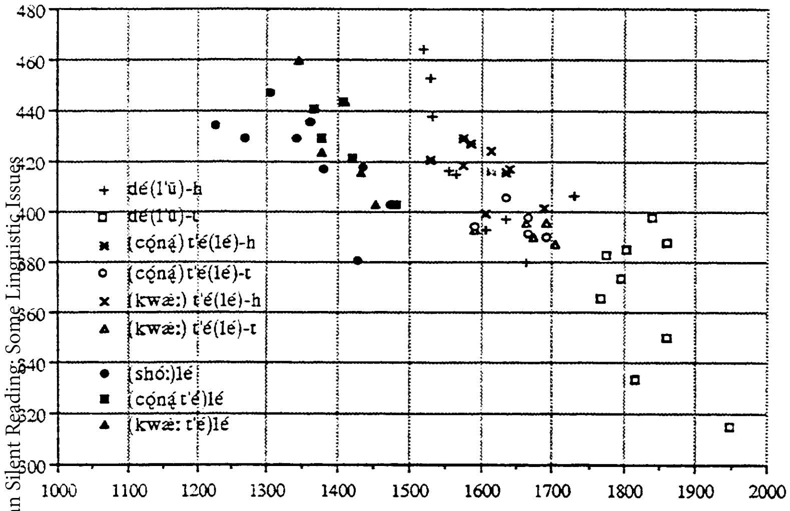

Figure 7. Initial and noninitial *é*.

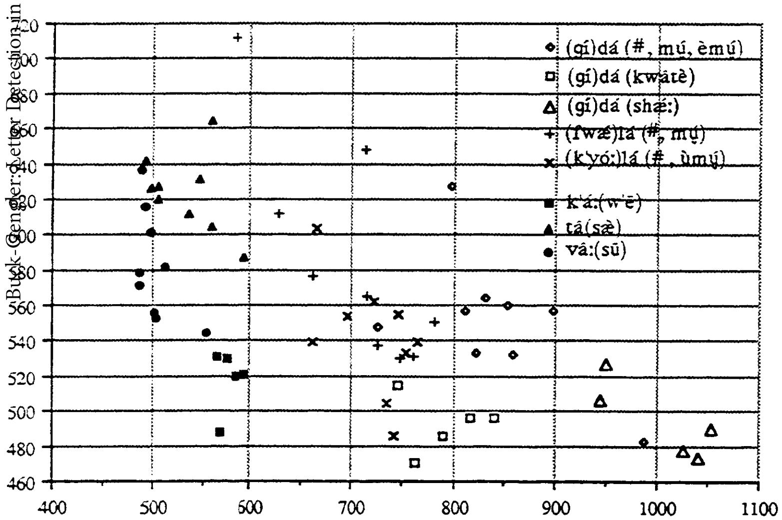

Figure 8. Initial *á*, *ǎ* and noninitial *á*.

LETTER DETECTION IN GERMAN SILENT READING: SOME LINGUISTIC ISSUES*

CAROLYN BUCK-GENGLER

In a German variant of a letter-detection experiment, native speakers of German read passages in German, searching for the letter *d*, *t*, *n*, or *r* in four passages. 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*. Cluster status and word location of the letter did not affect the results for final *d*. 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. Other preliminary analyses of various linguistic phenomenon were more inconclusive, and point out areas for further research.

1. 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 by only 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, & 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 particular paradigm for studying this 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. With this task, psychologists have over the course of many experiments attempted to isolate various factors that influence the choice.

An early letter detection task 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 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. This led to several studies by Healy and colleagues (Healy 1976; Drewnowski & Healy 1977; Healy & Drewnowski 1983; Healy, Oliver, & McNamara 1987; Hadley & Healy 1991) which 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 1976:235); thus letters are less likely to be detected in those words than in words occurring less frequently in the language. Some of the experiments in Healy's original study (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, especially content words such as nouns. Furthermore, *t* in *the* was missed more often than *t* in *thy*, showing that it was not due only to the different pronunciation of the digraph *th*. In addition, *t* in a frequent word such as *fact* was missed more often than in a rarer word such as *pact*, again showing frequency effects, as well as controlling for word location and showing the effect to occur word-finally as well as word-initially.

Thus one type of unit in facilitating lexical access is the word, but there could well be units within the word, such as the syllable, the stem or root, and even common orthographic combinations such as consonant clusters. It is also possible that there are combinations of words that occur so frequently together that they can be recognized more quickly as a unit, for instance PREPOSITION+ARTICLE in a prepositional phrase. Healy, Conboy, & Drewnowski 1987 conducted an experiment that provides 'evidence for the existence of reading units that include more than one word, ... also ... supporting the hypothesis that the formation of these units depends more on familiarity than on linguistic function' (p. 289). In other words, the units pointed to in this instance cross syntactic boundaries, the articles associating not with the noun in the noun phrase, but with the preposition in the higher prepositional phrase.

There are also various views as to what parts of words are most salient, and how words are stored in the mental lexicon. The answers to these questions will probably influence detection of letters in a word. Both Aitchison 1987 and Emmorey & Fromkin 1988 suggest, in their reviews of various studies of the mental lexicon, that there are entries in the lexicon in which some affixes are already attached, but that other affixes are more likely to be stored separately and assembled when required. Aitchison attributes the difference to derivational (attached) versus inflectional (stored separately) morphemes. Emmorey & Fromkin read the evidence as showing that the difference is between Level I morphology (which causes phonological changes in the stem) and Level II morphology (which does not affect the stem). Aitchison also relates research indicating a 'bathtub effect' for word memory,[1] in which the beginnings and ends of words are more salient than the middle parts of words. Emmorey & Fromkin indicate that words seem to be stored at least by their initial phonemes or syllable, with other possibilities including storage by length of word (e.g. all words of the same length, at least for mono- and disyllabic words, stored together) and by final segments. One model they cite for beginning-of-the-word storage is the cohort model developed by Marslen-Wilson for speech recognition.[2] A reading version of this model might imply recognizing letters starting at the beginning of the word, and continuing until the word is uniquely identified (context would probably play a large part in identification, as well). Emmorey & Fromkin also cite support for parallel orthographic and phonological paths to accessing the lexicon. However, at least some of the evidence for the mental lexicon models reviewed in these articles, and the models proposed by Aitchison and Emmorey & Fromkin, is based on production/speech errors rather than on recognition in reading, and thus may not apply directly to access during reading.

