the homophones were analyzed ( $n = 4,139$ , 71.31% of the data; 2,566 <d> spellings, 88.48%, for the <d> dominant verbs; 920 <dt> spellings, 74.25%, for <dt> dominant verbs), with an even higher association strength ( $\Phi = .62$ ).

### *Adolescents' reliance on spelling rules.*

As the effect of Homophone Dominance is triggered by the failure to apply the spelling rule in time, it should also surface in the absence of (good) rule knowledge. Still, it seems reasonable to assume that chatters (sometimes) rely on spelling rules. To test this, we used one-sample z-tests and compared the mean error rates in all groups defined by the orthogonal combination of the three social variables to random guessing, i.e., a population mean of .50. At first sight, random guessing may seem a strange yardstick: it would mean that spellers know that there are two possible spellings but are always unsure which is the right one. Still, *this* theoretical possibility could be a possible *result* of the Flemish educational system, at least in the minds of poor spellers. Indeed, the problem that is raised by the morphographic spelling of verb homophones is often explicitly presented as a choice that must be made between the endings <d> and <dt> or



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between <t> and <d>. Many verb spelling exercises in school books explicitly require students to make such binary choices (e.g., “Replace the missing letters with d or dt”). Hence, as a first approximation to the problem, it seems reasonable that many spellers experience the spelling of verb homophones as a forced-choice binary problem. The latter can be successfully solved when the speller knows the rules and can rapidly apply them, but can only be solved by random guessing in the absence of rule knowledge or knowledge that is applied too slowly.

Importantly, such random guessing was generally not observed. When the <d> spelling was correct, all groups performed significantly better than chance (mean error rates ranged between 3%-14%; all  $ps < .0001$ ). When the <dt> spelling was correct, three of the four groups defined by Gender and Grade in GE performed significantly better than chance (range error rates: 27%-38%;  $p \leq .001$ ), whereas 7 of the 8 groups in TE and PE performed significantly worse than chance ( $ps < .0001$ ).<sup>10</sup> As the performance of the GE group was better than chance on both the <d> homophones and <dt> homophones, they seem to have relied on rules in a sizeable number of cases. In contrast, the fact that the TE and PE groups performed quite well on the <d> spelling but very poor on the <dt> spelling suggests a strong <d> bias (see below).

Note that these analyses neither demonstrate that TE and PE teenagers never applied the rules nor that they did not know these rules. They may have been unable to apply them sufficiently fast or have ignored them from time to time. At the same time, the analyses do not rule out that GE adolescents may also have had a (weaker) <d> bias when they were too slow to apply the rule. We will return to this below.

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<sup>10</sup> The group of 2<sup>nd</sup> grade boys in GE and 3<sup>rd</sup> grade girls in TE performed at chance level (44%,  $p = .26$  and 50%,  $p = .92$ , respectively).

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Obviously, these findings do not inform us on the risk of homophone intrusions in the groups defined by our social variables. There is sufficient room for these (and other) errors, as the overall error rate was 30%. Moreover, in all groups, one-sample z-tests comparing the error proportion to a population mean of error-free performance (population mean = 0) revealed significantly higher error rates in all groups defined by the social factors (range: 2.32-28.10,  $.02 < p < 0.001$ ).

### *Results*

Table 2 gives the output of the best fitting statistical model<sup>11</sup>. The intercept is the mean performance on the <d> spelling of <d> dominant verbs by male teenagers in Grade 2 of GE. It also includes the theoretically relevant contrasts that were motivated by the third-order interaction (by changing the intercept values of the same model). To facilitate the readability of the table, the effects are clustered as a function of the effect to which they pertain. Recall that the Benjamini and Hochberg's procedure for controlling the False Discovery Rate was applied, which may make some *p*-values below .05 non-significant (only on two occasions). Note that a logistic regression model uses logits in its calculations, i.e., the logarithm of the odds ratio. Hence, the intercept is contrasted with logit = 0, which corresponds to an error proportion of 0.50, i.e., random choice behavior<sup>12</sup>.

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<sup>11</sup> Both random factors (Lemma and Chatter) were kept after likelihood ratio tests and were thus included in the final model. The corresponding standard deviations are: 0.88 (Lemma) and 1.12 (Chatter).

<sup>12</sup> This follows straightforwardly from the logit formula:  $\text{logit} = \log_e[p / (1 - p)]$ . As the exponential function is the inverse of the logarithmic operation – if  $y = \log_{\text{base}}(x)$ , then  $x = \text{base}^y$  – the logit equation can be progressively rewritten as (using *y* as a shorthand for logit):  $p / (1 - p) = \exp(y)$ ;  $p = \exp(y) * (1 - p)$ ;

INSERT TABLE 2 ABOUT HERE

*Spelling accuracy.*

This set of homophones contained 1,665 misspellings (28.69%). Although the large majority was spelled correctly, this error rate is very high when considering the clear-cut spelling rules. There was a huge contrast between the error rates on the <d> spelling (191 on 3,076 forms, 6.21%) and on the <dt> spelling (1,474 on 2,728 forms, 54.03%). As the effect of Correct Ending was involved in interaction effects, this effect will be discussed in relation to these other variables.

*Social variables.*

The effect of Gender and Grade have main effects and are not involved in any interaction. Female teenagers make fewer errors than their male peers ( $z = -3.55$ ,  $p = .0004$ ; boys: 37.41%, girls: 25.34%). Older teenagers make fewer errors than younger ones ( $z = -3.271$ ,  $p = .001$ ; Grade 2: 30.73%, Grade 3: 26.72%). Educational Track has an effect but is involved in a third-order effect with Correct Ending and Dominance Type. We will discuss this factor below. The model-building procedure revealed no interactions among the social variables.

*Homophone Dominance and its interaction with the social variables.*

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$p = \exp(y) - p^* \exp(y)$ ;  $p + p^* \exp(y) = \exp(y)$ ;  $p^* [1 + \exp(y)] = \exp(y)$ , and  $p = \exp(y) / [1 + \exp(y)]$ . If (the logit)  $y = 0$ ,  $p = \exp(0) / [1 + \exp(0)]$ , and since  $e^0 = 1$ , this equals  $p = 1/2 = 0.50$ , i.e., the guessing probability.

## THE HOMOPHONE DOMINANCE EFFECT IN REAL-LIFE DATA

Our major goal was to find out whether (a) the experimentally observed (and replicated) effect of Homophone Dominance also appears in a naturalistic situation and, if so, (b) whether it interacts with the social variables. The effect of Homophone Dominance is significant in the GE group ( $z = -12.76, p < .0001$ ), i.e., the relation between the error rates for the <d> spelling and <dt> spelling differed significantly between the <d> dominant and <dt> dominant verbs. This effect did not interact with either Gender or Grade, i.e., it was (statistically) constant for male and female teenagers and for younger and older teenagers. However, the effect strongly interacted with Educational Track. The size of the effect differed significantly between the GE group on the one hand and the TE and PE groups on the other hand (third-order interactions:  $z = 3.45, p = .0006$  and  $z = 4.12, p < .0001$ , respectively). The latter two groups did not differ from each other ( $z = 1.34, p = .18$ ). Including the TE or PE group as the reference level for Educational Track in the intercept revealed an effect of Homophone Dominance for these groups as well ( $z = -12.85, p < .0001$  and  $z = -7.42, p < .0001$ , respectively). Figure 1 visualizes the model's estimated error rates for the conditions involved in this third-order interaction. We used the model's estimated marginal means (in logits) to take the unbalanced nature of our 'design' into account (cf. Vignette topic for 'emmeans' package R, n.d.). For the sake of readability, the graphs plot the error proportions, i.e., the back-transformed logit values for the estimated marginal means.<sup>13</sup>

As Homophone Dominance reflects the interaction between Correct Ending and Dominance Type, the best way to understand this interaction is by inspecting the data from two perspectives: (a) the effect of Correct Ending at each level of the factor

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<sup>13</sup> Note that the plots on the basis of the raw data barely differ from those in Figure 1.

