

Capitalization of Nouns in German Sentences

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Abstract

German orthography has the somewhat unique property of systematically marking nouns by capitalizing their first letter. This gives the reader additional information with respect to the syntactic structure of a sentence but also burdens the writer with the task of making this structure explicit. In some older studies, the benefits of this information have been demonstrated for the reading process, it still remains unclear though, how the writer accomplishes this task. Two different processes are conceivable: The information is either delivered by the Orthographic Output Lexicon or is syntactically generated whilst the sentence to be written is constructed. In a series of experiments, evidence is provided for an interactive exchange between lexical and syntactic processing dealing with the question of when capitalization should occur.

1. Introduction

Various orthographic systems use an alternation of letter types – e.g. small and capital forms - to denote certain linguistic functions of words. Most prominent is the characterization of the beginning of texts, sentences, lines of verse, proper names, nomina sacra etc. Unlike other alphabetical writing systems based on the Roman alphabet, this letter alternation has been strictly grammaticalized in the history of German orthography. Accordingly, in present day German, capitalization is used to denote, among other things, the syntactic function of words that are nouns. As can be seen in figure 1, this is not a matter of a word form but only

of the syntactic function: The word LEBEN (live/life) has to be written with an initial capital letter only if it has the syntactic function of a noun.

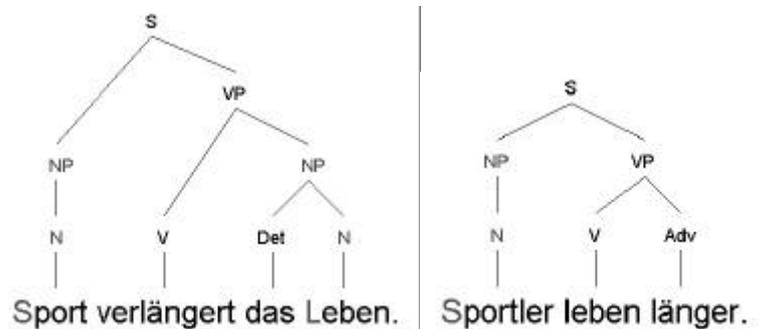


Fig. 1: Syntactic structures of two sentences containing the word LEBEN. In the left sentence *Sport verlängert das Leben* [Sport prolongs the life.] LEBEN functions as a noun. Accordingly, it is written with a capitalized initial letter. In the sentence on the right, *Sportler leben länger* [Sportsmen live longer.] it is written with a small initial letter because it functions as a verb.

The German writer has to decide whether the word is performing the role of a noun or a non-noun for every word of a sentence. If it is a noun, it has to be written with a capitalized initial letter, otherwise it starts with a small letter. This poses the question of how the respective information is delivered. Two alternatives can be considered:

Lexical pathway: The capitalization information is stored in the Orthographic Output Lexicon.

Generation pathway: No capitalization information is stored. It must be generated during the writing of the sentence. First, the syntactic structure of the actual sentence is generated and, during this process, some words are labelled as nouns. Subsequently, they receive the appropriate orthographic form, i.e. they are to be written with a capitalized initial letter.

If we look at the structure of German words, a preliminary answer can be given. For the present purpose we will distinguish between three types of nouns:

- Simple nouns: morphologically unmarked nouns where the nominal word category is lexically determined, i.e. the word category is inherent in the noun itself, e.g. <Baum> [tree], <Frau> [woman].
- Derived nouns: morphologically marked nouns where the nominal word category is determined by the morphological structure, more specifically by a suffix like *-nis* or *-heit*, e.g. <Erlebnis> [experience], <Krankheit> [illness]

- Converted nouns: nouns which show the identical phonological form and word shape as the corresponding verbs with the exception that their initial letter is capitalized, e.g. <Essen> [meal] vs. <essen> [to eat]. The nominal word category for this type of word can only be clearly identified on the basis of the syntactic structure of the sentence in which the respective noun occurs.

The analysis of the structure of German nouns can be summarized as follows: Two groups of nouns can be distinguished with one group containing simple nouns and derived nouns. Their nominal word category can be identified on the word level, either because the word category information is inherent in the noun itself, as is the case for simple nouns, or because the word contains a (nominal) suffix, as is the case for derived nouns. The second group contains words (converted nouns) which, seen or heard in isolation, cannot be unambiguously identified as nouns. This group of words is ambiguous in respect of its word category as they can be used as verbs as well as nouns. According to ordered access models, i.e. frequency-dependent models (e.g., Foster & Bednall, 1976), it can be assumed that, when an ambiguous word is presented in the absence of context, the more frequent word category alternative is retrieved first. Evidence for frequency-dependent lexical retrieval comes from studies of homophones/homographs. It was found that the more frequent meaning of a homophone/homograph was retrieved quicker than its less frequent meaning. (Simpson & Burgess, 1985; for a review, see Hillert, 1997). Examples of frequency distributions for this type of words in German are given in table 1.

	noun/verb	noun, absolute frequency	verb, absolute frequency	noun, relative. frequency
MISSTRAUEN	mistrust/mistrust	107	3	97,3%
LEBEN	life/live	2558	700	78,5%
VERSPRECHEN	promise/promise	69	58	54,3%
SCHREIBEN	writing/write	195	350	35,8%
BEMÜHEN	endeavour/endeavour	0	146	0%

Table 1: Frequency of words used as verbs as well as nouns in written language, CELEX

Therefore, the question posed is, how are these ambiguous words processed when they are presented in a sentence context. Are both alternative word category entries retrieved with no regard for syntactical information or is the syntactic context used from the outset to retrieve only the appropriate word category? Previous studies into the lexical ambiguity of

homophones/homographs (for a review, see Simpson & Burgess, 1985; Hillert, 1997) suggest that all meanings of an ambiguous word are initially retrieved. Subsequently, the sentential context is used to select the appropriate meaning.

