Still errors after all those years …

Limited attentional resources and homophone frequency account for spelling errors on silent verb suffixes in Dutch

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We review some of our research findings on verb spelling errors in Dutch. The spelling of Dutch regularly inflected verb forms is governed by rules of the simple concatenative type (stem + suffix). The spelling of a subset of these verb forms is determined by morpheme-based analogy, both at the level of the stem-final letter and at the level of the inaudible (i.e., silent) suffix. This subset of verb forms causes many spelling problems, both in the learning stage and in the spelling process of experienced spellers. Our research identifies two sources of these errors. First, the error risk results from the time-consuming nature of the cognitive operations needed for spelling the silent suffix. Second, the errors follow a particular pattern: the typical error is a homophonic verb spelling form which has a higher frequency of occurrence in the Dutch written language than the target form. This homophone frequency effect shows that regularly inflected verb forms with silent suffixes have their own orthographic representation in the mental lexicon, even though they are fully predictable by rule.

1. Introduction

There is an enormous literature on the involvement of morphology in the process of visual word recognition, i.e. word reading. Ever since the pioneering work by Taft and Forster in the mid-seventies (Taft & Forster, 1975, 1976), many psycholinguists have designed experiments to find out whether or not words consisting of several morphemes are recognised as wholes or are decomposed into their constituent morphemes as a precondition for lexical access.

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The productivity of this line of research is attested by the large diversity in the experimental techniques and in the diversity of manipulated factors, both linguistic and non-linguistic ones. Examples of linguistic factors are type of morphologically complex word (inflected word — e.g. Taft, 1979; Caramazza, Laudanna, & Romani, 1988–derivation — e.g., Bertram, Laine, & Karvinen, 1999; Bertram, Schreuder, & Baayen, 2000–compound — e.g., Sandra, 1990; Libben, 1994), type of affix (prefix versus suffix — e.g., Colé, Beauvillain, & Ségui, 1986), semantic transparency of the word (opaque versus transparent; e.g., Sandra, 1990; Marslen-Wilson, Tyler, Waksler, & Older, 1994; Zwitserlood, 1994). Examples of non-linguistic (usually quantitative) dimensions are the occurrence frequency of the whole word and the stem (e.g., Baayen, Dijkstra, & Schreuder, 1997; Taft, 1979), the ratio of words bearing a true prefix to words bearing a pseudoprefix (Laudanna, Burani, & Cermele, 1994), and the relative frequency of homonymous meanings of affixes (Bertram, Schreuder, & Baayen, 2000). Clearly, morphology in word reading has been a dominant theme in the psycholinguistic research of the past few decades.

In contrast, very little research has been done on the involvement of morphology in the process of writing, more particularly the process of word spelling (but see Fayol, Largy, & Lemaire, 1994; Largy, Fayol, & Lemaire, 1996). This is not really surprising, as the study of word spelling in general has been largely ignored in the psycholinguistic literature. This may be due to the fact that spelling is a much slower process than reading (or speaking, when a comparison is made with spoken language production) and, as a consequence, is more likely to mobilise conscious processes. Many psycholinguists are not really interested in the conscious processes involved in language processing and may even not want to do experiments in which such processes can occur, simply because these may mask their real focus of interest: the unconscious, automatised operations which make lexical processing possible. The above contrast between the reading and spelling of words has, of course, been simplified to a black-and-white picture. Word spelling also involves automatic components, and sometimes word reading may also involve conscious processing (e.g. when it turns out that one has segmented an unfamiliar word like BUSHEATER erroneously as BUSH/EATER, one may have to consciously restart the process and actively look for the contextually appropriate segmentation: BUS/HEATER; example taken from Libben, 1994).

The purpose of the present paper is to demonstrate that there are domains where the study of word spelling may be quite informative for psycholinguists who are interested in the mental lexicon. Regularly inflected verb forms in

Dutch represent one such domain. We will describe how we studied this domain and why the results of our experiments are informative for the study of the mental lexicon.