In this paper, I will describe the results of a letter detection experiment in German. The psychology tradition tends to focus more closely on variables such as length, frequency, position on the page, type size, and so on. This paper is a move to introduce more linguistic factors into the discussion. It begins with the issue of phonological recoding during reading, which provides a bridge because phonological recoding is one of the areas that psycholinguists, psychologists, and even cognitive computer scientists are interested in. Some other linguistic issues will also be addressed, such as clusters and information status of the article. This study by no means exhausts the set of linguistic factors that might be interesting to study using this paradigm, nor does it come near to resolving all the issues in the factors that are analyzed. Rather, it is intended to provide a first look from a linguistic viewpoint at some of the issues of language and reading that can be viewed in a new way through this task.

There are several reasons for the choice of German as the language under study. One reason is that the vast majority of the research, both in this area and on the mental lexicon in general, has been done in English. While 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 nevertheless still important to verify those similarities. Likewise, it is important to discover differences due to differences between the other languages and English, and also in how the people studied use their own, and other, languages (Aitchison 1987). The only study of this type in German I have been able to find is Ferstl 1991, whose main focus was to replicate the Healy word frequency findings. Another reason is the similarity of German and English. In this study, I will explore some linguistic issues that are very similar in English and German, and several others that involve processes found in German but not English.

In the current experiment, subjects read passages from a German story while looking for first one target letter from {*d*,*t*}, then the other, marking the letter as they read. Some subjects also read additional passages for which the target letters were {*n*,*r*}. Unlike the majority of Healy (et al.)'s experiments, the present experiment used a text written by a German author that was not

constructed for the purposes of any experiment, but rather is a natural, short story text. The purpose was to study results obtained while subjects are doing realistic reading. It was felt that a text created for the purpose of the experiment, with all conditions carefully balanced and well represented with a good number of tokens, would be very artificial and would distract the reader away from the ideal case of normal reading for comprehension. The drawbacks are that there are fewer tokens than optimal of a particular type of target in some cases, and the numbers of targets are not well balanced for some variables. Nevertheless, some interesting insights can still be obtained, even though they may not be as strong from this particular text. Also, some texts may lend themselves better to studying some particular phenomena, while others are better for different phenomena.

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 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. However, there are interesting differences beyond the orthographic and pronunciation issues (digraph vs. single letter, change of pronunciation in English 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, with the form being a function of the gender, number, and case of the noun it modifies, as illustrated in Table 1. Additionally, German articles also may be used as relative pronouns or demonstrative pronouns.

Case	Masc	Fem	Neut	Plural
Nom	der	die	das	die
Acc	den	die	das	die
Dat	dem	der	dem	den
Gen	des	der	des	der

TABLE 1. German article paradigm.

The German experiments carried out by Ferstl 1991 compared the letter detection error rates in detecting the letter *d* in articles and in the word *und* 'and' (another extremely common word), and compared them 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 detecting the *d* in articles and *und* as compared to other, less common words. The first group of analyses will replicate the studies of Healy 1976 and Ferstl 1991 by comparing letter detection errors in the test low frequency content words to letter detection errors for articles (as a class), *und*, and *mit* 'with'.[3]

Another interesting fact about German is its devoicing of obstruents. Although many texts call this devoicing 'word-final', and Hock (1986:240) indicates that 'languages with syllable-final devoicing are quite rare,' in German devoicing actually occurs syllable-finally, as is borne out by several other texts (see, for instance, Katamba 1989:167, and Vennemann 1988). 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 obvious path. For example, the word *Handlich* is pronounced [hant lɪç], but *Handlung* is pronounced [han dlʊŋ], and *Ordnung* is pronounced [ɔr dnʊŋ].

The second group of analyses will be of letter detection errors for the letters *d* and *t* in content words (nouns, adjectives, verbs), in syllable-initial position versus in syllable-final position. In this analysis, as in the previous one, to count as 'initial' ('final'), the target letter can be anywhere in the onset (coda) of the syllable. This analysis is to determine if there is an effect on letter detection in a silent reading task from 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) is missed more frequently than syllable-initial (voiced) *d*, as well as being missed more frequently than syllable-final *t*.[4] Likewise, the difference for the two positions of *d* should be

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greater than that for *t*. On the other hand, if the syllable is perceived as a unit AND the first part is more salient than the last part, then error rates for final *d* and final *t* should both be significantly more than initial *d* and *t*.

Alternatively, the German reader may still be aware of the underlying phoneme /d/ and access it as readily as when it is not devoiced. Indirect support for this possibility comes from several studies quoted in the literature as showing that there are some underlying phonetic distinctions in the 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). If this is the case, this would predict that error rates for syllable-final *d* should differ from those for syllable-initial *d* no more than the error rates for syllable-final and syllable-initial *t* differ.

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 is expected that each type (in terms of letter and its position in the word) of high frequency function word should have a higher error detection rate than low frequency words with the same target letter in the same syllable position. It is also expected that for words of both frequency levels, the syllable-final targets should 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 *d*s in the word *und*, 43.42% in the combined set of articles, and 28.86% in other words.

(These first two groups of analyses, for frequency and syllable-final obstruent devoicing, comprise the primary or first round of analyses. The remainder of the analyses comprise the second round of analyses, and are designed to delve further into what the data can tell us about German reading processes.)

The devoicing result may be confounded with the issue of consonant clusters. As noted above, it is possible that clusters are one unit that a reader might recognize and not process further. Furthermore, in particular consonant clusters, there is a particular phonetic process that affects the letter *t*, namely the loss of aspiration in syllable-initial *st* and *str*, just as in English. In general, German and English behave similarly in aspiration of initial voiceless obstruents except after *s*; syllable-finally they are in free variation between aspirated, unaspirated, and unreleased (Moulton 1962). Thus, one would expect initial *st*(*r*) clusters to increase error rates for initial *t*, and, if clusters form a recognizable unit, that clusters in general should increase the error rates for letter detection. Whether this is solely because of the cluster or additionally because of the loss of aspiration will probably be difficult to test (and will not be addressed here), as there is no voiced analog in German to compare to. However, if the devoicing encoding is affecting the recognition task, the effect should still occur when such clusters are eliminated from the analysis.

The result may also be impacted by whether the target letter is medial or peripheral. If something like the 'bathtub' model mentioned in Aitchison 1987 is relevant in reading, then the effect may differ in strength or may not even exist in one of those environments. An additional analysis will separate these two environments to examine whether the effect is related to word boundaries or is affected by the presence or absence of the orthographic physical space before or after letters. This analysis can also confirm that *d*s are affected not only word-finally, but also word-medially.