According to this assumption, the processing of converted nouns presented in the context of a sentence ought to pose a greater cognitive load compared to simple and derived nouns. This should be the case since the former have two word category entries, while the latter have only one. The greater cognitive load should be reflected in longer processing times for converted nouns.

The main purpose of the present study is to assess whether the capitalization information is stored in the lexicon or generated syntactically during sentence construction. The experiments examine the decision time for three word types under capitalization conditions (nouns for simple, derived and ambiguous words) and non-capitalization conditions (adjectives for simple and derived words and verbs for ambiguous words) in the context of a sentence and in isolation. If, in keeping with the prediction mentioned earlier, decision time for ambiguous words is longer than for simple and derived words, the finding can be taken as evidence for the assumption that capitalization information is stored in the lexicon. Otherwise, i.e. if no capitalization information is stored, no decision time differences would be expected. In this case, we would assume that the capitalization information is generated whilst the phrase structure is being constructed.

The capitalization of nouns can be considered as a reader oriented function of German orthography. It should help the reader to syntactically analyse a given sentence by highlighting the argument(s) as opposed to the predicate of the proposition. Accordingly, it can be hypothesized that the reading of texts with capitalized nouns facilitates reading compared with texts whose nouns are not capitalized. Indeed, previous on-line studies (e.g., Bock et al, 1985; 1989; Bock, 1986; 1989; 1990) provide empirical evidence for this hypothesis. Bock et al. (1985) found a correlation between the capitalization of the noun and the reading rate (number of words per minute). The reading rate for texts decreased when the readers were presented with texts violating the German capitalization rules compared with texts where these rules were observed. For the stimuli texts, the spelling of words was systematically varied with regard to the capitalization of their initial letter so that each text was produced in five differently spelled versions. One version corresponded to the capitalization rules of German (standard capitalization rules). The violations of the rules in

the remaining four texts arose from the non-capitalization of all words including nouns (constant non-capitalization), the capitalization of all words inclusive non-nouns (constant capitalization), the capitalization of non-nouns and the non-capitalization of nouns (capitalization rules inversion) or from the random variation of capitalization and non-capitalization for all words (random variation). The reading rate for the standard capitalization rule condition was faster than for all other reading conditions. The slowest reading rate was registered for the condition where the capitalization rules were inverted. Nevertheless, as the authors themselves noted, these findings do not provide evidence that the German noun capitalization rules facilitate reading. Rather, the obtained effect could also be ascribed to the fact that any violation of capitalization rules leads to unaccustomed word shapes and therefore to slower reading rates. However, in a further study carried out with English and Dutch texts, Bock et al. (1989) demonstrated that the capitalization rules do indeed have a function which is independent of the stored written word shapes. In this study, German students were asked to read German and English texts while Dutch students were asked to read Dutch and German texts. The stimuli texts were presented in the five spelling versions described above. For both the German and Dutch participants, the reading rate for the German texts decreased in the same order as in Bock et al. (1985). For the English texts, the reading rate for texts with non-capitalized nouns (standard English capitalization rules) was as fast as for texts with capitalized nouns (standard German capitalization rules). This finding suggests that the German participants transferred the German capitalization rules to the English texts so that the unaccustomed word shapes, i.e. the capitalized nouns, did not retard the reading rate. However, the unaccustomed word shapes delayed the reading in the cases when they did not correspond to the standard German capitalization rules as indicated by the slower reading rate for the three remaining spelling versions. In Dutch texts, a transfer of the German capitalization rules was also observed. As expected, the Dutch participants read texts obeying the standard Dutch rules faster than texts in the remaining four spelling versions. The most important finding though, is the fact that the reading rate for Dutch texts, written according to the German capitalization rules, was faster than for the remaining three text versions, although all four text versions showed deviations from the Dutch rules leading to unaccustomed word shapes. The faster reading rate for texts written according to the German capitalization rules seems to arise from the fact that the Dutch readers transferred the rules to the Dutch texts and hereby compensated for the unaccustomed word shapes. On the basis of the English and Dutch text findings, Bock et al., (1989) argued that, at least for silent

reading in a practised reader, the German capitalization rules have a function which is independent of the stored word shape.

As far as we know, there is no experimental research on capitalization from the perspective of the writer. It can be assumed that, whereas capitalization facilitates the reading process, it should pose an additional cognitive load for the writer. They have to explicitly state a linguistic structure that can otherwise – e.g. in the English or Spanish writing systems – remain implicit.

The assessment of this hypothesis together with the issue of whether the capitalization information is stored in the lexicon or generated syntactically during sentence construction are the topic of the experiments reported in the following sections.

2. Experiment 1

2.1. Method

2.1.1. Participants

Twenty two students from the University of Osnabrück (17 female and 5 male) aged between 22 and 34 years (Mean: 23.8) took part in the experiment. All participants were native speakers of German and all were naïve with respect to the purpose of the experiment.

2.1.2. Stimuli

192 sentences were used as stimuli, 96 of which were the sentences which would be analysed (we refer to these sentences as testing sentences). The remaining 96 were used as filler sentences. Each testing sentence contained a target word which, according to the orthographic rules of German, should be written with a capital or non-capital¹ initial letter. The target word was one of three categories; a noun, an adjective or a verb and was positioned either in the third or the final position of the sentence. Each target word category was further split into three types:

The *suffixed* type denotes words which are clearly identifiable as nouns or adjectives by their morphological structure, i.e. by their suffixes, (e.g. <Freundschaft> [friendship] where the

¹ From now on words of this type will be referred to as capital and non-capital.

suffix <schaft> clearly determines the word category as a noun; <beachtlich> [considerable] where the suffix <lich> identifies the word category as an adjective).