## THE HOMOPHONE DOMINANCE EFFECT IN REAL-LIFE DATA

Dominance Type, a measure of the intrusion effect (henceforth: spelling effect<sup>14</sup>), and (b) the effect of Dominance Type at each level of the factor Correct Ending (henceforth: dominance effect).

### *(a) The spelling effect*

For <d> dominant verbs, the spelling effect was significant in the GE group ( $z = 15.04$ ,  $p < .0001$ ; <d> spelling: 1.71%, <dt> spelling: 69.07%) and did not interact with the effect in the TE and PE groups (both  $z$ -values  $< 1$ ), which did not differ with respect to it either ( $z$ s  $< 1$ , TE: <d> spelling: 5.23%, <dt> spelling: 87.07%; PE: <d> spelling: 7.38%, <dt> spelling: 90.88%). The pattern is the same across educational tracks: few homophone intrusions when the (dominant) <d> spelling is correct but huge error rates when the <dt> spelling is correct.

For <dt> dominant verbs, the spelling effect in the GE group showed a trend towards significance but failed to reach significance ( $z = -2.56$ ,  $p = .01$ , a value that exceeds the value of .005 based on the Benjamini and Hochberg's procedure; <d> spelling: 37.46%, <dt> spelling: 22.50%). This effect in the GE group interacted significantly with the one in the TE and PE groups ( $z = 4.83$ ,  $p < .0001$  and  $z = 5.97$ ,  $p < .0001$ , respectively). In the TE group, the spelling effect was highly significant ( $z = 4.55$ ,  $p < .0001$ ; <d> spelling: 28.74%, <dt> spelling: 52.66 %); it did not interact with the effect in the PE group ( $z = 1.92$ ,  $p = .06$ , far removed the cut-off value of .006; PE: <d> spelling: 31.81%, <dt> spelling: 72.25%). Unlike the situation for the <d> dominant verbs, the

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<sup>14</sup> A model in which the factor Intrusion Type (intrusion of dominant vs. non-dominant spelling) is used instead of Correct Ending, yields identical estimates of the beta coefficients for the interaction Intrusion x Educational Track as the estimates for the interaction Correct Ending x Educational Track in Table 2.

## THE HOMOPHONE DOMINANCE EFFECT IN REAL-LIFE DATA

pattern is not constant across groups. GE teenagers tend to make fewer homophone intrusions when the (dominant) <dt> spelling is correct than when the <d> spelling is correct. Note, however, that both the TE and PE teenagers made *more* errors on the dominant <dt> spelling than on the lower-frequency one (a reverse spelling effect).

INSERT FIGURE 1 ABOUT HERE

### *(b) The dominance effect*

When focusing on the <d> spelling, the dominance effect is highly significant in the GE group ( $z = 6.47, p < .0001$ ; <d> dominant: 1.71%, <dt> dominant: 37.46%). It significantly interacts with the effect in the TE and PE groups ( $z = -3.45, p = .0006$  and  $z = -3.50, p = .0005$ , respectively). The dominance effect is significant in the TE group ( $z = 4.18, p < .0001$ ; <d> dominant: 5.23%, <dt> dominant: 28.74%) but does not differ from the one in the PE group ( $z < 1$ ; <d> dominant: 7.38%, <dt> dominant: 31.81%). Adolescents in all educational tracks made fewer errors when the <d> spelling is dominant (<d> dominant verbs) but this effect is more outspoken in the GE group.

In the subset of verb forms requiring the <dt> spelling, the dominance effect is significant for the GE group ( $z = -4.65, p < .0001$ ). This effect did not differ between groups (GE-TE:  $z < 1$ ; GE-PE:  $z = 2.19, p = .03$ , far removed from the cut-off value of .006; TE-PE:  $z = 1.60, p = .11$ ). Despite large differences in the actual error rates on the <dt> spelling of both <d> dominant and <dt> dominant verbs, all groups show the same dominance effect. The corresponding error rates for the two dominance types in each Educational Track (back-transformed from the model's estimated logit values): <d>

## THE HOMOPHONE DOMINANCE EFFECT IN REAL-LIFE DATA

dominant: 69.07%, <dt> dominant for GE, 22.50%; <d> dominant: 87.07%, <dt> dominant: 52.66% for TE; <d> dominant: 90.88%, <dt> dominant: 72.25% for PE).

### *Discussion*

#### *Social factors.*

The social factors yield a sensible pattern. The attested gender effect is a familiar phenomenon in sociolinguistic research. Women have been reported to “conform more closely than men to sociolinguistic norms that are overtly prescribed” (Labov, 2001, p. 293) and to avoid stigmatized forms (e.g. Tagliamonte, 2011, p. 32). Errors on Dutch verb homophones are indeed highly stigmatized, because they are strictly rule-governed. The finding that older adolescents (effect Grade) make fewer errors on such homophones does not come as a surprise either. It is plausible that such adolescents are more conscientious about their spelling, and more norm-compliant, and therefore attempt to allocate more working memory resources to verbs, especially because they are so stigmatized. The finding that there is a decrease in error rates from the GE group, over the TE group, to the PE group makes sense as well (here, we abstract from the interaction with the Homophone effect) – total error rates for GE: 16.81%, TE: 30.59%, PE: 44.47%. Students in more theoretically oriented tracks are more likely to make fewer verb spelling errors, since their educational curriculum offers more room for reflection on the abstract concepts that are involved in the spelling rules.

#### *Homophone Dominance.*

The major finding of this study was the effect of Homophone Dominance: the relationship between errors on the <d> spelling and <dt> spelling was significantly

different in the <d> dominant and <dt> dominant verbs. This effect did not interact with either Gender or Grade. It did interact with Educational Track below (see below), but we first want to emphasize that this effect was significant in each educational track. To date, this effect had been demonstrated in the (artificial) experimental context of several dictation experiments under time-pressure (see references to Sandra and co-workers above). These findings converge with those presented in a recent study by Schmitz et al. (2018). However, as we mentioned earlier, they studied Twitter data, which are often the result of a more deliberate writing style than chat messages.

### *Bias for <d> spelling.*

The data reveal another pattern, which is reflected in the effect of Correct Ending. Despite the interaction of this effect with both Dominance Type and Educational Track, it is clear from Figure 1 that teenagers have a strong bias to produce the <d> spelling. This pattern has been attested before: Schmitz et al. (2018) and Verhaert (2016, p. 138) also demonstrated this <d> bias in stem-final /d/ verbs. In our study, this is particularly evident for the <d> dominant verbs, where there is huge difference between very low error rates on the <d> spelling and (very) high error rates on the <dt> spelling. We emphasize that this cannot only reflect the intrusions of the dominant <d> homophone because the dominance effect is much smaller in the set of <dt> dominant verbs. Moreover, for the latter type of verbs, TE and PE teenagers even made *more* intrusion errors on the (dominant) <dt> spelling than on the <d> spelling, which is an especially strong indication of a <d> bias. At the same time, the observation that the error rates of TE and PE spellers on the <dt> spelling were smaller for <dt> dominant verbs than for <d> dominant ones, reveals that they were also sensitive to the frequency relationship



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between the two homophone spellings, i.e., the basis for the effect of Homophone Dominance. Finally, the fact that GE teenagers made fewer errors on the <dt> spelling of <dt> dominant forms than on their <d> spelling demonstrates that their <d> bias (as evidenced by their spelling of <d> dominant verbs) is weaker than in their TE and PE peers.

