# Letter Detection in German Silent Reading: Issues of Unitization and Syllable-Final Devoicing[1]

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## Abstract

In a German variant of a letter-detection experiment, native speakers of German read passages in German, searching for the letters d or t. Many more instances of the letter d in definite articles and in the word und were missed than were missed in nouns, verbs, and adjectives. Subjects also missed more syllable-final instances of the letter d than syllable-initial d or syllable-final t. The first finding supports earlier similar findings by Healy (e.g., 1976) for English, and Ferstl (1991) for German, with respect to high frequency words in the language being read in units larger than the letter. The second finding is understood in terms of the German phenomenon of neutralizing the difference in pronunciation between d and t in syllable-final position.

## Introduction

Lexical access in silent reading has been studied in various ways for many years. One major issue is whether it is mediated by an internal phonological representation or directly by the visual representation, or, if indeed both methods are used in a "dual access" model. In their 1981 review of the reading research to that point, McCusker, Hillinger, and Bias note that along the continuum of necessity for phonological recoding -- with it playing no part in reading at the one extreme, and it being absolutely necessary at the other -- evidence of varying strengths has been found for every position. Thus, they conclude that there is likely a parallel operation of phonological recoding and visual access for most readers. The next question is what factors come into play in determining which route is used for a given word.

One paradigm for studying this issue is the letter detection task, in which a subject reads a passage at normal reading speed, marking every recognized instance of a particular target letter. An early letter detection study was done by Corcoran (1966) in which the letter e was missed more often when it was silent in the pronounced word than when it was a pronounced phoneme of the word. Several possible explanations were put forth, including those referring to position of the letter in the word, word frequency, inflectional/derivational morpheme versus stem status, and function versus content word status of the test word (see, e.g., Drewnowski & Healy, 1982). A series of studies by Healy and colleagues (Drewnowski & Healy, 1977; Hadley & Healy, 1991; Healy, 1976; Healy & Drewnowski, 1983; Healy, Oliver, & McNamara, 1987) resulted in the formulation of the unitization hypothesis: Words with high frequency in the language are more often perceived as a "unit or chunk rather than in terms of [their] component letters" (Healy, 1976, p. 235); thus letters are less likely to be detected in those words than in words occurring less frequently in the language. For example, Healy (1976) found that t in the, one of the most frequent words in English, was missed more often than t in other, less frequent, words. Furthermore, t in the was missed more often than t in thy, showing that the high error rate on the was not due only to the different pronunciation of the digraph th. In addition, t in a frequent noun such as fact was missed more often than in a rarer noun such as pact,

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showing that the effect of word frequency was not limited to function words.

In this paper, we will describe the results of a letter detection experiment in German. There are several reasons for the choice of German as the language under study. One reason is that the vast majority of the research with the letter detection paradigm has been conducted in English and Hebrew (see, e.g., Koriat, Greenberg, & Goldshmid, 1991). Although it is likely that languages in general, and languages related to English in particular, have many similarities in how the mental lexicon is structured and accessed, it is still important to verify those similarities. Likewise, it is important to discover differences due to differences between the languages per se and in how the speakers use the languages (Aitchison, 1987). The only letter detection study involving German known to us is one by Ferstl (1991), whose main focus was to replicate the English word frequency differences.

In the current experiment, subjects read passages from a German story while looking for first one target letter from the set (d,t), then the other, marking the letter as they read. To motivate them to read for comprehension, subjects answered a few simple questions about the content of the text after reading each passage, and they were given a warning of this test in advance.

By having subjects look for d in German, a comparison to results in English when searching for t can be drawn, due to the similarities between German articles, which start with d, and English the. In German the definite articles are used similarly to English the both in terms of discourse, and in their position in the noun phrase; furthermore, the initial phonemes of each are voiced and fairly close in place of articulation. Finally, the words in both languages are short (three letters), and the target letter is in the same location in the word. However, there are interesting differences beyond the orthographic and pronunciation issues (digraph vs. single letter, pronunciation in English but not in German different from that of the most common pronunciation of the letter, and fricative rather than obstruent pronunciation). The main difference is that German uses six forms of the definite article (der, die, das, dem, den, des), with the form being a function of the gender, number, and case of the noun it modifies. Additionally, German articles also may be used as relative pronouns or demonstrative pronouns.