The *non-suffixed* type denotes words where the category (noun or adjective) is lexically determined, i.e. the word category is inherent in the word itself (e.g. <Buch> [book]; <blau> [blue]).

The *ambiguous* type words are identifiable as a noun or verb based solely on the syntactic structure of the sentence. Words of this type can be written with a capital initial letter (noun) or non-capital initial letter (verb), depending on their syntactic function in the sentence (e.g. <leben> [to live] when the word is used as a verb; <Leben> [life] when the word is used as a noun).

We used 48 capital and 48 non-capital target words equally distributed among the three types. The filler sentences contained an equal amount of capital and non-capital target words. In addition to nouns, adjectives and verbs, the filler sentences also contained articles and prepositions in different positions.

2.1.3. Procedure

Stimuli were presented on a 19" computer screen and the acoustic stimuli were produced by a computer whose output was heard by the participants through headphones.

Participants heard a tone which was followed, 750 ms later, by the spoken stimuli sentence. 750ms after the end of the voice signal a fixation point appeared in the upper half of the screen for 250 ms. This was followed by a blank screen for 500 ms before the target word appeared, entirely in capital letters (e.g. LEISE [quiet]). The next trial started after 2000 ms.

Participants were asked to decide whether the target word was to be written capital or non-capital, in the context of the presented sentence. The decision was registered by the participant pressing buttons on the computer keyboard. Participants were instructed to press one button with the forefinger of the left hand and a second button with the forefinger of the right hand. The two decision buttons were balanced across participants so that half pressed the first button for capital and the second button for non-capital. The other half received the inverse instruction. The end of each trial, and thereby the initiation of the next, was signalled by the pressing of the "decision" button. Each participant completed a pre-test with a set of 10 sentences which were not part of the main test.

2.2. Results and discussion

For the analysis of the timing results, only correct responses and those response times shorter than 2000 ms were considered. The percentage of errors was very small (1.8%) and the total amount of excluded data was 4.4%.

A repeated measures ANOVA with the factors capitalization (capital vs. non-capital) and type (suffixed vs. non-suffixed vs. ambiguous) was performed. The analysis revealed a main effect of capitalization ($F(1, 21) = 9.78, p < .01$), a main effect of type ($F(2, 42) = 20.19, p < .0001$) as well as a main effect of interaction between the two variables ($F(2, 42) = 9.49, p < .005$).

The mean reaction time for the capital target words (781 ms) was faster than for non-capital target words (848 ms). Within the three word types, suffixed words displayed the fastest reaction time (772 ms) followed by non-suffixed (787 ms) and ambiguous words (883 ms). Furthermore, a small effect analysis for the type variable (suffixed vs. non-suffixed vs. ambiguous) was performed. The analysis revealed that the mean reaction times of the ambiguous words differed significantly from those of the suffixed words as well as the non-suffixed words. No significant difference was found between the mean reaction times of suffixed and non-suffixed words.

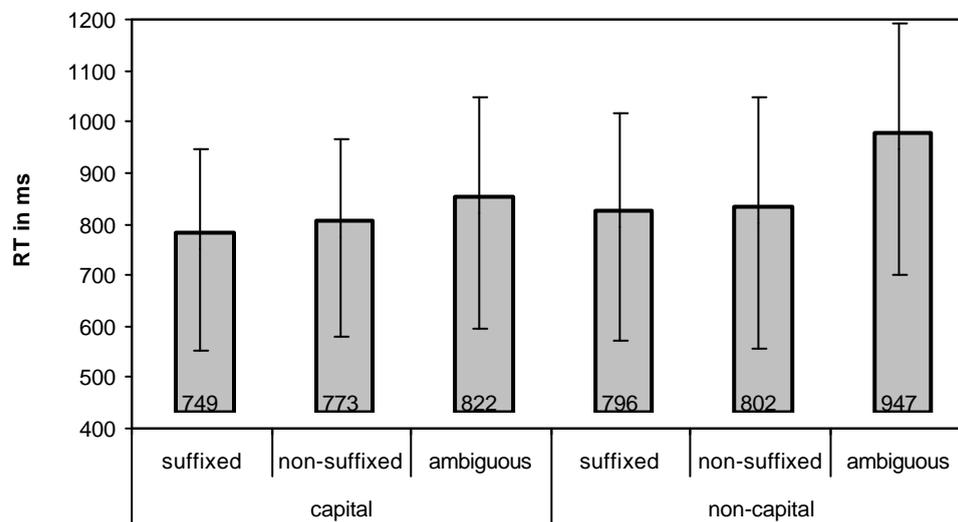


Fig. 2: Mean values with standard deviation of reaction time (RT) for the individual factors in experiment 1.

One purpose of experiment 1 was to determine whether noun capitalization poses an additional cognitive load for the writer. The results so far indicate that capitalization is decided with less effort compared to non-capitalization. Nevertheless, an additional cognitive load may exist, although it does not make itself apparent for the capitalized words but raises

its head for the non-capitalized words in the form of increased reaction times. This may be the case because, at least in this experimental condition, capitalization could have been considered by the participants as a “yes”-decision whereas non-capitalization was their “no”-decision, and therefore slower.