2. The morphological principle in Dutch spelling

The spelling of Dutch is governed by a small number of principles, two of which stand out as the constitutive rules of the spelling system. The most important principle stipulates that words are generally spelled the way they sound. Hence, the strategy "spell what you hear" works quite well in Dutch. For that reason, the language can be said to have a shallow orthography. Yet, this *phonogical principle* does not apply across the board. As a matter of fact, there are many words in which one or several letters do not reflect the application of the phonological principle. In many cases this letter reflects the operation of a different spelling principle, which is more abstract but descriptively equally clear-cut as the phonological one. This is the so-called *morphological principle*, which stipulates that a morpheme has the same spelling across the set of words in which it appears, even when the pronunciation of the morpheme is not entirely identical in these words. An example can make this clear. Consider the words PLANT (plant) and HAND (hand), which are pronounced as /plant/ and /hant/, respectively, i.e., with a final T-sound. Except for the final letter in the word HAND, all letters in both words result from the application of the phonological principle: each sound is mapped onto a letter in a one-to-one fashion. The last letter in HAND is D rather than T because a morphologically related form (the plural form HANDEN) has a D-sound. This same principle predicts that the last letter of PLANT must be a T because of the T-sound in the plural form PLANTEN. As the example illustrates, the morphologically "extended" form is considered to contain the underlying phoneme.

The above example demonstrates how the morphological principle governs the spelling of *word-final letters* in monomorphemic words. Analogy is based on words sharing the stem. Our research focused on the application of the morphological principle in a different region of the lexicon: the spelling of *verb suffixes*. Indeed, the same form of morphologically-based analogy accounts for the spelling of some verb suffixes. An example will make this clear. Consider the following written verions of 3rd person singular verb forms in the present tense: KOMT (comes) and WORDT (becomes). The former verb form is spelled the way it sounds because the suffix is clearly audible in the word's pronunciation:

KOMT is the concatenation of the stem KOM and the suffix T. In contrast, the verb form WORDT is not spelled the way it sounds (/wort/). As a matter of fact, in order to spell this verb form correctly, the morphological principle must be applied twice: at stem-final position and at suffix position. The letter D in the word-final letter cluster DT is the result of stem-based analogy with forms like WORDEN. The letter T is the result of suffix-based analogy: the suffix spelling is T, as in other 3rd person singular forms like KOMT. We will refer to suffixes whose pronunciation is not distinct from the pronunciation of the stem-final sound as *silent suffixes.*

3. Silent suffixes cause spelling problems

In our research we focused on the spelling of regularly inflected verb forms with silent suffixes. This was a deliberate choice. These verb forms lead to large numbers of spelling errors in Dutch. Children who have to learn the Dutch spelling system stumble over these spelling rules for years. Whereas this may only indicate that the rules are rather abstract and hence require an extended learning process, the same errors are also made quite often by highly educated adults. The error rates in the adult population are, of course, much smaller, but spelling errors on regularly inflected verb forms are extrememy persistent. They appear in texts of all kinds: papers of university students, newspapers and magazines, books, e-mails, websites. They even appear in texts which are generally well re-read, like grant applications by intelligent people. And professors who teach languages themselves sometimes contribute to the error corpus. The general attitude towards these errors is very negative. Whoever makes them is considered to be either not very smart or uncareful. Despite this, spellers make the errors.

We were intrigued by these errors because they confront us with a paradox. On the one hand, the rules for inflected verb forms are descriptively extremely simple (rules of the type "add suffix") and are few in number. On the other hand, these same simple rules cause errors in the writings of even experienced writers. How is this possible?

The rationale behind our research was the same as the one underlying the study of speech errors. By analysing error patterns one can discover systematic patterns in the data, which can be used to uncover factors that are important at the level of representation. Basically, there are two ways of studying errors. One is to study a database of errors that writers spontaneously produced, i.e. errors

in ordinary texts (students' writings, newspapers, etc.). The other is to devise a technique which is suited to elicit errors and then manipulate dimensions which are hypothesised to cause errors. Whereas we have been setting up a database of spontaneously occurring errors in all kinds of texts over the past two years, we will focus in the present paper on data which were collected by way of experimentation.