As noted above, the German article carries more information on it than English *the*. To some extent this information is predictable. For example, prepositions determine the case of the following noun phrase. Some prepositions require a particular case, while others can take one of two cases, depending on various factors. However, it is conceivable that the difference in information that is in the German article as compared to *the* WILL influence letter detection error rates for the articles in German. It is also possible that because the information is encoded AFTER the *d*, this effect would be stronger only if the final letters, rather than *d*, were being searched for.

In an unplanned analysis, Ferstl 1991 found evidence that 'the case of the article seemed to have an influence on letter detection over and above frequency' (p. 10): Error rates roughly correlated with the respective frequency of the particular form of the article (the higher the error

rate, the more frequent the form).[5] Error rates also increased as the case of the article differed, with accusative having the lowest rate, genitive next, dative next, and nominative with the highest error rate. However, Ferstl cautioned that these particular findings are preliminary, the text was not designed to properly deal with the interaction of case, gender, and potential for target letter in the surrounding words, and that for some forms she had too few tokens to rely upon. She advocated a study with matched pairs of cases. The present study, using a natural text, was not set up to finely pinpoint the differences in the way Ferstl suggested. Nevertheless, preliminary analyses of such things as shape, case, whether the article is after a preposition, and whether the target letter is *d* or the last letter of the article will be attempted, to see what can be learned.

2. METHOD.

2.1. SUBJECTS. Twenty native speakers of German, who at the time of the experiment resided in or were visiting the Boulder, Colorado, area, participated in this experiment. The age range of the subjects was 22 to 38. Six were female and 14 were male. Sixteen were from Germany (mostly the western part), 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.

2.2. MATERIALS AND APPARATUS. All test materials were in German. The core was the actual passages to be read. The passages were portions of a short story, 'Die Fahrt' ('The Drive') by Wohmann 1975. Because decreases in subject performance can occur in very long passages (around 500 words, A. F. Healy, personal communication)--that is, subjects can start to miss fewer letters than they normally would if the task goes on too long without some change--the story was split into four similarly sized parts deemed to be long enough to have a good number of targets of each type, yet short enough that the point of diminishing returns was not reached. Each passage fit onto one page. Two additional pages were associated with each passage: A paragraph of instructions was on the page before the passage, and a set of two or three questions about it was on the page after it. The number of words in each passage was 308, 385, 293, and 344, respectively. Where relevant, Passages 1 and 2 will be referred to as Experiment 1, and Passages 3 and 4 will be referred to as Experiment 2.

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. The page following each passage had short comprehension questions, three for the first two passages, and two for the final two passages. Subjects were instructed to answer the questions without turning back to the text. Questions did not differ based on which condition (order of target letters) a subject was in. The questions were included to give the subjects an added impetus 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 15-25 minutes for each subject. Some subjects were run simultaneously.

2.2.1. TEST WORDS. This section lists the criteria for selection of test words (that is, which words were examined to see if the target letter was circled or missed) for each analysis, and summarizes how many test words are in each category. As discussed above, due to the fact that a real German text was used, the numbers in each category are not balanced, and some target types have few actual targets in their counts.

WORD FREQUENCY AND SYLLABLE-FINAL DEVOICING. The number of words with target letters in the target positions for each passage are given in Table 2. 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 *t*s counting as one target). High-frequency words were the articles (*der*, *die*, *das*, *dem*, *den*, *des*), *und*, and *mit*. Words in which the target letter was upper case were also excluded from the sets of test words.

	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

TABLE 2. Number of test words by passage, target letter, word frequency, and syllable position of target letter.

CONSONANT CLUSTERS. Using the low frequency test words identified above, words will be further grouped depending on if the target letter is in a cluster or not. First, the previous analysis of low frequency words (factors: letter and syllable position) will be repeated, this time excluding words in which the target letter *t* in syllable-initial position is part of an *st* or *str* cluster, that is, words where *st* or *str* are part of the onset of the syllable, such as in *stumpf*. The number of words affected is shown in Table 3.

	all test words with initial *t*	no *st(r)*	contains *st(r)*
Passage 1	16	6	10
Passage 2	17	11	6

TABLE 3. Number of test words with *t* as target letter in initial position, with and without initial *st(r)*.

Next, all of the low frequency words will be divided into cluster and non-cluster groups, and the same letter by syllable position analysis will be made with cluster status as an additional factor. The definition of cluster used is any multi-consonant grouping, including those that cross syllable boundaries; exceptions are in clear cases of words (mostly compounds) where the syllable boundary and morpheme boundary are obviously the same. (In these cases, the cluster is also not a commonly seen cluster in the language, as compared to, for instance, *nd*, *st*, *tz*, etc.) The number of words in each group is given in Table 4.

	syllable-initial		syllable-final	
	not in cluster	in cluster	not in cluster	in cluster
Test words with *d*				
Passage 1	7	3	3	5
Passage 2	8	3	4	7
Test words with *t*				
Passage 1	3	13	5	9
Passage 2	4	13	4	10

TABLE 4. Number of test words by target letter, syllable position, and cluster status of target letter.

A third analysis will look only at words in which the target letter, either *d* or *t*, is both word medial and syllable initial. Error rates for words in which the target letter is NOT in a cluster (*Glieder*, *Seite*) will be compared with error rates for words in which the letter is in a cluster that crosses syllable boundaries (*finden*, *wahrhaftig*) to see if being in a cluster, even though it crosses syllable boundaries, increases the error rates for those letters. The number of words in each group is given in Table 5.

Finally, the fourth cluster analysis looks at only the *d*-words from the second cluster analysis (first two lines of Table 4) to give further insight into the devoicing issue. Specifically examined are *d* clusters that cross syllable boundaries, namely *n-d* clusters, and their relationship to non-

cluster *ds* and *d* clusters that are syllable-final. The purpose is to see if *ds* in clusters that cross syllable boundaries have error rates closer to the non-cluster initial *ds*, or if being in a cluster, even across boundaries, causes error rates closer to clusters that do not cross syllable boundaries (in which the *d*, being syllable-final, is subject to devoicing).

	not in cluster	in cluster
Targets with *d*		
Passage 1	4	3
Passage 2	7	3
Targets with *t*		
Passage 1	3	7
Passage 2	4	8

TABLE 5. Number of test words with syllable-initial, word-medial target letter by target letter and cluster status of target letter.