The main purpose of experiment 1 was to assess whether the capitalization information is stored in the lexicon or syntactically generated during sentence construction. The results obtained suggest that the lexicon is involved in the capitalization decision as supported by the slower reaction time for ambiguous words compared to suffixed and non-suffixed words. In contrast, no significant difference between the reaction times for the two latter word types was found. One might argue that the significantly different reaction time arose from different word frequencies. This account can be ruled out when one considers the almost equal frequencies of the stimuli (according to the CELEX database, Baayen et al., 1993) for the ambiguous words (average: 215) and the suffixed and the non-suffixed words (average: 178). Perhaps a more plausible assumption is that, the longer decision time for ambiguous words is due to these words having two word category entries. It appears to be the case that, if participants were presented with a letter string for an ambiguous word, both capitalization alternatives for the word are initially retrieved before the appropriate one is selected on the basis of the available syntactic information. This interpretation implies that the syntactic context initially exercises no influence on the access to the appropriate capitalization information. On the other hand, the faster reaction time for suffixed and non-suffixed words can be attributed to the fact that only one capitalization feature is associated with the presented letter string, so that, in contrast to ambiguous words, no additional selection process is needed.

The results of experiment 1 suggest that lexical processes are involved in the capitalization decision. If this is indeed the case, we should obtain a different reaction time pattern when lexical influences are precluded; for example, if pseudo-words are used as target words. Since pseudo-words have no lexical entries, the capitalization decision should rely solely on syntactic information delivered by the sentential context. Therefore, we would expect no significant differences between the reaction times of the three word types used. This prediction was examined in experiment 2.

3. Experiment 2

3.1. Method

3.1.1. Participants

Sixteen students from the University of Osnabrück (14 female and 2 male) aged between 22 and 35 years (Mean: 24.6) took part in the experiment. All participants were native speakers of German and all were naïve with respect to the purpose of the experiment.

3.1.2. Stimuli

192 sentences were used as stimuli, 96 of these were the sentences which would be analysed (again referred to as testing sentences) while the remaining 96 were used as filler sentences. Each testing sentence contained two pseudo-words, one being the target word. The pseudo-words were non-occurring words of German but were constructed according to the phonotactical/graphotactical rules of German. The target words occupied the syntactic positions of nouns, adjectives or verbs. As in experiment 1, three types of words were used:

The *suffixed* type denotes pseudo-words that are unambiguously identifiable as being nouns or adjectives by their morphological structure (e.g. <Bedugtheit> where the suffix <heit> identifies the word as a noun; <buglich> where the suffix <lich> identifies the word as an adjective).

The *non-suffixed* type denotes pseudo-words where the word category (noun, e.g.<Kobos>; or adjective, e.g. <schond>) was only indicated by the syntactical environment.

The *ambiguous* type denotes pseudo-words that were constructed along the lines of the patterns found for German ambiguous words (see section 2.1.2.), i.e. the pseudo-words end in *-en*. These were used in two different syntactic functions within a sentence, i.e. verbs and nouns (e.g. <Kaben> as a noun in <Am Drussig gab es ein schweres *Kaben*.> or <kaben> as a verb in <Die Männer *kaben* die schwere Granne.>).

The target word was either in the third or final position of the sentence while the position of the second pseudo-word varied. The distribution of target word types was carried out in the same way as in experiment 1 (see section 2.1.2. for details). The filler sentences also contained pseudo-words, although these occupied the syntactical position of articles and prepositions.

3.1.3. Procedure

Procedure and timing were identical to experiment 1 (see section 2.1.3. for details).

3.2. Results and discussion

For the analysis, only correct responses and those response times shorter than 2000 ms were considered. The percentage of errors was 3.8% and the total amount of excluded data was 8.4%.

A repeated measures ANOVA with capitalization (capital vs. non-capital) and type (suffixes vs. non-suffixes vs. ambiguous) was performed. The analysis revealed a main effect of capitalization ($F(1, 15) = 8.30, p < .05$), a main effect of type ($F(2, 30) = 6.08, p < .01$) as well as a main effect of interaction between the two variables ($F(2, 30) = 5.28, p < .05$).

The mean reaction time for the capital target words (677 ms) was faster than for the non-capital target words (728 ms). The mean reaction time for non-suffixed (677 ms) target words was faster than suffixed (705 ms) and faster than ambiguous target words (725 ms). A small effect analysis for the type variable (suffixes vs. non-suffixes vs. ambiguous) was performed. The analysis revealed a significant difference between the mean reaction times for ambiguous words and non-suffixed words, but no significant difference was found between the mean reaction times of ambiguous words and suffixed words and those of suffixed and non-suffixed words.

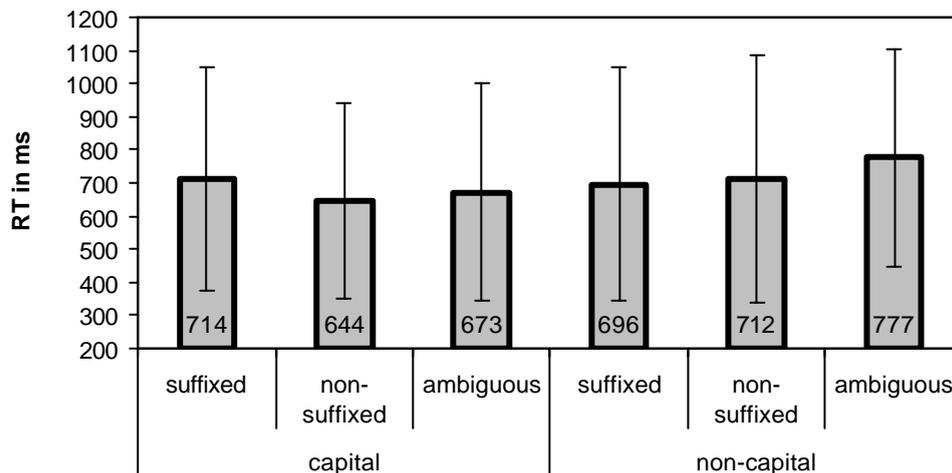


Fig. 3: Mean values with standard deviation of reaction time (RT) for the individual factors in experiment 2.

