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The Missing-Letter Effect for Common Function Words Depends on Their Linguistic Function in the Phrase

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It has been proposed that function words such as *for* and *on* conceal their letters because their higher familiarity allows fast access to their unitized representations. However, in this study we show that letter detection in function words varies with their linguistic role in text. When such words were embedded in a phrase where they were forced into a content role by the surrounding context (e.g., *for or against* or *on switch*), letter detection improved markedly and did not differ from that of matched content words. The result was replicated when the context preceding the function word and the overall sentential meaning were equated for both function and content usages. The results support a late-stage structural account of the function–disadvantage effect, where the syntactic units that support the structural frame of a sentence are lost in the transition from structure to meaning.

Healy and her associates (e.g., Healy, 1976; Healy & Drewnowski, 1983; Proctor & Healy, 1985) claimed that reading of text is carried out simultaneously at several levels of analysis. Familiarity with units at a given level facilitates activation of those units and bypasses the need to complete the processing of lower level component units. Thus, very common words, such as *the* and *and* are said to allow fast activation of their unitized whole-word representations, preempting complete identification of their constituent letters. Ample support for this position, known as the *unitization model*, comes from a series of studies suggesting that very common words tend to conceal their constituent letters. Thus, readers find it more difficult to detect *t* embedded in the high-frequency word *the* than in words of lower frequency such as *weather*. The phenomenon of familiar units hiding constituent letters has been referred to as the *missing-letter effect* by Healy (1976).

An additional finding is that the missing-letter effect is more likely to occur when *the* is part of a normal word sequence than when it is embedded in a perverted word sequence (e.g., *the ran boy*; Drewnowski & Healy, 1977, 1980; Healy, 1976). This was taken to imply a unitization at the phrase level, with frequent function words being processed in terms of supraword units such as short syntactic phrases or short word frames (e.g., *from the* _____; see Healy, Conboy, & Drewnowski, 1987).

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Clearly, letters are at least as familiar as the words in which they appear. So, if the perceptual system is sensitive to stimulus frequency, we might ask, why do the higher order familiar units have an advantage over their extraordinarily frequent letter components? Why do the letters not consistently win the race to identification? One must assume that the text-processing system is sensitive to the value of higher level units. Presumably, because reading normally requires focusing on meaning rather than form, processing is adjusted to favor higher order units. However, this assumption implies that the missing-letter effect reflects not a perceptual race of sorts, but rather a competition based on a unit's utility in achieving meaning.

Indeed, several researchers proposed that letter detection in words is determined by the relative importance of the word to a sentence's meaning (e.g., Corcoran, 1966; Krueger, 1989; Schindler, 1978). That is, the detectability of a constituent letter is a function of the semantic–syntactic sentential role of the word in which the letter is embedded. One notes that the high-frequency words that repeatedly hide their letters are also function words that carry little semantic content (e.g., Schindler, 1978). Thus, perhaps the missing-letter effect is due to the greater redundancy and predictability of the common function words in connected text, allowing readers to deploy little attention to them during reading. This redundancy account gains support from research on eye movements during reading, which indicates that readers make fewer and shorter fixations on short frequent function words than on other words in a sentence (Carpenter & Just, 1983; Rayner, 1977).

Recently, a study by Koriat, Greenberg, and Goldshmid (1991) provided evidence in support of the idea that the missing-letter effect for common function words is due to the linguistic role of these words rather than to their familarity or perceptual unitization. Using a letter detection task with Hebrew text and native Hebrew readers, Koriat et al. showed that when function and frequency are dissociated, letter detection is primarily due to word function rather than to word frequency. In English, separating the effects of function and