4. Rationale behind the experiments

In the experiments we focused on present tense forms in the 1st and 3rd person singular, i.e. forms like the examples in Section 2. When thinking about possible factors underlying spelling errors on these verb forms, two properties of these verbs stand out: (i) they have a *silent suffix* and (ii) they are *homophonic* with other verb forms in the same lexical paradigm. For instance, the present tense forms WORD (1st person singular) and WORDT (3rd person singular) have the same pronunciation but a different spelling. We hypothesised that silent suffixes increase the processing load and thus, given the limited resources during writing, *cause errors*. We further hypothesised that verb form homophony *determines the nature* of the errors (i.e., homophonic intrusions).

It seems plausible that silent suffixes will increase the *processing load* of verb forms relative to verb forms with an audible suffix. When there is a silent suffix the speller either has to make the analogy with a verb form with an audible suffix or has to retrieve and apply the appropriate spelling rule. This spelling rule is, of course, an abstract formulation of the information which can also be derived from analogy-based reasoning (e.g. "3rd person singular present tense takes the suffix T"). There is no other way to be certain that the verb form will be spelled correctly. Whatever process of these two is called upon, it will be time-consuming. If spellers have (or take) insufficient time to determine the spelling of the silent suffix, the error-risk will increase.

Besides the question which conditions are required for errors to occur, there is the question which form the errors will take. We were interested what we would be able to learn from this about the production system behind written language. Given the notion that the spelling of silent suffixes is time-consuming and thus leads to spelling errors, several possible error types suggest themselves. A first possibility is that spellers are conservative and only write down what they are certain of at a given point in time. When they have insufficient time to determine the spelling for the suffix they may decide to spell only the stem. This

would mean that the errors always look the same: the stem without a suffix. A second possibility is that spellers know that in the singular forms of the present tense there are only two possible suffixes: the zero suffix (1st person) and the T-suffix (2nd and 3rd person). When they have insufficient time to determine the spelling of the suffix, they may randomly choose between the possibilities of no overt suffix and the T-suffix. This would mean that two types of errors occur: the T-suffix is spelled instead of the zero suffix and vice versa. Moreover, both error types would be equiprobable and be distributed in the same way in all verbs with a stem-final D. A third possibility is that spellers indeed guess the suffix but not in a random way. Rather than randomly guessing the suffix, spellers may rely on a form of educated guessing. This is where the notion of *verb form homophony* comes in. However, homophony by itself does not lead to a different prediction than the notion of random suffix guessing. Indeed, the homophonous forms only differ in their suffix. However, the notion of homophony can be tied to the concept of *response probability* through the occurrence frequencies of the homophonous forms. Frequency of occurrence is an important factor in many linguistic and non-linguistics tasks. For instance, frequency effects have been widely attested in the word recognition literature. In many different kinds of experimental settings frequent words are recognised faster than infrequent words. Such frequency effects do not seem typical for the retrieval of linguistic representations. For instance, we recognise faces of familiar people faster than faces of unfamiliar people. Occurrence frequency seems to be a general property governing information retrieval from memory. This leads to the hypothesis that spellers who lack the time to spell a verb suffix correctly may rely on the frequencies of the homophonous forms in their mental lexicon and spell the most frequent form. Note that the concept of relative homophone frequency makes a different prediction than the idea of random guessing. It predicts different error patterns for different verbs: more errors on 1st person verb forms when the 3rd person form is more frequent, more errors on 3rd person verb forms when the 1st person form is more frequent. Note also that a homophone frequency effect would indicate that word forms which are fully predictable by rule are nevertheless represented in the mental lexicon, as the result of mere exposure to their written forms.

Hence, a priori three distinct types of spelling errors are theoretically possible: (i) errors on the overt suffix T only (strategy: only spell what you are certain of), (ii) random errors on zero and overt suffixes, or (iii) errors on zero and overt suffixes which are based on the frequency relationship between the associated homophones.