WORD POSITION OF TARGET LETTER. The next analysis is of peripheral versus medial position of the target letter in the word. This analysis includes all content words of the original analyses regardless of cluster status of the target letter. Furthermore, a letter in a cluster counts as peripheral even if it is not the first letter of the cluster, for instance *t* in *stumpf*. Table 6 gives the number of test words in each environment.

	syllable-initial		syllable-final	
	peripheral	medial	peripheral	medial
Test words with *d*				
Passage 1	3	7	5	3
Passage 2	1	10	9	2
Test words with *t*				
Passage 1	6	10	10	4
Passage 2	5	12	10	4

TABLE 6. Number of test words by target letter and syllable and word position of target letter.

ARTICLE ISSUES. For the analyses of article shape, case, and comparison of articles that are after a preposition versus those that are not, the article *des* was excluded because it occurred once in one passage, and did not occur in the other passage. Also, because there were only, at most, two articles being used as relative pronouns per passage, they were also excluded. As above, articles starting the sentence and thus capitalized were also excluded.

Several analyses are included in this group. First, error rates for the five articles are compared to their frequencies as given in both Wängler 1963 and Meier 1967, and compared to Ferstl's 1991 findings. Table 7 gives the number of instances of each article, as well as their frequencies. Wängler frequencies are from the written language list.

	Passage 1	Passage 2	frequency rank Meier	Wängler
der	7	6	2	1
die	5	6	1	2
das	8	7	7	6
dem	6	2	15	14
den	3	5	6	5
(*des*	*0*	*1*	*12*	*17*)

TABLE 7. Number of articles in the passages and their frequency ranks.

Next, an analysis by case is made. However, an analysis of articles broken down into all the case/gender/number conditions is not made, due to the fact that several conditions have no entries. Table 8 shows the number of articles by case of the noun phrase.

	Nom	Acc	Dat	Gen
Passage 1	8	11	9	1
Passage 2	4	14	6	3

TABLE 8. Number of articles by case of the noun phrase.

In the third analysis of this group, the articles were separated into groups based on whether they follow no preposition, a single-case preposition, or a dual-case preposition. Single-case prepositions in the text include *für*, *gegen*, and *durch*, which take accusative case, and *aus*, *mit*, and *von*, which take dative case. Dual-case prepositions in the text include *auf*, *hinter*, *über*, *unter*, *an*, and *in*, which take either accusative or dative case, depending on the verb and the situation (typically, if movement is indicated, then accusative case is used, and if location is indicated, dative case is used). As a follow-on, an additional analysis examines only the accusative and dative articles with regard to following a preposition, because only in those two cases can all three conditions be seen. The numbers of articles in these conditions are shown in Table 9.

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With data from Experiment 2 combined with that of Experiment 1, error rates for circling *d*s versus circling *r*s and *n*s in articles are examined. Table 10 gives the numbers of instances of articles overall, *den*, and *der*, in each passage.

	no prep	single-case prep	dual-case prep
all cases			
Passage 1	18	7	4
Passage 2	16	5	6
Accusative			
Passage 1	8	2	1
Passage 2	9	3	2
Dative			
Passage 1	1	5	3
Passage 2	0^6	2	4

TABLE 9. Number of articles in the passages as a function of whether the article follows a preposition.

2.3. 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 additionally, 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 (in English) to go through the packet in order, and not to go back to any previous pages. The order of the pages associated with each passage was instructions, passage, and comprehension questions about that passage. The final page of the packet was a brief questionnaire. 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 one passage, the subjects went immediately to the instructions for the next passage. The instructions for the second, third, and fourth passages were nearly identical to those for the first passage except for a difference in target letter. After reading the last passage and answering its questions, the subjects were requested to fill out the questionnaire.

	order of looking for letter			
	tdnr	tdrn	dtnr	dtrn
looking for initial letter (*d*)				
all articles	27	27	31	31
der + *den*	11	11	10	10
der	6	6	7	7
der	5	5	3	3
looking for final letter (*n* or *r*)				
der + *den*	13	9	13	9
der	6	1	6	1
den	7	8	7	8

TABLE 10. Number of articles, *der*, and *den* for each between-subjects grouping.

Eight subjects did Experiment 1 (the first two passages) only, and looked for *d* or *t*. The remaining 12 subjects did Experiment 1 followed immediately by Experiment 2, reading all four passages in one sitting. In Experiment 1, they looked for *d* or *t*, just as the first group did. In Experiment 2, they looked for *n* or *r*.

All subjects read the passages in the same order, but the order of targets in a particular passage was counterbalanced across subjects: In Experiment 1 half of the subjects looked for *t* first and *d* second, the other half looked for *d* first and *t* second. In Experiment 2, the order of targets in a particular passage was again counterbalanced across subjects, and across d-first/t-first condition. Half of the subjects that looked for *d* first looked for *n* in the third passage and *r* in the fourth passage, and the other half looked for those letters in the reverse order. The same was true for the t-first group.

The design of the first three analyses of the primary round of analyses involving Experiment 1 was a 2 x 2 x 2 mixed factorial. (The first factor, the between-subjects factor of letter order, was found in a preliminary analysis to yield no significant main effect or interactions in most analyses; therefore while the analyses reported here included it, it will not be discussed except where appropriate.) The second and third factors were varied within subjects. The factors of the first analysis were letter position in syllable (initial, final) and frequency (high frequency, low frequency). The factors of the second analysis were frequency and target letter (*d*, *t*). The factors of the third analysis were letter position in syllable and target letter. Two additional analyses in the primary round were 2 x 2 mixed factorials; the first factor of each was the between-subjects factor of target letter order (*d*-first, *t*-first), and the second factor of each was the within-subjects factor of letter position in syllable (initial, final). Additional, more fine-grained analyses were also made to

examine subsets of words, with one or more of the following within-subjects factors: cluster status (not in cluster, in cluster), letter position in word (peripheral, medial), shape of article, case of article, whether and what kind of preposition the article comes after (no preposition, single-case, or dual-case preposition), and position of letter in the article (*d*=first letter, *n* or *r*=last letter). The dependent variables were the letter detection error rates for the target letters in the test words.

3. RESULTS.

3.1. UNITIZATION HYPOTHESIS AND SYLLABLE-FINAL DEVOICING. The first round of analyses was for frequency and for letter position in the syllable. The first analysis was for the letter *d* and includes the factors of frequency and syllable position of the letter. The second analysis was for the letters *t* and *d* and includes the factor of frequency. Only syllable-final position was considered because there are no functor or other short, frequent words in German with the letter *t* in syllable-initial position. The third analysis was for low frequency content words only and includes the factors of letter and syllable position of the letter. Two additional analyses, one for the letter *d* and one for the letter *t*, examined content words only and included the factor of syllable position of the letter.