It is important to note that a <d> bias makes sense for this verb type, as the <d> spelling coincides with the stem, which occurs in all regular forms in the verb's inflectional paradigm (e.g., *red*, 'save', which occurs in the homophone pair *red-redt*, is also embedded in the infinitive and present tense plural *redde*, the past tense *redde*, and the past participle *gered*). A study on analogical effects conducted by Ernestus and Mak (2005) revealed the importance of other inflectional forms of the same verb in reading Dutch verb forms. They showed that an incorrectly spelled verb form caused a smaller reading delay in a self-paced reading task when other inflected forms of the same verb (and other verbs) supported this spelling. If (non-homophonous) inflectional variants of the verb co-determine the frequency of the <d> spelling, this will result in a different frequency relationship between the <d> spelling and <dt> spelling than one that is merely based on the frequency of the homophone spellings only. We performed a lexical-statistical study of the frequency distribution of Dutch verb forms of the verb tenses represented by these homophone types (1<sup>st</sup> vs. 2<sup>nd</sup>/3<sup>rd</sup> person singular present tense), which sheds light on this issue. We used CELEX (Baayen, Piepenbrock, & Gulikers, 1995) to retrieve all verb forms in the 1<sup>st</sup>, 2<sup>nd</sup>, and 3<sup>rd</sup> person singular present tense with a minimum frequency of 1 per million – this database includes these grammatical codings – and retrieved their frequencies from a frequency corpus based on subtitles SUBTLEX-NL (Keuleers et al., 2010). Summing the token frequencies of the

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set of verb forms with a stem-final /d/ (hence, with a <d>/<dt> homophone pair) indicated that they represent only 3.37% of the sum of token frequencies across the entire set of verb forms (i.e., 4,311 of 128,068 tokens, with similar percentages for the 1<sup>st</sup> person, 3.85%, and the 2<sup>nd</sup>/3<sup>rd</sup> person, 2.93%). The pattern is the same when considering only verbs whose homophones both occur at least once per million (in 84 of the 183 verbs with stem-final /d/) and, hence, present spellers with true competitors: 3.19% (all forms), 3.47% (only 1<sup>st</sup> person), 2.93% (2<sup>nd</sup>/3<sup>rd</sup> person). A type-wise count further underscores this minority position of stem-final /d/ verbs: only 186 of the 2,465 Dutch verbs have a stem-final /d/ (7.55%; this percentage is somewhat higher, i.e., 11.46%, when only counting verbs that occur at least once in the 1<sup>st</sup> or 2<sup>nd</sup>/3<sup>rd</sup> person, i.e., 170 of the 1,483 verbs). As repetition progressively leads to automatic behavior in many domains (inside and outside language), the fact that Dutch spellers are extremely seldom confronted with this spelling problem (the token-wise figures especially drive spellers' frequency 'counts') makes it likely that the computation of the suffix spelling remains a time-consuming process in working memory. This, in turn, might increase the probability that spellers develop a preference for the spelling whose orthographic pattern recurs across the inflectional paradigm, in addition to being sensitive to the verb-specific frequency relationship between the two homophones.

### *Interaction between Homophone Dominance and Educational Track.*

We had predicted that the effect of Homophone Dominance would not interact with the social factors. These factors are likely to affect the error rates (which they do) but are not expected to change the unconscious interplay between working memory and the frequency information in the mental lexicon. Our prediction is borne out by the absence

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of an interaction between the effect of Homophone Dominance and both Gender and Grade. However, it is contradicted by the finding of a (highly significant) interaction between Homophone Dominance and Educational Track, i.e., the third-order interaction.

Whereas the combined effects of homophone intrusions and a <d> bias are in part responsible for this effect, there is more going on. It is important to elaborate on this because it reveals a crucial aspect of the statistical analysis of datasets like these. It turns out that the homophones of two verbs dominate the dataset: *vinden* ('to find', a <d> dominant verb) and *worden* ('to become', a <dt> dominant verb) together make up 84.60% of the data (*vinden*: 3,376 tokens; 58.17%, *worden*: 1,534 tokens; 26.43%). This reflects two facts: (a) there are huge frequency differences among the words in a language (which is predicted by Zipf's law) and (b) the nature of the chat medium makes some verbs very popular (e.g., in Dutch *vinden* is used to express an opinion: *ik vind ...*, *hij/zij vindt ...*, 'I find', 'he/she finds'). Such unbalanced data are obviously not an ideal situation when it comes to statistical analysis, but they simply reflect the nature of this study object, and researchers have to take deal with them. The issue is all the more important because the data are also unevenly distributed across chatters. Some teenagers provided us with many tokens, whereas many others provided very few homophones. Eight chatters provided about one fifth of all data (1,249 homophones; 21.52%), whereas 419 chatters provided 842 homophones (14.51%)<sup>15</sup>.

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<sup>15</sup> This imbalance is due to the procedure for data collection. Students in the two grades of the three educational tracks were requested to voluntarily donate their chat posts. We did not want to exert any pressure and therefore did not set a lower limit. In the end, some people were much more willing to

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Removing the high-frequency verbs is not an option, as one would be left with only 15% of the dataset (894 observations). Similarly, removing chatters with high numbers of homophones is not the way to go. Nonetheless, it is important to establish that the effects do not hinge on these two verbs or a handful of chatters only. To find out whether the effects were independent of the imbalances among verbs and chatters, we split the dataset into subsets. We are aware that multiple testing on the same dataset increases the risk of Type I errors. However, we were only interested in the systematicity of the effect of Homophone Dominance and its interaction with Educational Track, not in the  $p$ -values as such (we will only report this value when it indicates a very strong, theoretically relevant effect).

This exercise revealed an interesting pattern. The third-order interaction, i.e., a significantly different effect of Homophone Dominance in GE than in TE and PE (which did not differ), was independent of the contribution frequency of the chatters. In a first operationalization of contribution frequency, the data were split into two halves, i.e., at the median of the cumulative frequency distribution (above-median group of chatters: 2,966 tokens vs. below-median group: 2,838 tokens)<sup>16</sup>. In a second operationalization, they were split on the basis of the outliers at the higher end of the contribution scale. High-contribution chatters provided more than 50 homophones (based on a visual inspection of the histogram representing chatter contribution). In a final operationalization, the data were split on the basis of the outliers at the lower end

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donate large parts of their chat history than others and we respected that. All chat data were anonymized and the procedure was given clearance by an ethical committee, according to the GDPR guidelines.

<sup>16</sup> We divided the set in-between the data of two chatters, which explains why the two subsets are not equally large.

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of the contribution scale. The lowest-contribution chatters were defined as those who provided 13 tokens or less (based on the same histogram). The interaction between Homophone Dominance and Educational Track was significant in all these subgroups (analyzed separately).

The data split on the basis of the verbs' contribution to the dataset was obvious: we made separate analyses of the two high-frequency verbs (one <d> dominant and one <dt> dominant one) and of the data set without these verbs. The interaction between Homophone Dominance and Educational Track was very strong in the former set but disappeared in the latter (there was not even a trend of an interaction between the effects for the GE, TE, and PE groups: all  $p$ s > .15). However, the effect of Homophone Dominance remained highly significant ( $p = .007$ ) and was significant in all analyses above (in all educational tracks).

The pattern is clear: the interaction between Educational Track and Homophone Dominance is entirely dependent on two verbs. As these are high-frequency verbs, they are present in the data of all chatter subsets and, hence, consistently produce a third-order interaction there as well. Closer inspection of the error patterns produced by these two verbs made it clear that the true source of the third-order interaction is *vinden* ('to find'). Indeed, the removal of this verb makes the interaction disappear (but not the effect of Homophone Dominance, which remains highly significant:  $z = -9.05$ ,  $p < .0001$ ). It turns out that the error rates on the <d> spelling of this verb differ across the educational tracks (despite the <d> bias in all groups): 1.22% (GE), 4.27% (TE), and 7.11% (PE). These are small differences, but their impact is huge, considering the omnipresence of this verb's <d> spelling. The (correct) spelling *vind* ('find') occurs in 2,520 of all 2,662 tokens (94.67%) where a <d> spelling of a <d> dominant verb is

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expected (based on tokens from 34 verbs of the 76 in the entire database). The very small error rate for GE teenagers widens the gap between the error rates on the <d> spelling of <d> dominant and <dt> dominant verbs (Figure 1), which is ultimately responsible for the interaction between Educational Track and Homophone Dominance. Importantly, the GE teenagers' small error rate on the <d> spelling of this verb is in line with the claim that the error patterns of TE and PE adolescents are to a larger degree affected by other disturbing factors than homophone intrusions, even though spellers in all educational tracks reveal the Homophone Dominance effect. We already demonstrated a stronger <d> bias in these groups, causing a reverse homophone effect in the set of <dt> dominant verbs, but this finding suggests that TE and PE teenagers sometimes randomly produce a <d> spelling or a <dt> spelling (random noise), which may work against both their <d> bias and the effect of the higher-frequency homophone (as in the spelling of *vind*).