5. The experimental data

5.1 Adult data

The purpose of the experiment was to collect spelling data on verb forms with silent suffixes and find out which factors account for the spelling errors (Sandra, Frisson, & Daems, 1999). We will refer to 1st and 3rd person singular present tense forms as D-forms and DT-forms respectively: the D is the stem-final letter, whereas the T is the suffix. Three factors were orhogonally combined in the experimental design: Grammatical Person (1st and 3rd person singular), Homophone Frequency (frequency relationship between 1st and 3rd person homophones), and Subject-Verb Distance (adjacent-distant). Subject-verb distance was used as a design factor to find out whether errors result from a lack of sufficient *processing resources* (time needed to determine the suffix spelling). If verb errors result from lack of time to determine the suffix, we should observe more errors when the verb form is separated from its subject by several intervening words than when the verb form immediately follows. Homophone frequency was used to find out whether this factor shapes the *nature of the errors* in error-risk conditions. If the relationship between the homophone frequencies is involved, intrusion errors should occur more often in the 1st person than in the 3rd person when the 3rd person form has the highest occurrence frequency and vice versa.

We selected three sets of verbs with homophonous 1st and 3rd person singular present tense forms. The verbs were selected from the CELEX database for Dutch (Baayen, Piepenbrock, & Gulikers, 1995), which is based on a corpus of 42 million tokens. One set contained verbs whose D homophone was more frequent than its DT homophone (henceforth: D>DT). Another set contained verbs whose homophones were matched on frequency (henceforth: D=DT). A final set contained verbs whose D homophone was less frequent than its DT homophone (henceforth: D<DT). Each set contained eight verbs. It was not possible to select more items per set if we wanted to create a sizeable frequency contrast.

For each verb a sentence was made. Given the design factors Grammatical Person (first, third) and Subject-Verb Distance (adjacent, distant) we constructed four versions of each sentence. The latter factor can be manipulated in Dutch because the grammar imposes different orderings of subject, verb, and objects in the main clause and in the subclause. In main clauses the inflected verb form appears immediately after its subject (adjacent) whereas in subclauses the objects intervene (distant). Hence, each selected verb was presented with a 1st

and a 3rd person subject, each time in a main clause and in a subclause (four intervening words). In order to counterbalance the verbs across the four condions formed by these two factors, we used four lists and presented these to about the same number of participants. Participants were tested at their schools, during a class.

Given our assumption that errors on silent suffixes occur as the result of the time-consuming process which is needed to determine the suffix, we opted for a task which we thought would maximise the error risk: a speeded dictation task. The sentences which contained the verb forms were presented in a dictation task to several classes of 18-year olds (last year secondary school). The participants did not have to write down the entire sentence but were presented with printed forms on which the sentences appeared. Two words were removed from each sentence: a verb form and another word. The latter word was never a verb, but any other word which was difficult to spell. Even though these filler words would not be able to mask the presence of the verb forms, they would certainly make the task difficult and prevent the participants from focusing too much on the verbs. The sentences were read at a speed which was aimed to be sufficiently fast to make it difficult to determine the suffix spelling, but which was at the same time sufficiently slow to make the task not frustrating for the participants. The speed should also make it difficult for the participants to engage in a verification process of their responses. It can be assumed that many spelling errors which initially "slip through" are corrected in this verification stage. In contrast to speakers, which cannot conceal their speech errors (only repair them) spellers can conceal their errors by correcting them during verification. Hence, it was necessary to make it hard for spellers to use verification processes.

In all we collected about 200 observations per condition. Figure 1 below shows the main outcome of the experiment. As can be seen, the error pattern is determined by the frequency relationship between the two homophones of the verb. When the homophone ending in D is more frequent, more errors are made on the 3rd person than on the 1st person. When the homophone ending in DT is more frequent, more errors are made on the 1st person than on the 3rd one. This error pattern is the fingerprint of the homophone frequency effect: when spellers have insufficient time to determine the suffix (time-pressure in the experiment) they are likely to spell the most frequent homophone.