In these analyses only words with the target letter in the stem were included; letters in the beginning (or end) of the word and word-medial letters were treated alike: Position in the syllable was the only factor. Table 11 summarizes the results in terms of mean error rates (i.e., proportion of errors, that is, proportion of letters missed of all target letters in a particular condition) as a function of word frequency, letter, and syllable position of the letter.

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

TABLE 11. Mean error rates as a function of target letter, word frequency, and syllable position of letter.

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). A repeated measures analysis of variance showed a significant main effect of word frequency, $F(1,16) = 41.61$, $p < .001$. This finding was also true for the letter *t*: More errors were made detecting *t* in *mit* than in low frequency words with syllable-final *t* with a significant main effect of word frequency, $F(1,16) = 95.44$, $p < .001$.

In support of the hypothesis that the position of *d* in the word should affect its detection, subjects missed significantly more syllable-final *d*s ($M = 56.5\%$) than syllable-initial *d*s ($M = 26.5\%$), $F(1,16) = 60.93$, $p < .001$. When only low frequency words with *d* were considered, syllable position was still significant, $F(1,18) = 33.61$, $p < .001$. In addition, there was a significant interaction between the word frequency and the location of the *d* in the syllable, $F(1,16) = 14.82$, $p = .002$. This result reflects the fact that the difference between the articles (*d* in initial position) and *und* (*d* in final position) in this experiment (see also Ferstl's 1991 study in which the relevant percentages were 43.42% and 85.71%, respectively) was greater than the difference between *d* in initial and final positions in low frequency words. Alternatively, this result also reflects the fact that the difference between *und* and low frequency words with *d* in final position was greater than the difference between articles and low frequency words with *d* in initial position.

In the second analysis, of high and low frequency words with syllable-final target letters, syllable-final *d*s were also missed more frequently than syllable-final *t*s, $F(1,16) = 28.96$, $p < .001$. This result is also supported by the significant interaction between letter and position of letter in the syllable in the third analysis (low frequency words only), $F(1,16) = 26.17$, $p < .001$. This reflects the fact that the large difference in error rate for initial and final *d* was not found for initial and final *t*. This interaction being statistically significant means that it is not only position in the syllable that is important, but that the combination of the particular letter and position also affects the error rate. As noted above, the difference between syllable-initial and -final *d* in low frequency words was significant. However, the difference between syllable-initial and -final *t* in low frequency words was not significant, $F(1,18) < 1$.

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3.2. CLUSTERS. The first cluster analysis attempts to provide a partial explanation for the error rate for syllable-initial *t* relative to syllable-final *t*, excluding *st(r)* clusters from the syllable-initial *t* words. Table 12 gives the mean error rates for each letter. For initial *t* the means are shown for all words as well as for only those words which do not include *st(r)*.

	syllable position of letter	
target letter	initial	final
d	.144	.315
t, includes initial *st(r)*	.111	.093
t, excludes initial *st(r)*	.077	.093

TABLE 12. Mean error rates for low frequency words as a function of target letter and syllable position of target letter.

As noted above in the analysis for low frequency words with *t*, when the words containing initial *st(r)* were not excluded, the difference between syllable-initial and -final positions was not significant. However, even when words with *st* or *str* were excluded, the interaction between position and letter was significant, $\underline{F}(1,18) = 24.18$, $\underline{p} < .001$, and in a separate analysis of the *t* test words only, there was not a significant difference in initial and final *t* error rates, $\underline{F}(1,18) < 1$. Either of these results taken alone, and both taken together, indicate that although excluding initial *st(r)* did lower the syllable-initial *t* error rate, the difference in initial and final *t* was still not significant, whereas the interaction of letter and position (reflecting the difference in initial and final *ds*) was significant.

Next, results for words with the target letter in a cluster were separated from those for words in which the letter was not in a cluster. The results are summarized in Table 13 in terms of mean error rates as a function of letter, syllable position of the letter, and cluster status of the letter. In three of the four letter/position conditions, subjects made more errors on letters in clusters than on letters not in clusters. (In the fourth, *t* in final position, the error rates were for all purposes equal.) This result can only be classified as a trend, however, because cluster status did not reach significance, $\underline{F}(1,18) = 4.03$, $\underline{p} = .057$. On the other hand, more *ds* than *ts* were missed, $\underline{F}(1,18) = 15.11$, $\underline{p} = .001$, more syllable-final letters than syllable-initial letters were missed, $\underline{F}(1,18) = 8.09$, $\underline{p} = .01$, and the interaction of letter and syllable position was significant as well, $\underline{F}(1,18) = 15.35$, $\underline{p} = .001$. This finding is further support for the hypothesis regarding the position of the *d*, because the interaction of letter and syllable position did not depend on whether the target letter was in a cluster or not.

		syllable position of letter	
cluster status	letter	initial	final
target letter not in cluster	*d*	.101	.300
	t	.075	.097
target letter in cluster	*d*	.217	.324
	t	.119	.093

TABLE 13. Mean error rates as a function of target letter, syllable position of target letter, and cluster status of target letter.

The third cluster analysis examined word-medial, syllable-initial position, including factors of letter and cluster status of the letter. In all cases, if the letter was in a cluster, the cluster crossed the syllable boundary, because the letter was syllable-initial. The results are given in Table 14. As before, more *ds* were missed than *ts*, $\underline{F}(1,18) = 5.41$, $\underline{p} = .03$. As in the last analysis, there was a trend for clusters, even across syllable boundaries, to cause higher error rates, but the increase did not reach significance, $\underline{F}(1,18) = 4.02$, $\underline{p} = .058$.

	cluster status	
letter	not in cluster	in cluster
d	.143	.217
t	.075	.092

TABLE 14. Mean error rates for word-medial syllable-initial letters as a function of target letter and cluster status of target letter.

The final cluster analysis examines clusters containing *d* that cross syllable boundaries, for example *nd* in *finden*, and clusters that do not, e.g. *nd* in *Hand* and *Handtuch*, and contrasts them with non-cluster *ds* in each position. Table 15 gives the relevant error rates.