Clearly, the interaction between Educational Track and Homophone Dominance is an artefact of a single verb, whose error pattern is, moreover, compatible with the concept of Homophone Dominance (in the GE group). We emphasize that this is not due to a lack of power. The analyses on the below-median chatters and lowest-contribution chatters contained about the same number of observations (range: 2,068-2,942), distributed across comparable numbers of chatters (range: 492-608) and verbs (range: 54-75). It is stunning that a single verb caused an effect that, at first sight, could not be explained in terms of the earlier account of the effect of Homophone Dominance proposed by Sandra and co-workers. The methodological implication is that datasets of this kind should be analyzed with scrutiny. A close inspection of the data distribution,

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both across items and participants, and its potential impact on the significance pattern is required.

### *Study 2: <t>/<d> homophones*

The dataset contained 2,441 homophones of verbs whose stem does not end in a /d/ (in contrast to the verbs in Study 1). These homophones are spelled with the suffix *-t*, to express the 2<sup>nd</sup> and 3<sup>rd</sup> person singular of the present tense (1,108; 45.39%), or the suffix *-d*, which marks the past participle (1,333; 54.61%). All homophones were tagged for dominance (<t> dominant: 868; 35.56 %; <d> dominant: 1,573; 64.44 %).

### *Preliminary Analyses*

#### *Collinearity between social variables.*

Neither the chatters nor the homophones were evenly distributed across the orthogonal combination of the three social factors. Hence, each pair of social variables was tested with respect to collinearity. The measure of association strength (Cramér's  $v$  or the phi coefficient) revealed a weak relationship in each of the three variable pairs, both when the number of tokens or the number of (unique) chatters were the dependent variable in the contingency tables (Educational Track - Gender: Cramér's  $v = .03$  and  $.04$ , respectively; Educational Track - Grade:  $v = .13$  and  $.14$ ; Gender - Grade:  $\phi = .11$  and  $.04$ ). As in Study 1, all values fall far below the cut-off points for a medium association ( $.30$  for a  $2 \times 2$  table,  $.21$  for a  $2 \times 3$  table) and several come close to or fall below the cut-

offs for a small association: .10 and .07, respectively; Kim, 2017). The collinearity between the social variables is too small to be worrisome.<sup>17</sup>

### *Homophones' distribution in corpus versus other text types.*

The distribution of the <d> spelling and <t> spelling as a function of the verbs' dominance type was the same as in other text types, i.e., on average, the dominance type of the verbs in the corpus corresponded with the distribution of their homophones in subtitles of movies and television programs, which have been shown to be a highly reliable estimate of word frequency (Keuleers et al., 2010). A chi-square analysis of the contingency table representing the occurrence frequencies of the teenagers' homophones as a function of Dominance Type and Correct Ending revealed a significant interaction with a strong effect size ( $\Phi = .51$ , <t> dominant: 693 <t> spellings, i.e., 79.84%, of these verbs' homophones; <d> dominant: 1,158 <d> spellings, 73.62%). This pattern was even stronger when only considering the teenagers' correct spellings, which constituted about three-quarters of the dataset ( $n = 1,741$ , 71.32%;  $\Phi = .59$ , <t> dominant: 497 <t> spellings, 81.88%; <d> dominant: 896 <d> spellings, 79.01%).

### *Adolescents' reliance on spelling rules.*

Did the adolescents rely on the morphographic spelling rules? We used one-sample  $z$ -tests to compare the mean error rates in all groups defined by the orthogonal

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<sup>17</sup> We followed the same procedure as in Study 1 to calculate the GVIF values in order to measure the degree of collinearity between the social and (psycho)linguistic predictors. The generalized VIF test indicated that multicollinearity was no cause for concern, as all squared generalized VIF scores were smaller than 1.12.



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combination of Gender, Educational Track, and Grade to a population mean of .50, i.e., random guessing. When the <t> spelling was correct, all GE and TE groups performed significantly better than chance (mean error rates: 16%-38%; all  $p$ s < .0005), whereas all subgroups in PE performed at chance level<sup>18</sup>. When the <d> spelling was correct, all groups performed better than chance level (mean error rates: 12%-32%), with the exception of the boys in Grade 2 of the PE group ( $p = .50$ ). These exploratory analyses suggest that the GE and TE teenagers relied on the spelling rules in a sizeable proportion of cases, whereas the PE teenagers did so to a much lesser extent and seemed to have a <d> bias.

### *Results and Discussion*

Considering the parallelism between Study 1 and Study 2, we will present and discuss the results of the <t>/<d> homophones in a single section.

Table 3 is the output of the final statistical model<sup>19</sup>. The intercept is the estimate for male teenagers in the 2<sup>nd</sup> grade of the GE group, more particularly, for the <d> spelling of <d> dominant verbs. The same remarks that were made with respect to Table 2 apply here.

INSERT TABLE 3 ABOUT HERE

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<sup>18</sup> Two  $p$ -values were smaller than .05 (.047 and .015) but did not reach significance after the application of Benjamini and Hochberg's procedure for coping with the issue of False Discovery Rate.

<sup>19</sup> Both random factors (Lemma and Chatter) were kept after likelihood ratio tests and were thus included in the final model. The corresponding standard deviations are: 0.32 (Lemma) and 0.65 (Chatter).

*Spelling accuracy.*

Overall, 700 homophones were intrusions of the homophonic spelling (28.68%). As was the case for the verb type in Study 1, this error rate is very high in the light of the clear-cut spelling rules (morphographic spelling: stem + *-t* or *-d*). More errors were made on the <t> spelling (373 errors on 1,108 forms, 33.66%) than on the <d> spelling (327 errors on 1,333 forms, 24.53%). This is a surprising finding, as the <t> spelling coincides with these homophones' phonetic spelling.

A possible explanation is related to distributional phenomena in this verb set, as evidenced by a lexical-statistical analysis. Most verbs that belong to the verb type in Study 2 have one of three prefixes (*be-*, *ge-*, and *ver-*). In the set of verbs with the prefix *ge-* or *ver-*, there is a strong predictive relationship between the prefix and the suffix: 85.3% of all verb homophones with the prefix *be-* in SUBTLEX-NL ( $n = 2,610$ ) end in the suffix *-d*, whereas this same association obtains in 76.42% of the *ver-* homophones ( $n = 1,275$ ). Moreover, 27 of the 37 verbs (72.97%) with the prefix *be-* are <d> dominant, whereas this is the case for 145 of the 209 verbs with the prefix *ver-* (69.38%). Even though homophone dominance manifests itself at the level of the individual verb, the fact that many verbs with the prefixes *be-* and *ver-* form a cluster in the <d> dominant set is likely to strengthen the association between these prefixes and the suffix *-d* that exists at the token level. The prefix *be-* is more balanced on these counts: its token frequencies of both spelling forms are about equal (506 <d> spellings, 45.34%) and 86 of the 138 verbs with this prefix are <d> dominant (62.32%). Importantly, our chat corpus contains 2,340 homophones with one of these three prefixes (*be-*: 945, *ge-*: 506, *ver-*: 889), i.e., these prefixed verbs represent 95.86% of all

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data for the <t>/<d> homophones in our corpus. From a type frequency perspective, the picture is the same (*be-*: 85, *ge-*: 10, *ver-*: 129), i.e., 224 of the 276 verbs with <t>/<d> homophones in the corpus contain one of these prefixes (81.16%). When only focusing on *ge-* and *ver-* (as these prefixes are more likely to reliably predict the <d> spelling than the prefix *be-*), many tokens and types in our corpus would still trigger the <d> form, solely on the basis of their prefix (tokens: 57.15%, types: 50.36%). The token frequency is likely to be the major determinant of the prefix-suffix associations (exposure frequency), together with the fact that all three prefixes are more likely to belong to the set of <d> dominant verbs. Hence, it seems plausible that these distributional facts explain why considerably less errors were made on the <d> spelling. However, as this effect interacted with other factors, it will be further discussed below.