As predicted, participants showed a different decision time pattern for pseudo-words compared to the German words (experiment 1). As mentioned above, the longer decision time for the ambiguous words, compared to the suffixed and non-suffixed words in experiment 1, was due to lexical factors, i.e. to the additional lexical selection process in ambiguous words:

Participants had to select one of two alternative word category entries on the basis of the sentential context. As expected, and because of the absence of lexical influences, the systematic difference between the decision times for the non-suffixed and suffixed type, on the one hand, and the decision time for the ambiguous type, on the other, was not found in pseudo-words. The only significant difference found was between the non-suffixed and ambiguous types: The main decision time for the latter was slower than for the former. This finding cannot be ascribed to lexical factors though, due to the fact that pseudo-words have no lexical entries.

Furthermore, an unpaired *t*-test was performed to compare the mean reaction times for pseudo-words and German words (experiment 1). The test revealed a significant difference ($t(74) = 2.12$, $p < .05$): The pseudo-words reaction time was faster than that of the German words. This result suggests that the reaction time is faster when the capitalization decision relies only on the sentential context, as is the case for pseudo-words. On the other hand, it can be assumed that the slower reaction time of the German words is due to the fact that syntactic processes as well as lexical processes are involved in the capitalization decision.

Another question is, to what extent capitalization is influenced by morphological information. A possible morphological influence on capitalization should be reflected in different reaction times for the suffixed and the non-suffixed types. Assuming that the information encoded in the suffix supports, and thereby facilitates, the capitalization decision, we would expect a faster reaction time for the non-suffixed type compared to the suffixed type. On the other hand, according to the lexical decomposition hypothesis (e.g. Badecker et al., 1990), morphologically complex words are parsed into stems and suffixes creating a larger cognitive load than mono-morphemic words. Therefore, we would expect slower reaction times for the suffixed type than for the non-suffixed type. Neither the results of the German words (experiment 1) nor the results of the pseudo-words (experiment 2) showed a morphological influence on the decision time as illustrated by the fact that no significant difference was found between the reaction times for the suffixed and non-suffixed types. This finding suggests that the additional morphological information encoded in the suffix, at least for words presented in the context of a sentence, did not crucially influence the capitalization decision.

Admittedly, it is likely that this result was a consequence of the stimuli presentation timing, i.e. from the interval between the presentation of the stimuli sentence and the target word. It could be the case that participants tried to guess the target word immediately after hearing the sentence. Therefore, the decision process could have begun before the target word

was presented, thus resulting in any possible difference in the decision times, for the suffixed and the non-suffixed types, not being recorded. This question was addressed in experiment 3.

4. Experiment 3

In order to assess whether or not the above findings arose as a result of the presentation timing, experiment 3 was conducted. It used a reduced delay and an almost immediate target word presentation after the stimulus sentence.

4.1 Method

4.1.1. Participants

Nineteen students from the University of Osnabrück (14 female and 5 male) aged between 21 and 32 years (Mean: 24.6) took part in the experiment. All participants were native speakers of German and all were naïve with respect to the purpose of the experiment.

4.1.2. Stimuli

The same stimuli sentences (96 testing and 96 filler sentences) were used as in experiment 1 (see section 2.1.2. for details).

4.1.3. Procedure

The procedure was identical to experiment 1 (see section 2.1.3. for details) with the exception that the presentation flow timing was modified. The pause times were reduced so that there was no pause between the acoustic signal and the voice onset of the stimuli sentence. The visual fixation point appeared immediately after the end of the voice signal for 250 ms followed by a blank screen for 150 ms. The target word was then presented. The pause between the trials was also reduced to 1500 ms. Each participant completed a pre-test with a set of 10 sentences which were not part of the main test.

4.2. Results and discussion

Only correct answers were considered in the timing analysis. The total percentage of data which were not used for the analysis was 4.7%. This percentage was composed of 3.2% incorrect answers and 1.5% answers which took longer than 2000 ms.

A repeated measures ANOVA with capitalization (capital vs. non-capital) and type (suffixed vs. non-suffixed) was performed. The analysis revealed a main effect of capitalization ($F(1, 18) = 23.25, p < .005$) as well as a main effect of type ($F(2, 36) = 21.40, p < .0001$). No interaction between these two variables was found.

The mean reaction time for capital target words (690 ms) was again faster than for non-capital target words (803 ms). The fastest mean reaction time was recorded for non-suffixed words (692 ms) followed by suffixed words (736 ms) and ambiguous words (812 ms). Furthermore, a small effect analysis was performed for the type variable (suffixed vs. non-suffixed vs. ambiguous words). It revealed that the mean reaction time for ambiguous words was slower than for suffixed words and non-suffixed words, but no significant difference between the mean reaction times for suffixed and non-suffixed words was found.