The German experiments conducted by Ferstl (1991) compared the error rates in detecting the letter d in articles and in the word und ('and', another extremely common word), and compared these to the error rates in detecting d in other words. She found results for German similar to those of Healy for English, with regards to differences between detection errors in frequent function words compared to other, less common words. The first two analyses used in the present study follow those in the Healy (1976) and Ferstl (1991) studies by comparing letter detection errors in low frequency content wordsto letter detection errors for articles (as a class), und, and mit ('with').[2]

Another interesting fact about German is the widely observed phenomenon of syllable-final devoicing of obstruents (stop and fricative consonants). Specifically, the contrast between obstruents that differ only in voicing (i.e., differ only in that one has the feature [+voice] and the other [-voice]) is minimized or neutralized in syllable-final environment by changing [+voice] obstruents to [-voice]. For example, the word Hand is pronounced [hant], but in the plural, Hände, the d is now syllable-initial and the word is pronounced [hɛn də]. A non-word-final example is Adjektiv [at jɛk tif]. Devoicing occurs in all obstruents of a syllable-final cluster if it ends in a voiceless obstruent, for example, Landsknecht [lants knɛçt]. German syllabication is relatively straightforward in most cases, and typically coincides with morpheme boundaries (a major exception is represented above, when inflectional morphemes are added). However, within some multi-syllabic stem morphemes, the syllabication, as evidenced by the resulting syllable-initial dn or dl cluster, does not follow the usual path. For example, the word Handlich is pronounced [hant liç], but Handlung is pronounced [han dluŋ], and Ordnung is pronounced [ɔr dnuŋ].

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[2] Mit is the most frequent word that both ends in t and is of the same length as the articles and und; no similar word could be found that begins with t.

The third analysis used in the present studies compares letter detection errors for the letters d and t in content words (nouns, adjectives, verbs) in syllable-initial position to those in syllable-final position. In this analysis, as in the others, to count as 'initial' ('final'), the target letter can be anywhere in the onset (coda) of the syllable. The purpose of this analysis is to determine whether letter detection in a silent reading task is influenced by the spoken devoicing of the obstruents in syllable-final environment. If there is any phonological coding occurring, one might expect that syllable-final d (devoiced) would be missed more frequently than syllable-initial d (voiced), as well as being missed more frequently than syllable-final t. Likewise, the difference for the two positions of d should be greater than that for t. On the other hand, if the first part of a syllable is more salient than the last part, then error rates for final d and final t should both be more than those for initial d and t.

Alternatively, the German reader may still be aware of the underlying phoneme /d/ and access it as readily when it is devoiced as when it is not. Indirect support for this possibility comes from several studies quoted in the literature as showing that there are some underlying phonetic distinctions in words which are still maintained after the occurrence of phonological processes. For instance, longer vowel length was found before the devoiced (underlyingly voiced) obstruents (Dinnsen, 1985, and others cite this evidence). This argument leads to the prediction that error rates for syllable-final d should differ from those for syllable-initial d no more than error rates for syllable-final t would differ from those for syllable-initial t.

An analysis of the interaction of word frequency with position of d in the syllable will also be made, comparing error rates for the articles with error rates for low frequency syllable-initial d content words, and error rates for und with error rates for low frequency syllable-final d content words.

It was predicted that each type of high frequency function word would have a higher error detection rate than low frequency words with the same target letter in the same syllable position. It was also expected that for words of both frequency levels, the syllable-final targets would have higher error rates than the syllable-initial targets. Interestingly, even though Ferstl (1991) was not looking for any effect of syllable-final devoicing, her results agree with this prediction. Her subjects missed 85.71% of the ds in the word und, 43.42% in the combined set of articles, and 28.86% in other words.