### *Social variables.*

Educational Track had a significant effect and did not interact with any other variable. The GE group (intercept) made significantly fewer errors than chance performance ( $z = -6.93, p < .0001$ ). Significantly more errors were made in both the TE and PE groups ( $z = 4.40, p < .0001$  and  $z = 4.70, p < .0001$ , respectively), which did not differ from each other ( $z < 1$ ). The corresponding error percentages were: 18.91% (GE), 31.87% (TE), and 36.52 % (PE).

Gender interacted with the factor Correct Ending ( $z = 3.38, p = .001$ ) but with no other variables. The effect of Gender was significant for the <d> spelling ( $z = -2.54, p = .01$ ), but not for the <t> spelling ( $z = 1.66, p = .10$ ). Girls made significantly fewer errors on the <d> spelling than their male peers (22.54% vs. 28.88%) but did not perform systematically worse on the <t> spelling, despite a tendency in the mean error

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rates (36.21% vs. 29.37%). Since Correct Ending also participates in a third-order interaction with Dominance Type and Grade, the model's estimates are not reliable. Hence, contrasts were applied on the estimated marginal means for the Gender x Correct Ending interaction. The effect of Correct Ending was not significant for boys, whose error rates were virtually identical for both spellings ( $z = -1.11, p = .64$ ), but was highly significant for girls, who made about 14% fewer errors on the <d> spelling ( $z = 3.60, p = .001$ ).

Whereas boys ran the same error risk on the <t> spelling and the <d> spelling, girls' better performance on <d> spellings than on <t> spellings suggests a preference for the <d> form. A possible account is that the distributional facts concerning the strong association between the prefixes and the <d> spelling triggered many errors on the <t> spelling of girls (36.21% vs. 29.37% for their male peers) but also more correct spellings of the <d> spelling (22.54% vs. 28.88%), because they might be more sensitive to that association. This does not imply that the statistical learning of these prefix-suffix associations did not occur in male chatters; it only suggests that these boys rely less on this information, at any rate in informal situations like a chat context.

Although this lexical-statistic error source does not overrule the effect of Homophone Dominance (see below), it is likely to be an extra trigger for spelling errors (comparable to the <d> bias that is created by the high frequency of the stem in verbs whose stem ends in a /d/).

The effect of Grade was involved in an interaction with the effect of Homophone Dominance (third-order interaction) – it will be discussed below. None of the interactions among the social factors was significant.

### *Homophone Dominance and its interaction with the social variables*

As the verbs with a stem-final /d/ in Study 1, these verbs also revealed an effect of Homophone Dominance, i.e., the relationship between errors on the <d> spelling and <t> spelling was dependent on which spelling was the higher-frequency one. This finding strengthens our conclusion from the first study that homophone intrusions produced by teenagers mimic the nature of the intrusion errors in other writing contexts, as previously assessed in experiments. As the effect interacted with a social variable, it will be discussed below.

The effect of Homophone Dominance was significant in the model with Grade 2 as intercept ( $z = -2.99$ ,  $p = .003$ ). Adolescents (across educational tracks and genders) produced considerably more homophone intrusions on the lower-frequency <t> spelling of <d> dominant words than on the higher-frequency <d> spelling (89 on 207 tokens, 43%, vs. 157 on 591 tokens, 26.57%) but made no more errors on the lower-frequency <d> spelling of the <t> dominant verbs (30 intrusions on 96 forms, 31.25%, vs. 109 errors on 361 tokens on the <t> spelling, 30.19%).

The effect of Homophone Dominance did not interact with either Educational Track or Gender, but did interact with Grade ( $z = -2.35$ ,  $p = .02$ ). Figure 2 shows this interaction effect. As in Figure 1, proportions are plotted that are derived by back-transforming the logit values for the estimated marginal means.<sup>20</sup> This effect was not only significant in Grade 2, but also in Grade 3 ( $z = -6.09$ ,  $p < .0001$ ). However, in contrast to what was the case in Grade 2, teenagers from Grade 3 made significantly more intrusions on the lower-frequency spelling of both <d> dominant and <t> dominant verbs (<d> dominant: 88 on 208 <t> spellings, 42.31%, vs. 105 on 567 <d>

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<sup>20</sup> The plots based on these proportions barely differ from those based on the raw data.

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spellings, 18.52%; <t> dominant: 35 on 79 <d> spellings, 44.30%, vs. 87 on 332 <t> spellings, 26.20%). As in Study 1, we will analyze this third-order interaction by inspecting the spelling and dominance effects.

INSERT FIGURE 2 ABOUT HERE

### *(a) The spelling effect*

The effect of Correct Ending in Grade 2, as revealed by contrasts on the estimated marginal means of this interaction, was significant in <d> dominant verbs ( $z = 3.42, p = .007$ ) but not in the set of <t> dominant verbs ( $z = -1.24, p = .86$ ). The same contrasts in Grade 3 revealed a significant effect of Correct Ending for both <d> dominant and <t> dominant verbs ( $z = 6.23, p = .0001$  and  $z = -3.15, p = .02$ , respectively).

### *(b) The dominance effect*

As the change in the effect of Homophone Dominance concerned a rise in the error risk on the <d> spelling of <t> dominant verbs, the dominance effect interacted with Grade for the <d> spelling ( $z = 2.45, p = .01$ ) but not for the <t> spelling ( $z < 1$ ). The dominance effect in Grade 2 was non-significant for the <d> spelling ( $z = 1.08, p = .28$ ) but highly significant in Grade 3 ( $z = 4.04, p < .0001$ ). In Grade 2 (no interaction with Grade), it was significant for the <t> spelling, with a higher error risk for the <d> dominant verbs ( $z = -2.79, p = .005$ ).

Finally, there was an interaction between Grade and Correct Ending ( $z = 2.08, p = .04$ ).

In Grade 3, significantly fewer errors were made on the <d> spelling ( $z = -2.86, p = .004$ ) but no effect was found for the <t> spelling ( $z < 1$ ).

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In Study 1 the interaction between Educational Track and Homophone Dominance was hard to understand in terms of the account of the interaction between limited attentional resources in working memory and the frequency ‘pressure’ from the mental lexicon. An in-depth analysis of the data revealed that the interaction was an artefact of a single verb and, on closer inspection, was even in line with the account of Homophone Dominance. According to the same rationale, it is difficult to account for the third-order interaction between Grade, Correct Ending, and Dominance Type. We followed the same procedure as in Study 1 and split the data into separate subsets, based on the contribution frequency of verbs and chatters. Although the imbalance in this dataset was not as large as in Study 1, it could not be ignored. Only seven of the 133 verbs accounted for 63.35% of the data (1,546 tokens). Each of these seven verbs occurred more than 100 times in the corpus. On the other hand, 187 verbs occurred only 5 times or less. In the set of chatters, 62 of the 490 together provided 1,269 tokens, i.e., 51.97% of all data (each producing at least 10 homophones), whereas the remaining 428 chatters provided the remaining half of the dataset.