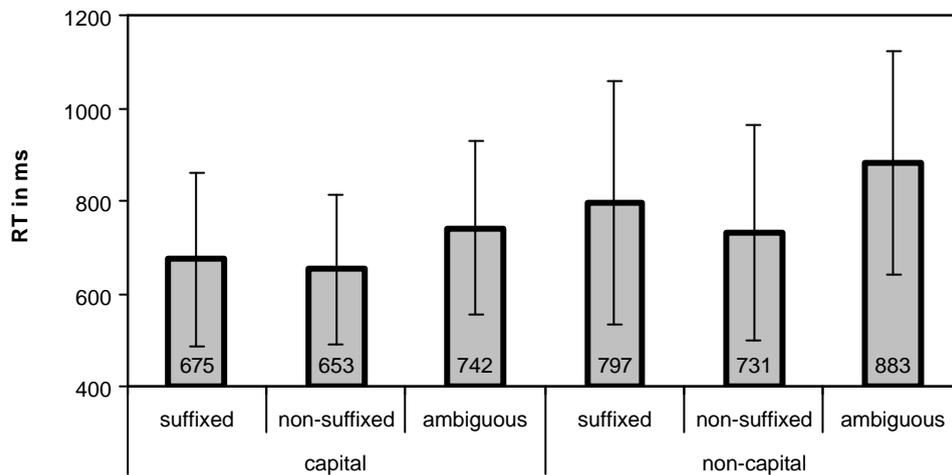


Fig. 4: Mean values with standard deviation of reaction time (RT) for the individual factors in experiment 3.

In order to examine whether the findings we observed in experiment 1 were due to the relatively long interval between the presentation of the stimuli sentences and the presentation of the target word, we reduced pause times within the trials using the same stimuli as in experiment 1. The results were identical to those of experiment 1, indicating that the observed effects did not arise from the presentation timing. As in experiment 1, the decision time for capitalized words was shorter than for non-capitalized words, the decision time for ambiguous words was longer than for suffixed and non-suffixed words, and no significant difference between the decision time for suffixed and non-suffixed words was found.

Even when pause times were reduced, compared to experiment 1, no significant difference was found between suffixed and non-suffixed words suggesting that there was no morphological influence on the capitalization decision. Admittedly, this finding could be

derived from the poor control of the amount of syllables in the word as well as the word-frequency. The suffixed words used in experiments 1 and 3 had, on average, more syllables (2.3) and were less frequent (117) than the non-suffixed words (1.25, 238 respectively). In order to exclude the influence of syllable number and word-frequency on the reaction time, experiment 4 was carried out. In this experiment the number of syllables in the word and frequency were controlled.

5. Experiment 4

5.1. Method

5.1.1. Participants

Twenty five students from the University of Osnabrück (19 female and 6 male) aged between 22 and 30 years (Mean: 24.9) took part in the experiment. All participants were native speakers of German and all were naïve with respect to the purpose of the experiment.

5.1.2. Stimuli

128 sentences were used as stimuli, 64 of which were the sentences which would be analysed (again referred to as testing sentences) whilst the remaining 64 were used as filler sentences. Each testing sentence contained a noun as a target word, which was either in the third or final position of the sentence. The target words were split into two types: Suffixed nouns and non-suffixed nouns (32 of each type). One half of the nouns had a high frequency (16 for each type) the other half had a low frequency (16 for each type) according to the CELEX database (Baayen et al., 1993). The stimuli were also matched in respect of the number of syllables they contained. In half of the testing sentences, the target word was 'misspelled' regarding the capitalization of the initial letter, i.e. the first character was written non-capitalized instead of capitalized.

Each filler sentence contained either a verb or an adjective as the target word whose position was randomly distributed. Half of the target words were also misspelled with respect to the capitalization of the first character, i.e. their first letter was written capitalized instead of non-capitalized.

5.1.3. Procedure

Participants were presented with a fixation point for 250 ms before the stimuli sentence appeared. The participants were then asked to decide whether the sentence contained a spelling mistake, with respect to the capitalization. The decision was registered by the participant pressing buttons on the computer keyboard. Participants were instructed to press one button with the forefinger of the left hand and a second button with the forefinger of the right hand. The two decision buttons were balanced across participants so that one half were instructed to press the first button in the case that the sentence contained a misspelled word and the second button if there were no misspelled words in the sentence. The remaining participants were instructed in the inverse way. The end of each trial, and thereby the initiation of the next, was self paced by the pressing of the “decision” button. Each participant completed a pre-test with a set of 10 sentences that were not part of the main test.

5.2. Results and discussion

For the following analysis, only correct responses for sentences containing an incorrectly spelled word were considered because it was obvious which word was intended as the target word, whereas, in the correctly spelled sentences, the participant could not know which was the intended target word. The percentage of incorrect responses was 2.5%. All response times that were longer than 5000 ms were excluded from the analysis. The total percentage of excluded data was 3.9%.

A repeated measures ANOVA with type (suffixes vs. non-suffixes), frequency (high vs. low) and position (third vs. last) was performed. The analysis revealed a main effect of frequency ($F(1, 24) = 4.86$ $p < .05$), a main effect of position ($F(1, 24) = 87.44$ $p < .0001$), but no type effect ($F(1, 24) = 2.22$ $p > .1$) or interaction ($F(1, 24) = .91$ $p > .1$). The mean reaction time for highly frequent target words (1777 ms) was faster than for low frequent words (1885 ms).

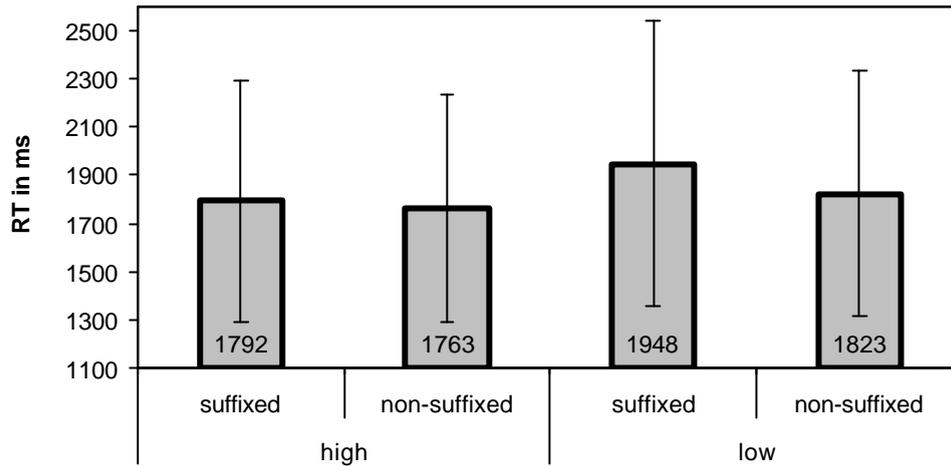


Fig. 5: Mean values with standard deviation of reaction time (RT) for the individual factors in experiment 4.