## Method

### Subjects

Twenty native speakers of Germanparticipated in this experiment. The age range of the subjects was 22 to 38. Six were female and 14 were male. Sixteen were from Germany, three were from Austria, and one was from Switzerland. They had been in the United States for varying amounts of time, ranging from one month to ten years. All were fluent speakers of English as a second language.

### Materials and Apparatus

All test materials were in German. The two test passages were portions of a short story, Die Fahrt ('The Drive') by Gabriele Wohmann (1975). The first passage contained 308 words, and the second passage contained 385 words. Two additional pages were associated with each passage: A paragraph of instructions was on the page before the passage, and a set of three short comprehension questions about it was on the page after it.

The number of words with target letters in the target positions for each passage are given in Table 1. Low-frequency words were content words in which the target letter occurred only once in the stem of the word, and in only one syllable position (the single exception was made that words containing two instances of the same target adjacent to each other in a syllable were included but counted as only one target; e.g., Bett was a test word with the two ts counting as one target). High-frequency words were the articles (der, die, das, dem, den, des), und, and mit.

The instructions before each passage told the subjects to read the passage silently at normal reading speed, circling the target letter when seen, but not to go back if they realized they had missed an instance of the letter. The instructions also told the subjects to turn to the page following the passage when they were done

reading the passage, where they would find questions about the content of the text just read. On the comprehension question page, subjects were instructed to answer the questions without turning back to the text. The questions were included to give the subjects an added incentive to read for comprehension. Each of these items, for each passage, was typed on a separate sheet of paper. A 12-point, one-and-a-half-spaced, Palatino font type was used throughout. Finally, after the experiment, each subject filled out a brief demographics questionnaire which was in English.

The experiment was carried out in various locations, wherever was convenient for the subjects and experimenter. It took approximately 15 minutes for each subject. Some subjects were run simultaneously.

## Procedure and Design

The experimental task was to search for a particular letter while silently reading a prose passage, circling that letter whenever seen, but not going back in the reading if it was realized that a letter was missed; and, after reading, to answer a few short comprehension questions about the material read.

Each subject was handed a packet with all the materials and told to go through the packet in order, and not to go back to any previous pages. After reading each passage, the subjects turned to the next page where they answered the comprehension questions on the content of the passage. After finishing the questions for the first passage, the subjects went immediately to the instructions for the second passage. The instructions for the second passage were identical to those for the first passage except for the difference in target letter. After reading the second passage and answering its questions, the subjects were requested to fill out the demographics questionnaire.

All subjects read the passages in the same order, but the order of targets was counterbalanced across subjects.

The design of each of the three analyses was a 2 x 2 factorial. (The between-subjects factor of letter order was found in a preliminary analysis to yield no significant main effect or interactions; therefore the analyses reported here do not include it.) The two factors were varied within subjects. The factors of the first analysis were letter position in syllable (initial, final) and word frequency (high, low). The factors of the second analysis were word frequency and target letter (d, t). The factors of the third analysis were letter position in syllable and target letter. The first, second, and third analyses were restricted to words containing d, words in which the target letter was syllable-final, and low-frequency words, respectively. The dependent variables were the letter detection error rates for the target letters in the test words.

## Results and Discussion

The first two analyses examined the issues of word frequency and the unitization hypothesis. The first analysis compared error rates for target letters in high- and low-frequency words when the letter was held constant, and the second analysis compared error rates when the position of the target letter was held constant.