We split the data into two halves, based on the median of either chatters’ or verbs’ cumulative frequencies. The above-median group for verbs (median frequency = 131) contained only four verbs, together accounting for 48% of the data. The above-median group of chatters (median frequency = 10) consisted of 56 (of the 490) chatters and provided 49.51% of the data. Other subsets, as in Study 1, were not necessary, as the imbalance in the data was (somewhat) less outspoken. The interaction between Grade and Homophone Dominance persisted in the group of below-median chatters ( $p = .02$ , a relatively high value considering the multiple comparisons) and in the group of above-median verbs (where it was very high:  $p = .007$ ). It disappeared in the groups of above-

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median chatters and below-median verbs. In the four combinations of above-median and below-median chatters and verbs, the interaction disappeared everywhere, except in the group of above-median chatters and above-median verbs. We emphasize that the effect of Homophone Dominance itself never disappeared.

Hence, in this study, too, the third-order interaction seems to be carried by the set of four verbs with high occurrence frequencies in the corpus. A closer inspection of these verbs revealed that it was carried by only one of these verbs. It turns out that this set contains only one <t> dominant verb (*bedoelen*, ‘to intend’). Recall that the difference between the effect of Homophone Dominance in Grades 2 and 3 was due to the absence of more intrusions on the lower-frequency <d> spelling of <t> dominant verbs in Grade 2 and the emergence of this effect in Grade 3. It appears that this change was caused by one verb (*bedoelen*), as the removal of this verb resulted in the disappearance of the interaction between Grade and Homophone Dominance in the analysis of the remaining entire dataset, i.e., the best fitting model was no longer one that included the third-order interaction. All other effects remained significant. Noteworthy are the large effect of Homophone Dominance ( $z = -4.99, p < .0001$ ) and the interaction between Grade and Correct Ending ( $z = 2.16, p = .03$ ). For the <d> spelling, there was a considerable reduction in error rates in Grade 3, i.e., fewer <t> intrusions (which is the phonetic spelling,  $z = -2.66, p = .008$ ; Grade 2: 26.27%, Grade 3: 20.10%), whereas the number of <d> intrusions did not change significantly ( $z < 1$ ; Grade 2: 33.56%, Grade 3: 33.74%). The <t> spelling clearly remained a difficult, albeit phonetically spelled, form. Note that this supports the above account in terms of a strong associative strength between the prefixes and the <d> spelling for these homophones.



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It turns out that the verb *bedoelen* contributed 358 homophones of the 868 tokens in the set of <t> dominant verbs (41.24%). Moreover, 94 of the 175 lower-frequency <d> homophones in this verb set were provided by this verb (53.71%). The verb weighed heavily on the intrusion errors of the critical <d> spelling in the third-order interaction. It is unclear why this particular verb should behave atypically, and we can only speculate about it. Even though this prefix does not reliably predict a <d> ending (<t> dominant), the fact that the majority of verbs with the prefix *be-* belong to the set of <d> dominant verbs may have ‘protected’ the lower-frequency <d> spelling against intrusions of the <t> dominant homophone, until this homophone is encountered so often that it eventually overrides this bias. At the methodological level, we are warned again, as in Study 1, that datasets that are collected in non-experimental situations, even though they represent naturalistic situations, should be analyzed and interpreted with caution because they run the danger of being (strongly) unbalanced. This may lead to conclusions that are unwarranted by the data.

### Conclusions

In this study, we analyzed spelling errors on verb homophones in informal online conversations produced by Flemish adolescent boys and girls of different ages and from different educational tracks. The major motivation for this merger of social and psycholinguistic variables was to test Sandra and coworkers’ psycholinguistic account of these persistent spelling errors on *fully regular* verb homophones in Dutch.

*The impact of the social variables on the error rates.*

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With respect to the sociolinguistic dimension of this study, we found that each of our social variables affected the error rates on (descriptively simple) verb homophones: In line with many sociolinguistic studies, women were found to behave more norm sensitive which, apart from one exception (<t> spelling for <t>/<d> homophones), tended to result in lower error rates. Furthermore, as we predicted, students in the theory oriented educational track generally produced fewer errors than students in the more technical and practice-oriented tracks, who did not differ from each other. Finally, older adolescents (Grade 3) had lower error rates than younger adolescents (Grade 2) for both spellings of the <d>/<dt> homophones and for the (non-phonetic) <d> spelling of <t>/<d> homophones. There were no significant interactions between the social variables.

### *The impact of the social variables on the error pattern (homophone dominance).*

As for the psycholinguistic dimension, we had two questions in mind. First, we wanted to find out whether the experimental results generalized to an informal naturalistic writing situation. Second, we wanted to test a prediction that follows directly from the account that Sandra and coworkers have given in several papers (see above). If their model is correct, any factor that affects the error rates should not affect the error pattern, i.e., the effect of homophone dominance itself. Chat conversations offer an ideal context for studying the interaction between social and psycholinguistic factors.

The first of these two issues received an affirmative answer: the effect of Homophone Dominance, which had been demonstrated in speeded dictation tasks in several studies by Sandra and co-workers, also occurred in Study 1 and Study 2, with two different types of homophone contrasts. Having replicated this effect with different

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verb types in a corpus of chat data, makes us confident that the account of homophone dominance, as an interaction between limited working memory resources and the frequency pressure from the mental lexicon, offers a good model for real-life writing situations as well. Our findings make sense: teenagers want to write fast and, hence, often run into working memory limitations, which is the trigger for intrusions from the higher-frequency homophone. In addition, the highly informal context in which the online messages were produced increases the chance that adolescents display a certain carelessness with regard to spelling(rules). Consequently, they might even switch off their working memory from time to time and not apply the spelling rules at all, resulting in homophone intrusions. This replicates the recent findings by Schmitz et al. (2018) in their analysis of Twitter data. Even though chatters arguably write under more time-pressure and in a more informal context than tweeters, both sets of findings pertain to CMC contexts, and demonstrate that the effect of homophone dominance exists ‘outside the lab’.

It is imperative to examine whether effects observed in artificial, experimental contexts also occur in natural writing situations. As a matter of fact, this was one of the main objectives of the present study (see also Pacton, Perruchet, Fayol, and Cleeremans, 2001, who demonstrated that children’s implicit learning of statistical tendencies in spelling, i.e., recurring spelling patterns that generalize across individual words, also occurs outside the lab). Still, the similarity between the two types of evidence does not come as a total surprise. If spelling errors on verb homophones are indeed the result of an interplay between working memory limitations and the automated process of retrieval from the mental lexicon, as argued in experimental papers, it would be very odd if these two cognitive processes did not interact during spontaneous writing. Yet, in

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various fields of psycholinguistic research it has been shown that generalizations from experimental research can be risky. Participants often develop response strategies to optimize their performance in experimental tasks. Moreover, they tend to be influenced by the types of stimuli (and their proportions) in the experiment. This was the case, for example, in research on the mental processes that are involved in associative and repetition priming, resulting each time in a significant change in the explanatory models (Bodner & Masson, 1997; Forster & Davis, 1984; Neely, 1977; Neely, Keefe, & Ross, 1989). However, since the results in our study validate the explanatory model from psycholinguistic experiments, we can conclude that the potential contamination by such factors in the earlier experiments did not lead to a model that gives a wrong representation of what happens in spontaneous spelling situations. The context of speeded dictation tasks might have put the attentional process in working memory under extremely high pressure, but the convergence between the experimental results and our current findings indicates that this technique served as a magnifying glass for bringing the two cognitive processes behind the errors to the fore: a conscious computational process in working memory and an automatic process for the retrieval of orthographic representations from the mental lexicon.