Note that the linear order of mean error rates is (1) initial (not in cluster), (2) initial (in cluster spanning syllable boundary), (3) final (not in cluster), and (4) final (in cluster). Although significant main effects were shown for both position ($\underline{M}_{initial} = 15.9\%$, $\underline{M}_{final} = 31.2\%$, $\underline{F}(1,18) = 15.81$, $\underline{p} = .001$) and cluster status ($\underline{M}_{not\ in\ cluster} = 20.0\%$, $\underline{M}_{in\ cluster} = 27.0\%$, $\underline{F}(1,18) = 5.00$, $\underline{p} = .036$), the interaction between these two factors was not significant, $\underline{F}(1,18) = 1.22$, $\underline{p} = .282$. This pattern probably resulted because spanning a syllable boundary in a cluster was confounded with being either initial or final; the only cross-syllable boundary clusters were those in which the target *d* was syllable-initial.

	syllable position of letter		
cluster status	initial	final	combined
target letter not in cluster	.101 (1)	.300 (3)	.200
target letter in cluster	.217 (2)	.324 (4)	.270
not in cluster, in cluster, combined	.159	.312	–

TABLE 15. Mean error rates as a function of syllable position of letter and cluster status; includes numerical ranking.

3.3. POSITION IN THE WORD. The next group of analyses separates words in which the target letter was in either the beginning or the end of the word, from those in which it was word-medial. This was to verify the results hold true in both environments. Table 16 gives relevant mean error rates. In this analysis, clusters were NOT excluded.

		syllable position of letter	
word position of letter	letter	initial	final
peripheral	d	.083	.311
	t	.135	.090
medial	d	.167	.333
	t	.095	.100

TABLE 16. Mean error rates as a function of letter, syllable position of letter, and word position of letter.

Once again, error rates were significantly higher for *ds* than for *ts*, $\underline{F}(1,18) = 11.53$, $\underline{p} < .005$, and they were significantly higher for syllable-final letters than for syllable-initial letters, $\underline{F}(1,18) = 11.93$, $\underline{p} < .005$. The interaction of those two factors (letter and syllable position) was also significant, $\underline{F}(1,18) = 19.87$, $\underline{p} < .001$. However, there was no significant difference in error rates for word-medial versus word-peripheral letters, $\underline{F}(1,18) < 1$. Also, word position did not significantly interact with any other factors. Thus the results for syllable-final *d* hold in either environment.

3.4. ARTICLE ISSUES. A comparison of the five articles *der*, *die*, *das*, *dem*, and *den*, shows a significant main effect of article shape, $\underline{F}(4,72) = 3.996$, $\underline{p} = .006$. The error rates are given in Table 17, and the frequency rankings are repeated. As can be seen, the error rates were lower for the less frequently used articles (as ranked by Meier 1967, but not as ranked by Wängler 1963), with the exception of the order of *das* and *den*. This appears on the surface to map relatively well with frequency. But again, simple frequency rankings do not acknowledge the interaction of gender, case, and number, as well as phrase-level considerations, which probably play a greater role than the shape alone. (The order reported by Ferstl 1991 was *die*, *der*, *dem*, *den*, *des*.)

	percentage missed	frequency rank	
		Meier	Wängler
die	.458	1	1
der	.421	2	2
das	.392	7	6
den	.353	6	14
dem	.233	15	5

TABLE 17. Mean error rates of articles by shape.

The error rates by case were also significantly different, $\underline{F} = 5.31$, $\underline{p} = .003$. Articles in the nominative case were missed least frequently, followed by dative, accusative, and genitive (mean error rates of $\underline{M} = .281$, $\underline{M} = .342$, $\underline{M} = .466$, and $\underline{M} = .517$, respectively). Again, the findings were very different from Ferstl's, who found the ordering nominative with the HIGHEST error rate, followed by dative, genitive, and accusative.

However, subjects in general did not miss the *d* in an article more or less often depending on whether the article followed a preposition, or, if they did, the differences were sometimes the opposite of the direction expected. Subjects missed more *ds* in standalone articles ($\underline{M} = .403$) than in articles that followed prepositions ($\underline{M} = .386$), but this was not significant, $\underline{F}(1,18) < 1$. Likewise they missed more *ds* in standalone articles and articles after single-case prepositions

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($\underline{M}$ = .407), than after dual-case prepositions ($\underline{M}$ = .363), but this also was not significant, $\underline{F}(2,36) < 1$.

On the other hand, when only accusative and dative articles were examined with respect to whether or not they follow a preposition, the interaction between those two factors (case, after preposition) was significant, $\underline{F}(1,9) = 5.94$, $\underline{p} = .036$, even though neither factor was significant on its own. When the results were split apart by type of preposition, the interaction of case and after preposition factors was no longer significant. The error rates are given in Table 18.

	no prep	after a prep
Accusative	.387	.600
Dative	.400	.325

TABLE 18. Mean error rates of accusative and dative articles as a function of being after a preposition.

Three analyses were conducted to examine whether there was a difference between finding the first letter in a German article and finding the last letter, the part that carries the information. This uses the data from the 12 subjects who participated in both Experiment 1 and Experiment 2. These analyses included two between-subjects factors of target letter order, t-first vs. d-first and n-first vs. r-first. The first analysis compared the error rate for finding *d* over all possible articles in Passage 1 or 2 with the combined error rate for finding *n* in *den* and *r* in *der* in Passage 3 and 4. The within-subjects variable was position in word (first, last). The second analysis only considered the combined score for *der* and *den* for the *d* passages. As Table 19 shows, whether all articles or only *den* and *der* were considered, subjects missed the first letter, *d*, significantly more than the last letter, *n* or *r*, $\underline{F}(1,8) = 16.68$, $\underline{p} = .004$ (all articles), and $\underline{F}(1,8) = 14.31$ $\underline{p} = .006$ (*den* and *der*). This result agrees with results found above for *d*, in which *d* in *der* was missed more than *d* in *den* (see Table 17).

	looking for *d*		looking for *n* or *r*
	all articles	*den* and *der*	*den* and *der*
error rate for target letter	.444	.452	.174

TABLE 19. Mean error rates for groups of articles.

The third analysis included the within-subjects factors of position (first, last) and article shape (*den*, *der*) to ascertain the effects of the individual article and target letter position. Table 20 gives the overall error rates. Subjects missed the initial *d* more often than the final *n* or *r*, but this difference was not significant, $\underline{F}(1,8) = 2.58$, $\underline{p} = .114$. Subjects also missed *d* and *r* in *der* significantly more often than *d* and *n* in *den*, $\underline{F}(1,8) = 15.86$, $\underline{p} = .004$. Finally, the interaction between those two factors (position, article shape) was also significant, $\underline{F}(1,8) = 8.48$, $\underline{p} = .019$. There was also a significant interaction between article shape and both between-subjects factors. The d-first subjects had a much greater difference between *der* ($\underline{M}$ = .609) and *den* ($\underline{M}$ = .178) than the t-first group ($\underline{M}$ = .361, $\underline{M}$ = .295, respectively), $\underline{F}(1,8) = 8.58$, $\underline{p} = .018$. A similar pattern was seen for the r-first group and the n-first group, $\underline{F}(1,8) = 5.79$, $\underline{p} = .041$. These three interactions coupled with the lack of significance of letter position in this analysis reflect the fact that overall, for *der* there were more errors made on *r* (final letter) than on *d*. This could be due to the small number of *der* instances in Passage 3.

article	target letter *d*	target letter *n* or *r*
der	.456	.514
den	.394	.079

TABLE 20. Mean error rates for *den* and *der* as a function of target letter/position of target in article.