The idea that errors originate under circumstances of limited processing resources is supported by the observation of a significant effect of subject-verb distance, which is shown in Figure 2. As can be seen, many more errors are made when the verb is separated from the subject by a number of intervening

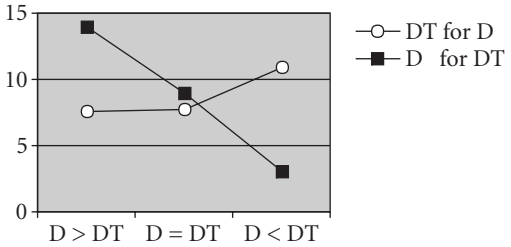

Figure 1. Percentage of homophone intrusion errors in 1st (open circles) and 3rd (black squares) person singular as a function of homophone frequencies

words than when the two are adjacent in the sentence. This distance effect can be explained in terms of the activation metaphor. The morphosyntactic information which is needed to determine the suffix spelling (e.g., 3rd person singular) is supposed to be activated upon reading the subject. As activation decays over time, this information will be less active when the verb is separated from its subject than when it immediately follows it. When spellers have only a limited amount of time to spell the verb form, they will be able to determine the suffix on a fewer number of occasions when subject and verb are separated. This will make the error risk higher. And since homophone frequency shapes the error pattern, the homophone frequency effect will appear in both main clause and subclause. This is exactly what we observed: no interaction between homophone frequency and subject-verb distance. It is important to emphasise that we replicated this basic pattern of results several times and that the data are compatible with earlier research on this type of verb spelling error in Dutch (Assink, 1985). In subsequent research we used different experimental techniques to confirm the notion of independent representations for homophonous verb forms with silent suffixes (see Frisson & Sandra, submitted).

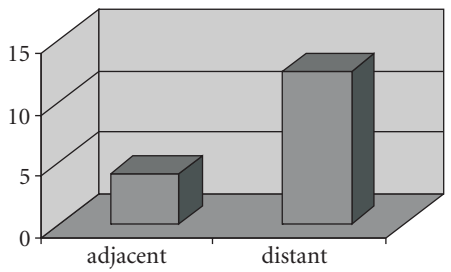

Figure 2. Percentage of homophone intrusion errors as a function of subject–verb distance

We can draw two conclusions from our results. First, limited processing resources account for the persistent errors on silent suffixes in Dutch verb forms. Evidence for this comes from the distance effect in the experiment: more errors when the distance between subject and verb form increases. It seems likely that the speeded dictation task elicited more errors than would occur in spontaneous writing. But, in doing so, a demonstration of the resources-dependent nature of the processes was provided. Yet, one might argue that speeded dictation artificially *imposed* processing limitations which are not representative for the normal writing situation. Still, it seems sensible to extrapolate from this laboratory situation to the real world. When writing a text one has to attend to several aspects simulaneously (content, structure, formulation, spelling). This results in a division of labour and in a corresponding division of one's (limited) attentional resources. If too few resources are available for spelling (e.g., because the writer concentrates on the content or the formulation) spelling errors will be made on those aspects in the spelling which require most attention. We have described above why determining the spelling of silent suffixes is time-consuming and thus forms a weak spot in the Dutch spelling system.

A second conclusion from our results is that the errors form a comprehensible pattern. Writers' spelling errors reflect the frequency relationship between homophonous verb forms. From a psycholinguistic perspective, this is an interesting finding, because it suggests that forms which are predictable by rule nevertheless have their own representation in the mental lexicon. When spellers cannot finish the cognitive operations which lead to the correct spelling of the suffix, they are dependent on the homophonic spelling patterns that are retrieved by the pronunciation of the verb form and tend to produce the most frequent homophone.

5.2 Child data

We also extended our research to the study of children's verb spelling errors. Children's errors are important for two reasons. First, the spelling of Dutch verb forms with silent suffixes is one of the most difficult spelling problems for children. Why do they require such a long learning process? Second, it is interesting to see whether the homophone frequency effect which we observed for experienced writers can also be found for children.