Participants' reaction time for high frequency nouns was faster than for low frequency ones, indicating an involvement of lexical processes in the capitalization decision. Frequency effects are generally understood as providing evidence for lexical access (Jescheniak & Levelt, 1994). The finding that the reaction time for target nouns in the final position of the sentence was slower than for those in the third position indicates that participants did not utilise a target-noun-oriented retrieval strategy, rather they read the sentence, at least, up to the point where they detected the misspelled word.

As in experiments 1 and 3, no significant difference was found between the reaction times for suffixed and non-suffixed words, although in the present experiment the syllable number and frequency were controlled. This result suggests that, at least for words presented in the context of a sentence, there is no morphological influence on the capitalization decision.

All four previous experiments dealt with the capitalization issue when words were presented in a sentence context. As mentioned above, our findings suggest that lexical, as well as syntactic, processes are involved in the capitalization decision. In the subsequent experiment (experiment 5), the time course of the capitalization decision was examined when words were presented in isolation, i.e. in the absence of a sentence context. Therefore, the capitalization decision was to be made on the word level, meaning that any syntactic influence on the capitalization decision was precluded.

6. Experiment 5

6.1. Method

6.1.1. Participants

Twenty students from the University of Osnabrück (15 female and 5 male) aged between 23 and 38 years (Mean: 27.1) took part in the experiment. All participants were native speakers of German and all were naïve with respect to the purpose of the experiment.

6.1.2. Stimuli

The same 128 target words (64 testing and 64 filler words) from experiment 4 were used. The words were presented without the original sentence context (see section 5.1.2. for details).

6.1.3. Procedure

The words were presented on a 19" computer screen. After a fixation point was displayed for 250 ms, a word appeared on the screen. The participants' task was to decide whether the presented word contained a spelling mistake with respect to the capitalization of its initial letter. The decision was registered by the participant pressing buttons on the computer keyboard. Participants were instructed to press one button with the forefinger of the left hand and a second button with the forefinger of the right hand. The two decision buttons were balanced across participants so that half pressed the first button if the word was misspelled and the second button when the word was correctly spelled. The other half received the inverse instruction. The end of each trial, and thereby the initiation of the next, was self paced by the pressing of the "decision" button. Each participant completed a pre-test with a set of 10 words that were not part of the main test.

6.2. Results and discussion

For the following reaction time analysis, only correct responses were considered. The percentage of errors was very small (2.8%). All response times that were longer than 2000 ms were excluded from the analysis. The total percentage of excluded data was 11.2%.

A repeated measures ANOVA with type (suffixes vs. non-suffixes), frequency (high vs. low) and presentation (correct vs. incorrect) was performed. The analysis revealed a main effect of type ($F(1, 19) = 9.07, p < .01$), a main effect of frequency ($F(1, 19) = 33.90, p <$

.0001) as well as a main effect of presentation ($F(1, 19) = 10.75, p < .005$), but no interaction of these factors. The mean reaction time for the suffixed words (1090 ms) was slower than for the non-suffixed words (1025 ms), the mean reaction time for words with high frequency (1005 ms) was faster than for words with low frequency (1110 ms). Also, the mean reaction time for ‘incorrect’-decisions (1103 ms) was slower than for ‘correct’-decisions (1012 ms).

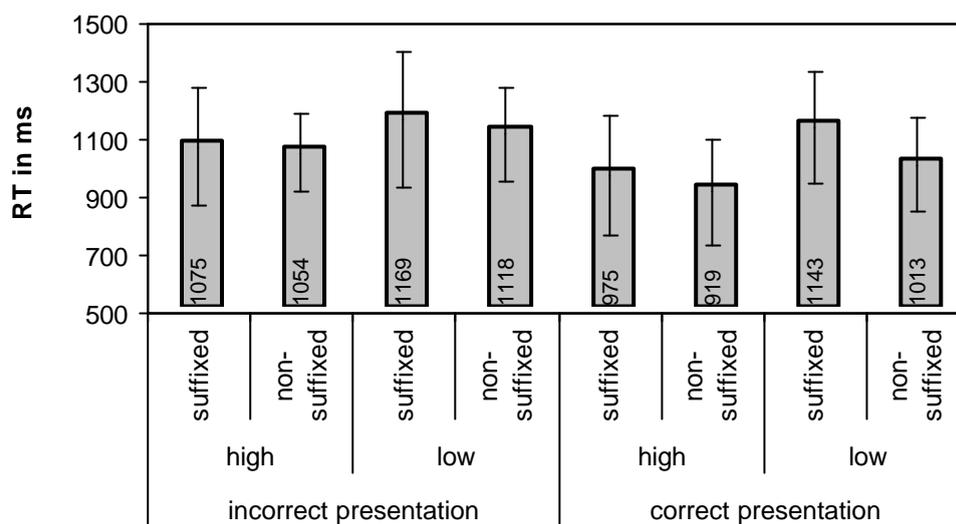


Fig. 6: Mean values with standard deviation of reaction time (RT) for the individual factors in experiment 5.