Our second psycholinguistic question, i.e., whether a testable prediction of the model that accounts for these persistent errors fits the observations, also led to an affirmative answer. This test concerned the issue whether three social factors affected the error pattern (the Homophone Dominance effect), thus merging the sociolinguistic and psycholinguistic dimensions of the study. In both studies we found an interaction between the effect of Homophone Dominance and one social factor (Educational Track in Study 1, Grade in Study 2), which is not predicted by the account of the Homophone

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Dominance effect: social factors (like many other factors) could increase error rates but should not affect the interplay between the unconscious operation of mental processes. However, in both cases, it turned out that the interaction was a spurious one, caused by the presence of a single verb with a high frequency in the corpus. Hence, there is no reason to revise the account of Homophone Dominance, all the more because the verb's 'deviant' behavior can be understood within this conceptual framework (e.g., the omnipresence of the verb *vinden*, 'to find', in Study 1 in its higher-frequency <d> spelling). However, the fact that we ran into this problem twice gives us an important take-home message: the present studies act as a methodological warning that one should take extra caution when analyzing dataset like these. On the one hand, they have the advantage of representing more naturalistic behavior but, on the other hand, this advantage can be offset by the disadvantage of an uneven distribution of the data across items and/or participants. An in-depth inspection of the data is needed to guard oneself against premature conclusions.

In other words, our two corpus studies support the conclusion that the social factors impact error frequency but do not affect the error patterns. Our results show that all social groups fall prey to the same type of homophone intrusions when the mental lexicon takes over from working memory, thus confirming the model of Sandra and colleagues on the cognitive processes underpinning the persistence of these errors (1999, see also Sandra, 2010; Sandra & Van Abbenyen, 2009). Only the computational process in working memory can be brought under conscious control, which means that a greater concern for spelling (rules) can reduce the number of errors but not the automatic process that retrieves orthographic representations from the mental lexicon.

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The result is that no one escapes intrusions of the higher-frequency spelling when one fails to apply the spelling rule in working memory.

*Two morphographic principles but only one spelling problem.*

Finally, in the context of a study on the application of a morphographic spelling principle, it is important to observe that the adolescents in both studies had no preference for a phonetic spelling of these verb homophones, especially in the context of the chat medium. In Study 1, there were only 14 such spellings on 5,804 homophones (e.g., *wort*, ‘become’). Considering the difficulties with the morphographic principle in regular verb homophones, this is surprising, at least at first sight. However, upon closer inspection, it is not. Stem consistency across inflectional variants is a common phenomenon in Dutch, across lexical categories (noun, adjective, verb). Accordingly, this part of the morphographic spelling of Dutch verb forms has become an automatic process in spelling, even though a final /d/ is pronounced as [t]. In Study 2, most errors were made on the <t> spelling, even though it matches the form’s phonetic spelling. Note that this match is coincidental, as the <t> spelling reflects as much a morphographic spelling principle (at the suffix level) as the <d> spelling (e.g., *hij vindt* ~ *hij werkt*, ‘he finds’ - ‘he works’). Neither boys nor girls had a preference for this form. Whereas the former made no more errors on the <d> spelling, the latter even preferred this non-phonetic form. Moreover, the Grade effect (after removal of *bedoelen*) was almost absent for the <t> spelling, but outspoken for the ‘non-phonetic’ <d> spelling. We suggest that the associative strength between the prefixes and the <d> spelling of the suffix is implicitly learned and is a stronger factor than the potential tendency to use the (phonetic) <t> spelling. The role of such a second error source, in

addition to the effect of Homophone Dominance, was also found in Study 1, where the recurrence of the stem across all regular verb forms in the inflectional paradigm is likely to have boosted the frequency of the <d> spelling. These findings underscore spellers' sensitivity to various kinds of frequency information in written language data. Note that the virtual absence of phonetic spellings in Study 1 also emphasizes the possibility that a morphographic spelling principle can be turned into an automatic process, provided that it occurs sufficiently often across word forms.

Still, the persistence of verb homophone intrusions shows that one aspect of the morphographic spelling of Dutch verb forms, i.e., analogy at the suffix level (e.g., *zij wordt*, 'she becomes', because *zij werkt*, 'she works'), fails to become an automatic process, a problem that already baffled linguists around the middle of the previous century (van der Velde, 1956). In light of the previous paragraph, we re-emphasize (as in earlier work) that the persistence of errors on verb homophones is not only due to working memory limitations. It also derives from the fact that these homophones so seldom occur (in less than 5% for the verbs in Study 1). Hence, writers cannot turn this morphological principle into a computational process that is automatically performed, i.e., without (or with much less) working memory involvement.

Our studies add to the idea that the systematic study of errors, across a variety of research methods (experimentation, corpus research), can lead to a comprehensive picture of how the mind deals with particular aspects of language.

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Acknowledgement

We thank the two anonymous reviewers for their helpful and constructive feedback on the previous version of this paper. The research reported here was supported by grant G023118N from the Research Foundation – Flanders (FWO).

Appendix

Table 1

*Distribution data over Gender, Educational Track and Age.*

<b>Variable</b>	<b>Variable levels</b>	<b>Participants</b>	<b>Posts</b>	<b>Tokens</b>	<b>Target forms</b>
<b>Gender</b>	<b>Boys</b>	631 (48.99%)	140,249 (34.76%)	774,530 (32.82%)	2,440 (29.59%)
	<b>Girls</b>	657 (51.01%)	263,242 (65.24%)	1,585,587 (67.18%)	5,805 (70.41%)
<b>Educational Track</b>	<b>General</b>	559 (43.40%)	115,900 (28.72%)	711,076 (30.13%)	2,737 (33.20%)
	<b>Technical</b>	370 (28.73%)	185,546 (45.99%)	1,090,580 (46.21%)	3,822 (46.36%)
	<b>Professional</b>	359 (27.87%)	102,045 (25.29%)	558,461 (23.66%)	1,686 (20.45%)
	<b>Education (GE)</b>				
	<b>Education (TE)</b>				
<b>Age</b>	<b>Younger adolescents (Grade 2: 15-16)</b>	978 <sup>21</sup> (52.16%)	213,761 (52.98%)	1,189,661 (50.41%)	4,106 (49.80%)

<sup>21</sup> Note that the sum of the number of the younger and older participants does not correspond to the total number of participants. That is because the same participants can occur several times (at different ages) in the corpus if they submitted both recent messages and older ones.



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<b>Older</b>	897	189,730	1,170,456	4,139
<b>adolescents</b>	(47.84%)	(47.02%)	(49.59%)	(50.20%)
<b>(Grade 3: 17-20)</b>				

*Note.* The column Target Forms refers to the number of homophones provided by the different groups (summed over two verb types, see below). All educational tracks refer to secondary education. The two age categories refer to the classification used in Flemish secondary education.

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Table 2

*Final model for the <d>/<dt> homophones*

<b>Effect</b>	<b>FM</b>	<b>Estimate</b>	<b>SE</b>	<b>z</b>	<b>p</b>	
Intercept: GE – Male – Grade 2 – <d>						
dominant – <d> spelling	x	-3.581	0.405	-8.834	0.000	*****
TE (vs. GE)	x	1.157	0.347	3.334	0.001	***
PE (vs. GE)	x	1.523	0.383	3.973	0.000	***
PE (vs. TE)		0.366	0.302	1.212	0.226	
Female (vs. Male)	x	-0.551	0.155	-3.550	0.000	***
Grade 3 (vs. Grade 2)	x	-0.393	0.120	-3.271	0.001	**
Spelling effect <d> dominant: GE	x	4.857	0.323	15.041	0.000	*****
Spelling effect <d> dominant: GE x TE	x	-0.053	0.369	-0.144	0.886	
Spelling effect <d> dominant: GE x PE	x	-0.028	0.435	-0.063	0.950	
Spelling effect <dt> dominant: GE		-0.724	0.283	-2.560	0.011°	
Spelling effect <dt> dominant: GE x TE		1.738	0.360	4.831	0.000	*****
Spelling effect <dt> dominant: GE x PE		2.443	0.409	5.969	0.000	*****
Spelling effect <dt> dominant: TE x PE		0.705	0.368	1.916	0.055	
Spelling effect <dt> dominant: TE		1.014	0.223	4.550	0.000	*****
Dominance effect on <d> spelling: GE	x	3.540	0.547	6.472	0.000	*****
Dominance effect on <d> spelling: GE x TE	x	-1.552	0.449	-3.454	0.001	***
Dominance effect on <d> spelling: GE x PE	x	-1.773	0.507	-3.500	0.001	***
Dominance effect on <d> spelling: TE		1.988	0.476	4.180	0.000	*****
Dominance effect on <d> spelling: TE x PE		-0.221	0.423	-0.523	0.601	