In Flemish schools the spelling rules for Dutch verb inflection (i.e., the problem of silent suffixes) are taught in the fourth year of primary school, i.e.

at the age of ten. As mentioned above, these rules take a long learning process with persistent errors on verb forms, even throughout secondary school. A simple explanation might be that children find it difficult to make morpheme-based analogies per se. However, this is not what observation tells us. As mentioned above, the morphological principle manifests itself in two different ways in Dutch spelling. It determines the final letter of a stem (stem-based analogy) and it determines the verb suffix (suffix-based analogy). Even though we have no direct experimental data bearing on this comparison, children's problems with the spelling of stems are far less severe than their problems with the spelling of verb suffixes. Of course, as each learning process causes errors, so does the process of learning to apply the morphological principle to stem-final letters. However, errors on stem-final letters do not persist very long and those cildren who continue to make errors are the weak spellers. In contrast, spelling errors on the verb suffix never disappear and are even made by highly experienced writers. Hence, children's learning problems with the spelling of verb forms cannot be reduced to a general problem with morpheme-based analogies.

One may wonder why it is easier for children to apply the morphological principle to stems than to verb suffixes. This question is especially relevant because children are taught the conventions behind the spelling of silent verb suffixes about two years later than the spelling conventions behind the spelling of stems. In other words, when they are confronted with verb spelling, they are already well familiar with applying the morphological principle during spelling and part of their classroom instruction consists in the training of this principle. So, one would expect that children benefit from this prior knowledge and training when learning to apply the same morphological principle in a different domain. There are two possible reasons why the spelling of verb forms is so difficult, even though (i) the underlying spelling conventions are very logical, (ii) children are able to cope with the morphological principle at the level of stems, and (iii) children have had prior training (two years) in applying this principle to stems. One possible reason is that the system, despite its descriptive simplicity, requires spellers to use cognitive operations at a high level of abstraction. A second possible reason is that children do not have to apply this principle sufficiently often in their writings.

The logic behind the spelling of verb forms is pretty abstract. This is the case irrespective of the teaching method which is used in the classroom. One way to teach how to spell verb suffixes is to give children the rules which lead to the correct spelling. This is the classical approach. Children have to learn, for instance, that "3rd person singular verb forms always end in a T in the present

tense". These rules are, of course, general (hence: abstract) formulations of the outcome of the morpheme-based analogy at the suffix level (write WORDT because of KOMT). It is evident that not all children will be able to make the grammatical distinctions which are required by the rule. The identification of sentential subject, grammatical number, and tense is relatively abstract for young children. A similar problem arises when children are taught to explicitly make analogies themselves (rather than relying on an abstract rule). When making an analogy in order to determine the spelling of the stem-final letter, the operation may not be too difficult because both words belong to the same lexical category (WORD–WORDEN). However, making a suffix-based analogy (WORDT–KOMT), i.e. finding exemplars belonging to the same *grammatical* category, may be much more difficult, as the two forms are lexically unrelated.

In addition to the abstract nature of the operations which are required to correctly spell the verb suffix, there is the fact that spellers do not need to spell verb forms with silent suffixes very frequently in Dutch. As a matter of fact, an estimate on the basis of CELEX indicates that only about ten per cent of the verb population in Dutch presents spellers with this problem. In all other cases the inflected verb form can be spelled correctly simply by applying the phonological principle (e.g., KOMT). This relatively low occurrence frequency of verb forms with silent suffixes may be an additional element in the explanation why children have more problems with the spelling of silent suffixes than with the spelling of stem-final letters. The latter spelling problem occurs much more frequently in written Dutch, as the principle applies across all lexical categories (verbs, nouns, adjectives).