The purpose of experiment 5 was to assess the extent the findings of experiments 1-4 were affected by syntactic factors. This was achieved by presenting the participants with words in the absence of a sentence context. The analysis revealed a significant difference in the reaction times for suffixed and non-suffixed words, an effect that was not found in experiments 1-4. The slower reaction time for suffixed words indicates that the capitalization decision was affected by morphological factors, when words were presented in isolation, i.e. without a sentence context. This result suggests that the information encoded in the suffix did not facilitate the capitalization decision. On the contrary, the suffix seems to hamper this decision. Given that morphologically complex words are parsed into stems and affixes in order to be recognized or produced, it can be assumed that the extended decision time for suffixed words was due to the additional cognitive load - caused by the processing of the suffix - compared to non-suffixed words.

7. General discussion

The main purpose of the present study was to determine whether the capitalization information is stored in the lexicon or generated by non-lexical processes, i.e. by syntactic processes, during phrase structure building. For this purpose, we conducted a series of experiments in which the reaction time for the capitalization and non-capitalization decisions for different word types were measured. In experiments 1-4, words were presented in a sentence context, while in experiment 5 words were presented in isolation.

To summarize the results from the 5 experiments, it appears that lexical as well as syntactic processes are involved in the capitalization decision. The results suggest that an interactive exchange of information between these processes takes place, a finding that has also been reported in recent studies dealing with syntactic ambiguity resolution (e.g. Novick et al., 2003). The involvement of lexical processes in the capitalization decision was indicated by two findings. First, the capitalization decision for ambiguous words takes longer than for suffixed and non-suffixed words (experiments 1 and 3). It is assumed that this finding arose from the additional process needed for the selection of the appropriate word category entry of the ambiguous words, indicating a lexical access. This process is not required for suffixed and for non-suffixed words, since these words have only one word category entry. Such a finding would not be expected when the capitalization decision was made solely on the basis of syntactic information. If this were not the case, we would expect no increase in the reaction time of ambiguous words compared to suffixed and non-suffixed words. The assumption that the longer reaction time for ambiguous words is due to lexical processes is confirmed by the result that a different reaction time pattern was found for pseudo-words (experiment 2) and German words (experiment 1). Unlike German words, no systematic difference between the reaction times for the suffixed and the non-suffixed type on the one hand, and the ambiguous words on the other, was found in pseudo-words. It is assumed that the absence of the reaction time pattern observed for German words arose from the fact that pseudo words have no lexical entries. Furthermore, this result is consistent with the multiple access model, by which all lexical entries of a word are activated without any regard for contextual information (Prather & Swinney, 1988; for a review, see Hillert, 1997). According to this model, the longer decision time observed for the ambiguous words can be interpreted as follows: Lexical processes make both word category entries associated with a letter string, i.e. the verbal as well as the nominal entry, available. The syntactic context initially exerts no influence on the access to the appropriate form. The selection of the appropriate word category then follows on the basis of the syntactic information available during lexical access. Second, a main effect of frequency was found in experiment 4: Participants detected capitalization errors faster in

high frequency words than in low frequency ones. It is generally accepted, that frequency effects indicate lexical access (Jescheniak & Levelt, 1994).

On the other hand, there are hints towards the involvement of syntactic processes in the capitalization task. Different effects were found for words presented in the context of a sentence and those presented in isolation. Reaction time was affected by morphological factors only when words were presented in isolation: In contrast, no significant difference was found between the reaction time for suffixed and non-suffixed words when presented in a sentence context. Given that morphologically complex words are parsed into stems and affixes, in order to be recognized or produced, it has been assumed that the slower reaction time for suffixed words presented in isolation, compared to non-suffixed words, was due to the larger cognitive load associated with the processing of these words. These findings suggest that the reduced morphological influence on the decision time is caused by the presence of syntactic information delivered by sentential context. Thereby it can be taken as an indication for the involvement of syntactic processes in the capitalization decision.

The interactive exchange between lexical and syntactic processing leads, mostly, to accurate performance, as indicated by the small number of incorrect answers. However, this exchange also appears to affect the capitalization process in an unfavourable way, as indicated by the significant difference between the reaction times for German words (experiment 1) and pseudo-words (experiment 2). It has been argued that the faster reaction time observed for pseudo-words was due to the fact that they have no lexical entries, so the capitalization decision is based solely on the syntactic information delivered by the sentential context. German words, on the other hand, when presented in a sentence context, seem to cause a syntactic as well as lexical processing activation in order to resolve the task, even though the syntactic information alone would be sufficient to complete it. One might argue that the lexical processing could be activated by the fact that, in experiments 1-3, the target words were additionally presented in isolation after the participants heard them in a sentence context. However, this explanation is untenable because of the finding that lexical processes were also involved in the error detection experiment (experiment 4), as indicated by the obtained frequency effect, although participants were shown the target words only in a sentence context.

Another purpose of this study was to assess whether noun capitalization poses a larger cognitive load for the writer. In previous studies (e.g. Bock, 1990), evidence was found that noun capitalization facilitates reading. We hypothesized that, whereas capitalization facilitates the reading process, it should pose an additional cognitive load for the writer. This

hypothesis was not confirmed directly by the finding of this study: The task of capitalization resulted in increased decision times for non-capitalized words, compared to capitalized words. If we consider the finding of Bock (1986) that the capital/non-capital distinction is the factor that positively influenced the reading process, we can assume that the additional cognitive load is existent but, unexpectedly, results in increased delays for the non-capitalized words, rather than for their capitalized words. The faster reaction time for words which have to be written with an initial capital letter can be ascribed to the fact that, at least under the present experimental conditions, capitalization could have been considered by the participants as a “yes”-decision whereas non-capitalization was their “no”-decision. Further studies have to reveal if this is also the case in standard writing situations.

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