frequency is very difficult, because the highest frequency words are generally function words (e.g., *the, and, in, for, with, to*; see Haber & Schindler, 1981). However, Hebrew has two ways of expressing many function words, either as independent words as in English or as single letters that are attached as prefixes to content words. Thus, *to Haifa*, can be written as *to Haifa* or as *tHaifa* (with Hebrew letters, of course, and no capitalization). Although both constructions have the same meaning, the prefixed word *tHaifa* is far less familiar as a whole-word pattern than the function word *to*, and not necessarily more frequent than content words that also begin with *t*. Nevertheless, both forms of *to* produced significantly more detection errors than did matched content words. Furthermore, the inordinately high percentage of letter omissions for Hebrew prefix words was found only for the letter representing the function morpheme and not for the other letters in the word. Therefore, the missing-letter effect seems to derive not from a greater unitization of the word as a whole, but from the linguistic role of the word or morpheme.

Another finding from the same study concerned ambiguous Hebrew words. In normal unvowelized Hebrew (see Koriat, 1984), the same sequence of letters (e.g., *smr*) could be interpreted as a function prefix plus stem combination (*s+mr, that mister...*) or as an unprefixed content word (*smr, kept*), depending on sentential context. In the above example, the *S* (Hebrew *Shin*) was missed significantly more often where context favored its interpretation as *that mister* than when it favored its interpretation as *kept*. Thus, once again function and not familiarity of the orthographic sequence (word) determined letter detectability.

A subsequent study by Koriat and Greenberg (1991) demonstrated that detecting letters in English nonwords (disguised as misprints) was more difficult when the nonwords (e.g., *fol*) appeared in a function position (e.g., "I am looking fol you"), than in a content position (e.g., "Girls just want to have fol"). Nonwords were used as a mechanism for holding letter sequences (and their frequency) constant in English, while varying implied syntactic function. This finding was also replicated with Hebrew. Furthermore, in another Hebrew experiment, the initial letter of a nonword was more often missed where sentential context favored its interpretation as a function prefix than as a part of the stem.

These results underscore the importance of linguistic function as a determinant of the missing-letter effect. It was proposed that this effect does not reflect the perceptual process that controls access to individual units in the lexicon, but occurs at a relatively late processing stage, when activated lexical representations are integrated into an overall meaning schema for the phrase or the sentence. Presumably, function words help to establish, early in sentence processing, the structural–syntactic frame of the sentence, but tend to recede to the background as the meaning representation of the sentence unfolds. Therefore, omission errors for the same unit may vary depending on the extent to which it supports the structural frame of the phrase or the sentence.

In the present study we adopted a different approach to contrast the function and frequency interpretations of the missing-letter effect, focusing on normal English text. Although the findings with Hebrew presumably reflect processes found in English reading, differences between the Hebrew and English languages (see Frost, Katz, & Bentin, 1987) make a test with proper English text desirable.

Although it is difficult to disentangle function and frequency using English words, there are a few exceptional opportunities. Specifically, some high-frequency prepositions have pseudo-content roles in a few common expressions. The example used in Experiment 1 is the expression *for or against*, where *for* has the role of a modifier, generally an adjective, but also an adverb, as does *pro* in the expression *pro or con* (see *Webster's Third New International Dictionary of the English Language, Unabridged*, 1981). The juxtaposition of the conjunction *or* and the preposition *for* suggests a content role for *for*. We compared *for or against* with another common expression, *for better or worse* where *for* is clearly a preposition.[1] The main prediction is that *for* in *for or against* will be treated more like a content word than the *for* in *for better or worse*, and hence detection of *f* in the former expression will be better than in the latter expression. Moreover, the detection rate of *f* in *for or against* is expected to more closely resemble that of *f* in short content words than of *f* in prepositions elsewhere in the passage. Results consistent with these predictions will argue against the unitization account, which attributes the missing-letter effect to the greater familiarity of the orthographic pattern, as such. However, such findings would be consistent with the structural view, where the missing-letter effect is linked to the processes leading to the establishment of an overall structural frame for the phrase or the sentence.

Experiment 1

Method

Subjects. Forty-eight Union College students were paid $1 each for participating in the experiment.