It is important to note that the abstract nature of the conventions behind verb spelling and the relatively infrequent usage of these conventions not only make it difficult to *acquire* the knowledge (extended learning process), but may at the same time explain the *persistence* of the spelling problems once this knowledge has been established. Indeed, both factors — abstractness and frequency of application — can be related to a factor which is crucially important during language processing: *time*. As mentioned before, the writer's attention is distributed over a number of aspects, which may result in the allocation of limited resources for spelling (or any of the component processes, for that matter). Even though writing is a slow process compared to speaking, this distribution of processing resources will sometimes result in insufficient resources for a particular component of the process and thus lead to errors. In the domain of spelling, error rates are expected to correlate with the time it takes to solve the spelling problem at hand. The spelling of verb suffixes seems

to meet all requirements for a high error-risk, as the cognitive operations which spellers have to perform are time-consuming (abstractness, usage frequency).

Considering the fact that children (i) initially do not master the rules for verb spelling very well and (ii) have to engage in time-consuming processes to determine the correct spelling once they do master them, many verb spelling errors are to be expected in their writings. In our research we wondered which kinds of errors children of various ages would make. More particularly, we wondered whether we could find traces of the homophone frequency effect in non-experienced spellers as well. Of course, when looking for such errors we must bear in mind that the frequency estimates are based on CELEX, a corpus derived from texts for adults. In the absence of any other reliable tool, we took these estimates in order to analyse the children's performance.

Our research on children will be described in more detail in other papers (Frisson & Sandra, 2002). However, the following patterns form the broad picture. Note that we used the same verbs as in the adult studies. At age ten, when children learn to spell inflected verb forms, they have a strong preference to spell the verbal stem correctly (i.e., to apply the morphological principle at the level of the stem) but to omit the suffix. In other words, they make many more errors on the 3rd person singular (T-suffix) than on the 1st person singular, in all three frequency conditions. Their correct stem spelling is not surprising, given their two-year long experience with the morphological principle behind the spelling of stem-final letters. The many suffix ommission errors are not surprising either, because these children are still in the initial phase of the learning process. However, even though more spelling errors are made in the 3rd person (suffix ommission) than in the 1st person, an effect of homophone frequency already emerges. The frequency of the DT-form determines the error pattern: when this form is more frequent than the D-form (D<DT) we observe an increase in errors relative to the D>DT condition in the 1st person singular and a decrease in the 3rd person singular. Note that the probability of a homophone effect in children's performance is smaller than in the case of adult spelling, because the frequencies of the two homophonous forms will be much lower as a result of less exposure to the written language. In order to find a homophone frequency effect the two forms must have been encountered sufficiently often to have stable representations in the mental lexicon. Still we found the interaction between homophone frequency and grammatical person to be significant.

The pattern of results from experiments with various age groups can be summarised as follows. As children grow older they make fewer errors on the

3rd person singular, i.e. they learn when they have to write the suffix T. This is, of course, a normal learning effect. It indicates that children gradually develop the knowledge which is necessary to spell verb forms correctly and that they can apply this knowledge within the time frame they have for spelling such a form. However, despite this constant progress and the corresponding decrease in error rates, the interaction between homophone frequency and person remains significant at all ages. In other words, at no age spellers can escape from the influence of verb form frequencies. As a matter of fact, it is *impossible to escape from this influence* as continued exposure to print will only serve to make the representations of the homophonous forms stronger. Note, however, that homophonic intrusion can only manifest itself when spellers find themselves in conditions which give rise to errors, i.e. situations in which they have limited processing resources for spelling the verb form. This is why our research results are informative on two counts: (1) they show that the spelling processes which are required for correct performance are time-consuming and (2) they show that under conditions of limited processing resources the nature of the errors reflects the existence of independent orthographic representations for verb forms whose spelling is predictable by rule.

So, as time progresses children go through two developmental processes. They develop the knowledge which is required to spell silent suffixes (rule-knowledge or analogy-based reasoning) and can apply this knowledge faster as a result of training. But at the same time they develop representations of individual verb forms. The latter lead to spelling errors in those cases where time limitations make it impossible to finish the cognitive operations that are needed to apply the knowledge underlying suffix spelling.