4. DISCUSSION.

4.1. FINDINGS OF THIS EXPERIMENT.

4.1.1. UNITIZATION HYPOTHESIS/WORD FREQUENCY. The present data support, and also replicate Ferstl's findings supporting, the basic form of the unitization hypothesis, which predicted the findings that the letters *d* and *t* in the extremely common definite articles, *und*, and *mit* would be missed more frequently than *d*s and *t*s in less common words.

4.1.2. SYLLABLE-FINAL DEVOICING. The data also support the hypothesis that the devoicing of the voiced stop *d* will negatively affect its detection in silent reading; that is, the voicing neutralization in the spoken language does seem to affect the letter detection of the letters in syllable-final position. This is evidenced by the fact that (a) syllable-final *d*s (in both high and low frequency words) were missed much more than syllable-initial *d*s, and (b) they were also missed much more frequently than syllable-final *t*s, but (c) syllable-final *t*s were not missed more frequently than syllable-initial *t*s. This combination of results would not be expected if letters were missed more simply on account 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 provides support for phonological recoding in (German) reading. This 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 almost always found less frequently than the letter *t*. On reflection, this is not surprising, because in general different letters might be easier or harder to find due to their features (curves, straight lines, vertical and horizontal size, and so on). In particular, the *d* bears a strong visual resemblance to several other letters, notably *p* and *b*, especially in some type fonts. Nevertheless, the statistical analyses bore out the prediction that there are important differences in the RELATIONSHIP of the pairs of error rates for initial and final *d* and *t*. That is, the differences between initial and final *t* are not significant, while those between initial and final *d*s are, as predicted. The differences must be due to something special about the *d* in that position, and one thing that is special is the obstruent devoicing.

4.1.3. CLUSTERS. Analyses also showed that the error rates are generally (though not significantly) higher for letters in clusters than for letters that are not in clusters. The trend is also present when clusters cross syllable boundaries. However, the error rates are higher yet for syllable-final *d*s even when not in clusters; the devoicing position affected error rates even more than being in a cluster. These findings suggest that clusters are indeed playing a part in the processing of the word, and may contribute to higher error rates for letters. Whether this is because the letter is simply harder to see because it is in a cluster, or if it is being processed as a unit, or some combination of both, is probably still open for inquiry. The particular effects of clusters might be better tested with a carefully controlled and balanced list of words where shape of the letter (e.g. by type font, and by comparing more letters) can be manipulated along with numbers of clusters and-non clusters both initially and finally. However, again note that the results showed that *t*s are still easier to see, even in clusters, than their *d* counterparts. This was true even though the majority of *t* clusters were *st*, in which the *t* is second, and also in which the *t*, as a skinny letter, might be harder to pick out. Again, the issue of orthographic features is probably playing a role here, and this data cannot disambiguate that from the other factors that might be influencing this result.

That clusters did not affect error rates as much when the clusters crossed syllable boundaries, however, does further support the notion that the syllable boundary is playing some role in the reading, because it is that boundary that determines whether the devoicing of the voiced obstruent occurs.

4.1.4. WORD POSITION. The results were also shown to hold when the very different environments of being word-medial as opposed to word-peripheral were separated, and the statistics indicate there is no difference for this result in those two environments. The null results are probably not as reliable for word periphery simply because there are many fewer tokens there, but it is likely that with more tokens the results would be similar.

4.1.5. ARTICLE ISSUES. The different articles, when analyzed only by their shape, and not taking into account any of the components that determine the shape, did indeed have different error rates that mapped roughly onto frequency. The articles also showed differences in error rates when grouped by case. On the other hand, various analyses of articles with respect to prepositions gave conflicting results. Finally, the final letters of the articles had lower error rates than the *d*s, as might be expected if the reader does need that information and processes different parts of the word differently. Also, the results for *den* and *der* were similar to the earlier results (*der* was missed more than *den*). However, the results were still not uniform when the two individual forms, *den* and *der*, were examined. The results for every condition studied were probably impacted by some or all of the other aspects not dealt with in a particular analysis. Also, the dearth of targets in some of the conditions analyzed undoubtedly affected the comparisons that were undertaken.

In all these analyses, various aspects of what goes into the article were addressed separately. However, it is probable that all of these aspects, including case, gender and number of the noun, phrase-level structure, the number of *d*s in surrounding words, the discourse status of the noun (specificity, referentiality, or identifiability), and maybe some others, interact. For instance, for a noun that is very active in the reader's mind, gender would be known. Depending on the construct (for instance, the genitive construct) or the article's relationship to the verb and any preposition, the reader may have no need at all to identify the article beyond the fact that it is an article. On the other hand, sometimes the case information is necessary to identify the role of the noun, or gender information is needed to disambiguate homophones that differ only in gender, or to help identify a word that is fairly rare for the reader. In these cases, it is likely that more attention would be paid to the article, especially the latter two letters.

As mentioned earlier, to properly study these factors, there should be a number of targets in each combination of factors, and multiple factors should be addressed together. The current text did not lend itself to the more in-depth analyses suggested here. The most ideal text, from the standpoint of carefully balancing several factors, would be one constructed for that purpose. However, from a linguistic point of view, a constructed text, especially one consisting of separate unrelated sentences, would be very questionable. Issues of reference and such probably could not even be addressed.

4.2. FURTHER QUESTIONS. One important feature of words that has not been looked at here is that of word length. One might predict under a model of word access in reading similar to the cohort model mentioned earlier that the longer a single-stem word is, the more likely that a letter later in the word stem would be missed. With the current text, the number of words in each condition--which would have to be a function of word length, position of the letter in the word (which syllable it is in), AND position of the letter in the syllable, because that has shown to have an effect--was far too small. An additional problem is how word length would be calculated. At least three ways exist, which would give very different sets of cells to plug words into: by the letter, by the phoneme, and by the syllable. Based on the earlier findings here, I would propose that the length in syllables be the unit of measure; this would also lead to the fewest different cells to be compared.