As predicted by the unitization hypothesis, subjects made more errors in detecting the letter d in high frequency words (articles and und combined) than in low frequency words (syllable positions combined). The same was true of either letter in syllable-final position:

*Table 1* Number of test words by passage, target letter, word frequency, and syllable position of target letter.

| | high-frequency test words | | low-frequency test words | |
|---|---|---|---|---|
| | syllable-initial | syllable-final | syllable-initial | syllable-final |
| Test words with d | | | | |
| Passage 1 | 31 | 10 | 10 | 8 |
| Passage 2 | 27 | 13 | 11 | 11 |
| Test words with t | | | | |
| Passage 1 | -- | 5 | 16 | 14 |
| Passage 2 | -- | 2 | 17 | 14 |

More errors were made in detecting d or t in und and mit than in the low frequency words. Table 2 summarizes the results. Repeated measures analyses of variance showed a significant main effect of word frequency, $F(1,19) = 42.7$, $p < .001$ for the first analysis, and $F(1,19) = 80.5$, $p < .001$ for the second analysis. Thus, the present data replicate Ferstl's (1991) findings supporting the unitization hypothesis.

In support of the hypothesis that the position of d in the word should affect its likelihood of detection, when only words with d are considered, subjects missed significantly more syllable-final ds (M = 56.6%) than syllable-initial ds (M = 26.5%), $F(1,19) = 62.1$, $p < .001$. This effect of position held for both high- and low-frequency words although it was larger for high-frequency words; the interaction of word frequency and syllable position was significant, $F(1,19) = 13.8$, $p = .002$. More importantly, the third analysis showed that there was a significant interaction between syllable position of the letter and the letter itself, $F(1,19) = 28.7$, $p < .001$ (in addition to a main effect of syllable position, $F(1,19) = 10.8$, $p = .004$). This interaction reflects the fact that the large difference in error rate for initial and final d was not found for initial and final t, as shown in the third and fourth columns of Table 2. In other words, it is not only position in the syllable that is important, but the combination of the particular letter and the position of the letter.

The data also supported the hypothesis that the devoicing of the voiced stop d would negatively affect its detection in silent reading; that is, the voicing neutralization in the spoken language did seem to affect the letter detection of the letters in syllable-final position. This evidence derives from the fact that (a) syllable-final ds (in both high and low frequency words) were missed much more frequently than syllable-initial ds, and (b) they were also missed much more frequently than syllable-final ts, but (c) syllable-final ts were not missed more frequently than syllable-initial ts. This combination of results would not be expected if letters were missed simply as a function of their location in the syllable or word. Nor would these results be expected if awareness of the underlying phoneme remained more salient than the effect of the pronunciation change. Thus, these data support the hypothesis that this particular pronunciation phenomenon may indeed impact reading processes in German, and provide support for phonological recoding in (German) reading. This finding also implies that syllable boundaries, even when not at the same point as morpheme boundaries, are salient even in silent reading.

The letter d was found less frequently than the letter t; the main effect of target letter was significant in both the second, $F(1,19) = 30.6$, $p < .001$, and the third, $F(1,19) = 12.9$, $p = .002$, analyses. This finding is not surprising, because different letters might be easier or harder to find due to differences in their visual features. Nevertheless, the statistical analyses bore out the prediction that there is an important interaction between the identity and syllable position of the target letter. That is, only the target letter d, not t, showed the pattern of a higher error rate for the final than for the initial position. Hence, the interaction must be due to something special about the letter d in the syllable-final position, and one thing that is special is the obstruent devoicing.

*Table 2* Mean error rates as a function of target letter, word frequency, and syllable position of target letter.

| Target | high-frequency | | low-frequency | |
|---|---|---|---|---|
| letter | initial | final | initial | final |
| d | .387 | .815 | .144 | .315 |
| t | --- | .580 | .111 | .093 |

## Summary

Two main hypotheses have been supported in this study. Effects of unitization, as reflected in letter detection rates for extremely common and frequent words as compared to less common, lower frequency words, are very strong, just as they are in English. In addition in German, the very regular phonological neutralization of voiced obstruents in syllable-final position also affects letter detection, and thus points to phonological recoding affecting lexical access. The current results were only found for the alveolar pair, d and t. It would be of interest to determine whether similar results would be found for the velar and bilabial obstruent pairs.

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