6. Conclusion

Even though Dutch has a very simple rule system for spelling regularly inflected verb forms, it causes both a difficult learning problem for children and a notorious spelling hurdle for experienced writers. Two properties of the verb spelling system create the necessary conditions for errors to occur, despite its transparent logic from a linguist's perspective. First, the morpheme-based analogy for suffixes is analytically very clear but is *abstract*, whether an explicit analogy is made (WORDT because of KOMT) or whether the rule is called upon which "summarizes" the outcome of such analogical reasoning. Second, silent suffixes occur relatively *infrequently*, i.e. only in about ten percent of the

verbs in the Dutch lexicon. The combined effect of these two properties leads to a *time-consuming* process. In a situation where the processing resources must be distributed over several components of the writing process (content, structure, formulation, spelling), such time-consuming operations will not always be able to finish within the time frame that the speller allocates for them and an error may occur. This is why even the best spellers still make mistakes on these descriptively very simple verb forms. Our experimental demonstration that more errors are made when the verb is a number of words removed from the subject than when the two are adjacent supports this idea of available processing resources.

When time is too short to finish a cognitive operation, the nature of the errors will depend on the potential sources of intrusion. In the case of Dutch verb forms for the 1st and 3rd person singular in the present tense, this source of intrusion is the homophony which exists in the verbal inflectional system. When spellers cannot finish the cognitive operations leading to correct suffix spelling, they tend to write the homophonous form with the highest occurrence frequency. Note that this will not lead to a spelling error on each occasion. As a matter of fact, since the system is biased to produce the most frequent form, reliance on homophone frequency will more often result in a correct spelling than in an incorrect one (as the highest frequency form is obviously the one which is most often encountered). However, since spelling rules determine the spelling of a word form in a deterministic way, probabilistic behaviour will lead to errors on a sizeable proportion of cases.

Our findings are very similar to the results which Fayol and his coworkers have obtained on the spelling of French verb forms with silent suffixes (Fayol, Largy, & Lemaire, 1994; Largy, Fayol, & Lemaire, 1996). The French spelling relies even more heavily on silent morphology than the Dutch one. In the domain of French verbal inflection many silent suffixes can be found in the spelling. Fayol et al (1994) demonstrated that spellers make more errors on a silent verb suffix when their processing resources have to be divided between the task of writing down a dictated sentence and the task of memorising a series of words or counting a sequence of clicks. Largy et al (1996) showed that when the target verb is homophonous with a noun, the error pattern is determined by the relative frequencies of the noun and the verb. More homophonic noun intrusions were found when the noun frequency was higher than the verb frequency. These studies of French spelling errors lead to very similar conclusions on the spelling of silent suffixes. First, errors on these suffixes are made "when the working-memory system is overloaded" (Fayol et al., 1994, p. 459). Second, the fact that determining the spelling of a silent suffix is time-consuming

and the fact that there are sources of intrusion in the system together explain "why errors are unavoidable, even by experts" (p. 463). This is exactly what we find: the nature of the cognitive operations (time-consuming) leads to errors and the patterns in the errors are determined by the nature of the stored orthographic representations (full forms). Since the frequencies of the homophones will stabilise the more writers are confronted with texts, experienced spellers who are faced with processing limitations will not be able to escape the influence from the stored homophones in their mental lexicon and make a spelling error.

Our research shows that a close examination of spelling errors can shed light on the nature of written language production, just in the same way as an analysis of speech errors can reveal the architecture behind speaking. Our spelling data show that, even though writing in general is probably the slowest language activity (hence, at first sight uninteresting for some psycholinguists, who are on the outlook for automatic processes), its spelling component must be accomplished within time frames which are often too short to allow certain processes to finish in time. The nature of the errors which result from this bottle-neck in time offers a diagnostic for understanding the representations in the mental lexicon. Even though regularly inflected verb forms with silent suffixes are fully rule-governed, they develop their own, independent representations in the mental lexicon, where they are the source of the homophone frequency effect.

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