One further problem with analyzing word length is that of compound words. It might well be that, whereas in non-compounds the identity of the word is ascertained from the first few letters, in compounds both parts must be accessed to get the meaning of the overall word (especially in those compounds created for the occasion, as opposed to the more lexicalized compounds). Thus the reader would have to be able to identify the starting point of the second word in the compound in order to be able to recognize it, because the information from the first part would give little to no information (again, depending on the lexicalization status of the particular compound).

A fascinating area of study that has not been explored here is the effect of the German speaker's native region or dialect on the issue of devoicing. Dialects of German vary greatly at every linguistic level across the German-speaking area, and this issue is no different. By all reports, most, if not all, dialects do devoice syllable-final *d*, yet the phones realized differ as to their exact phonetic quality. For instance, although all subjects agreed during the debriefing that they do devoice the voiced consonants syllable-finally, a subject from a northern area of Germany reported that in her dialect the devoiced *d* is realized with a very 'hard' [t] sound. Other more southern dialects realize the devoiced *d* with a much 'softer' sound. This is confirmed by Barbour & Stevenson 1990, who report that 'in some (other) types of German the consonants in such a position are voiceless and unaspirated, but lenis ... a sort of compromise between the voiced and

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voiceless series.' In the standard variety of German pronunciation, the sounds in syllable-final position are fortis and voiceless (Barbour & Stevenson 1990:153). In other words, in some dialects the distinction is not as marked, and this may affect the letter detection of the voiced letters in this syllable position for those dialects.

Some additional regional differences directly related to the current issue are that in some dialect/accent regions the voiced/voiceless distinction is also lessened or lost intervocalically (between two vowels) and/or word initially. More detail on dialect differences in German can be found in Barbour & Stevenson, especially chapter 5. While the varied dialects of the present subjects did not eliminate support for the hypotheses (and thus these results appear to be generalizable to the German-speaking population at large),[7] results would probably be stronger, and more generalizable to a particular dialect or region, if the subject pool for any particular experiment is limited only to speakers of the dialect in question. This certainly would be the case if one wanted to predict that this effect varies by dialect depending on how much the devoicing is realized in phonetic terms. On the other hand, a large subject pool of many speakers of many diverse dialects, for which the data still showed the significant difference for the different positions of *d* in syllables, might well be generalizable to all German speakers, especially if no data from a sub-group of subjects from a particular dialect stood out as being different.

Region and dialect will also come into play at other linguistic levels. Some vocabulary is particular to, or unfamiliar to, people on a regional basis. Individuals also have their own different levels of familiarity with any given word. These differences may affect frequency-related measures, and may contribute to an individual subject's ease in reading the text in general. The variety of regions of my subjects was reflected by the range of comments about the readability and even grammatical correctness of the text and the regional slang contained therein.[8]

Finally, the frequency issue in German has been examined in this study and in Ferstl 1991 only in terms of the most frequent words versus much less frequent words. The unitization hypothesis is intended to cover differences everywhere along the frequency continuum. A future study could analyze error rates for words matched for other characteristics of the word (such as syllable position of the letter) and ordered by frequency. Again, both individual differences in internal lexicon and regional differences for frequency would have to be expected. Beyond the general problems with frequency lists discussed earlier, difficulties would be posed by the fact that regional versions of a word frequency list probably do not exist, so it would be hard to quantify the regional differences. Additionally, test words would have to be taken from different, suitably distant, parts of the frequency continuum to counteract the likelihood that words very close to each other in terms of frequency would not be in the proper order every time, due, again, to individual differences among subjects and also differences in how the words are used in the text.

5. SUMMARY. The 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. Although the current results were only found for the alveolar pair, *d* and *t*, it is likely that similar results would be found for the velar and bilabial obstruent pairs as well. Furthermore, the effect of syllable-final devoicing was not changed by being in a cluster, or where the *d* was in a word. Other results, which are from preliminary analyses only, indicate that (a) some phonological processes may not affect readers' lexical access as much as others, (b) the issues in lexical access of articles are fairly complex, and (c) in many cases, a finer-grained analysis with better targets and perhaps different criteria for test words may yield more revealing results.

NOTES

* I am grateful to Alice Healy of the Psychology Department for her many hours of help with many issues, from explaining her unitization model and findings, to showing me how to compute,

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understand, and present the statistics. A portion of this paper will be presented at the 15th Annual Meeting of the Cognitive Science Society, and included in the proceedings of that conference as Buck-Gengler & Healy 1993.

1 So-called due to the image of a person in a bathtub, head and feet sticking out, that is evoked to explain the idea that '[p]eople remember the beginnings and ends of words better than the middles' (Aitchison 1987:119).

2 The primary article cited for this model is Marslen-Wilson 1980.

3 The word *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*.

4 Actually, that assumes similar difficulty in finding various letters, specifically *d* and *t*. This will be discussed further in the discussion section.

5 A word on word frequency: The source Ferstl 1991 used, and that I am using, is Meier 1967. Frequency counts are tricky, however; a different list (Wängler 1963), which is not as good in quality and especially number of words tabulated, nevertheless gives THREE measures of frequency: spoken language, written language (in newspapers and newsmagazines) and a combined total. On the other hand, it lists fewer than 1000 words (types) and was based on a tabulation of many fewer tokens than Meier. Meier was probably based on a written corpus, given the large number of tokens for the most frequent words.

Another hairy issue is deciding when different forms of the word count as one word, and when they count as different words. This is especially important in German, where, even without taking singular vs. plural into account, a noun can have more than one form just based on case. Both of these sources treat different forms as different words. Also, these sources are simple counts of forms; there is no analysis of the particular use (e.g. for articles, is the *der* masculine nominative singular, feminine dative singular, or feminine or plural genitive?). What type of materials are used, regional or dialectal vocabulary differences, and so on all can lead to very different lists and orderings.

Clearly, while frequency lists can give useful information, caution must be taken. Still, for the types of analyses in Healy's work, Ferstl 1991, and the part of this paper that deals with the frequency issue, Meier will suffice.

6 Because Passage 4 had no dative noun phrases that weren't determined by a preposition, the first analysis examines only the data of the six subjects who looked for *n* in Passage 3. An additional analysis compares only those articles that come after the two types of prepositions.

7 Or at least, German speakers who also know English and have been in Colorado, but this phenomenon should have nothing to do with these two restrictions.

8 I was assured by several, however, that the text was correct. I also did not introduce any changes into the text with the exception of correcting one misspelled word. Any non-standard forms at any level, from lexical to grammatical to use of slang, are the work of Gabrielle Wohmann.

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