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Dominance effect on <dt> spelling: GE		-2.040	0.438	-4.653	0.000	****
Dominance effect on <dt> spelling: GE x TE		0.239	0.253	0.944	0.345	
Dominance effect on <dt> spelling: GE x PE		0.698	0.318	2.193	0.028°	
Dominance effect on <dt> spelling: TE x PE		0.459	0.287	1.597	0.110	
Homophone Dominance: GE	x	-5.580	0.437	-12.763	0.000	****
Homophone Dominance: TE		-3.789	0.295	-12.850	0.000	****
Homophone Dominance: PE		-3.109	0.419	-7.417	0.000	****
Homophone Dominance x TE (vs. GE)	x	1.791	0.519	3.452	0.001	***
Homophone Dominance x PE (vs. GE)	x	2.471	0.600	4.117	0.000	****
Homophone Dominance x PE (vs. TE)		0.680	0.509	1.335	0.182	

*Note.* All effects marked with an ‘x’ in column FM (Final Model) are the output of the model with the conditions included in the intercept. The others were obtained by releveling the intercept (see text). The effects are clustered. Benjamini and Hochberg's (1995) formula was applied to these contrasts to control the False Discovery Rate (non-significant values marked with °). Homophone Dominance refers to the interaction between Dominance Type and Correct Ending.

\*\*\*\*  $p < .0001$  \*\*\*  $p < .001$  \*\*  $p < .01$  \*  $p < .05$

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Table 3

*Final model for the <t>/<d> homophones*

<b>Effect</b>	<b>FM</b>	<b>Estimate</b>	<b>SE</b>	<b>z</b>	<b>p</b>	
Intercept: GE – Male – Grade 2 – <d>						
dominant – <d> spelling	x	-1.459	0.211	-6.929	0.000	****
TE (vs. GE)	x	0.681	0.155	4.401	0.000	****
PE (vs. GE)	x	0.813	0.173	4.697	0.000	****
PE (vs. TE)		0.132	0.162	0.811	0.417	
Gender x Correct Ending	x	0.716	0.212	3.376	0.001	***
Gender (for <d> spelling)	x	-0.431	0.170	-2.535	0.011	*
Gender (for <t> spelling)		0.284	0.171	1.660	0.097	
Correct Ending	x	0.301	0.237	1.273	0.203	
Correct Ending: Male (EMMs)		-0.206	0.186	-1.105	0.641	
Correct Ending: Female (EMMs)		0.510	0.142	3.601	0.001	**
Grade x Correct Ending	x	0.561	0.270	2.079	0.038	*
Grade (for <d> spelling)	x	-0.477	0.167	-2.857	0.004	**
Grade (for <t> spelling)		0.085	0.232	0.364	0.716	
Dominance x Grade (for <d> spelling)	x	0.940	0.384	2.445	0.014	*
Dominance in Grade 2 (for <d>						
spelling)	x	0.326	0.301	1.082	0.279	
Dominance in Grade 3 (for <d>						
spelling)		1.266	0.313	4.043	0.000	****
Dominance x Grade (for <t> spelling)		-0.188	0.290	-0.649	0.516	

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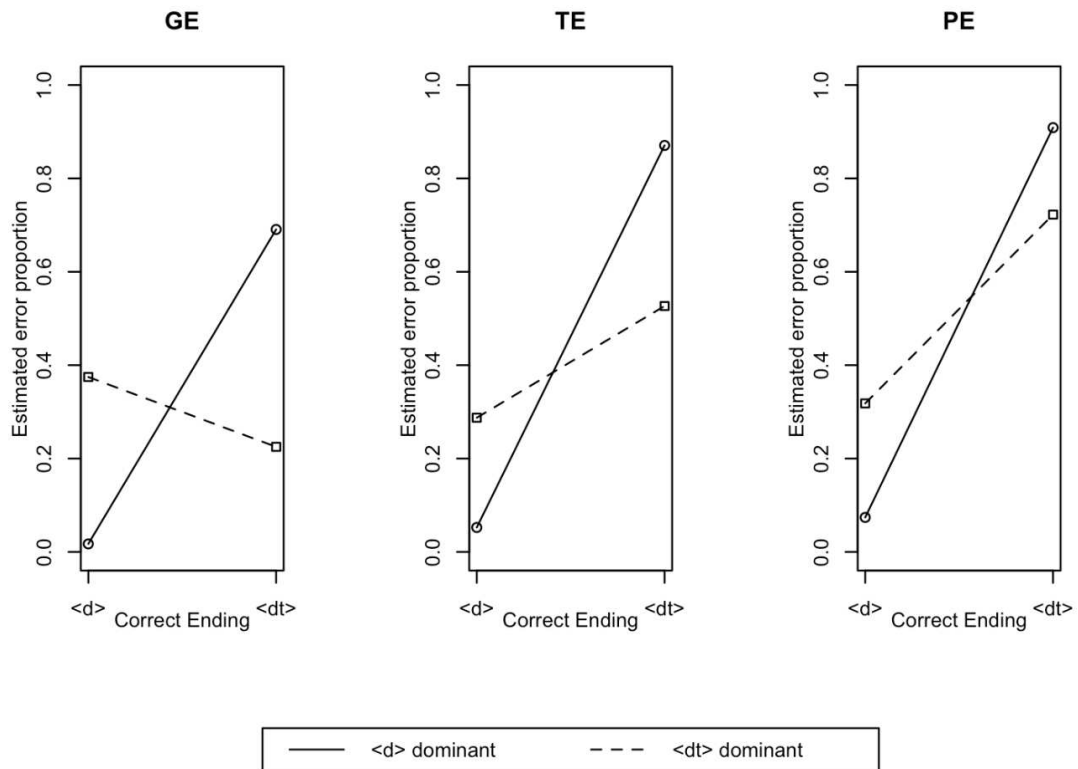
Dominance in Grade 2 (for <t>						
spelling)		-0.686	0.246	-2.791	0.005	**
<hr/>						
Spelling effect in Grade 2, <d>						
dominant (EMMs)		0.659	0.193	3.417	0.007	**
<hr/>						
Spelling effect in Grade 2, <t>						
dominant (EMMs)		-0.353	0.284	-1.243	0.859	
<hr/>						
Spelling effect in Grade 3, <d>						
dominant (EMMs)		1.221	0.196	6.230	0.000	****
<hr/>						
Spelling effect in Grade 3, <t>						
dominant (EMMs)		-0.919	0.292	-3.145	0.018	*
<hr/>						
Homophone Dominance (for Grade 2)	x	-1.012	0.339	-2.986	0.003	**
<hr/>						
Homophone Dominance (for Grade 3)		-2.140	0.352	-6.087	0.000	****
<hr/>						
Homophone Dominance x Grade	x	-1.128	0.481	-2.346	0.019	*
<hr/>						

*Note.* All effects marked with an ‘x’ in column FM (Final Model) are the output of the model with the conditions included in the intercept. The others were obtained by releveling the intercept (see text). The effects are clustered. Benjamini and Hochberg's (1995) formula was applied to these contrasts to control the False Discovery Rate. EMM's were used for some contrasts because the spelling effect is involved in two interaction (causing incorrect model estimates). Homophone Dominance refers to the interaction between Dominance Type and Correct Ending.

\*\*\*\*  $p < .0001$  \*\*\*  $p < .001$  \*\*  $p < .01$  \*  $p < .05$

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Figure 1. Estimated error percentages for the GE, TE, and PE groups, as a function of Dominance Type and Correct Ending



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Figure 2. Estimated error percentages for Grade 2 and Grade 3, as a function of Dominance Type and Correct Ending