Design and materials. Two passages were constructed where the target letter *f* appeared exactly 15 times: 10 times in the word *for* and once in each of five different content words beginning with the letter *f*. The frequency of appearance for *for* is rated 9,489, whereas the mean frequency of the five *f*-content words is 105 per million accord-

[1] We have consulted with several experts regarding the linguistic status of *for* in the two different contexts. Although some agree that *for* in *for or against* can be properly classified as a predicate adjective (like "Are you fat or skinny?") and thus as a "content" word, others preferred an analysis where *for* remains a preposition, but with an elliptical object. Yet another suggestion was that *for* is used *metalinguistically*, a usage that would normally prompt quotation marks, e.g., "Are you 'for' or 'anti'?" In this case, too, it would be classified as a content word. Clearly, although a linguistic analysis can help in clarifying the psychological processes underlying the observed results, these results must ultimately be explained in psychological rather than in linguistic terms. As is suggested hereinafter, (see also Experiment 4), the critical factor appears to reside in the extent to which the preposition takes on a semantic burden within its circumscribed local context. Such appears to be the case with *for or against* no matter how *for* is analyzed. Therefore, in what follows, we shall use the terms *function* and *content* as a shorthand for referring to the two types of *for* used, delaying discussion of their presumed psychological differences until the results have been presented.

ing to Kucera and Francis (1967). Half the *fors* in each passage appeared as part of a familiar *critical* phrase. The critical phrase was *for or against* in one passage and *for better or worse* in the other passage. The remaining *fors* appeared as prepositions, but were not associated with a particular phrase. The three different types of *f* sentences were evenly distributed throughout each passage. Experimental sentences alternated with filler sentences that did not contain the target letter *f*, and the first and last sentences of a passage were also fillers. Finally, care was taken so that the critical words containing the target *f* never appeared at the beginning or end of a line of text, or at the beginning or end of a sentence.

Procedure. Half of the subjects were randomly assigned to read the *for better or worse* passage (Group 1), and the remaining subjects were assigned to read the *for or against* passage (Group 2). They were encouraged to read for comprehension by being told that questions about the passage's contents would be asked after they had finished reading. Furthermore, subjects were told to circle each *f* appearing in the passage as they detected it; they were asked not to retreat in order to circle *f*s, but to constantly move ahead as they normally do when they read.

Results

Means and standard errors of the percentages of detection errors are summarized in Table 1. It may be seen that the usual missing-letter effect is replicated, with *f*s appearing in content words being easier to detect (7.1% errors) than *f*s in the function word *for* embedded in noncritical phrases (22.5% errors), $F(1, 46) = 16.94$, $p < .0005$. This finding is also consistent with the basic unitization account. The particular goal of the present experiment, however, was to show that the detection of errors for the same word varied with its role in the sentence. The key comparison then was between the two critical *for* phrases. In the phrase *for better or worse*, subjects missed 25% of the *f*s, comparable to the error rate found with other *fors* in the same passage and considerably higher than the error rate associated with the content words. In contrast, subjects missed only about 6% of *f*s when *for* was embedded in *for or against*, and this error rate was closer to that exhibited by the content words.

Several analyses of variance (ANOVAs) confirmed these conclusions. Excluding the data for content words, a two-way ANOVA, Context (critical vs. other phrase, within subjects) × Phrase Type (*for or against* vs. *for better or worse*, between subjects) yielded $F(1, 46) = 3.55$, $p < .07$, for context, and $F(1, 46) = 6.50$, $p < .02$, for the Context × Phrase Type interaction. Simple comparisons explain the interaction: Although it mattered not at all where *for* appeared in the *for better or worse* passage, $F < 1$, error rate in the *for or against* passage was much lower in the critical phrase than in *fors* appearing elsewhere, $F(1, 23) = 8.33$, $p < .005$. Also a between-groups comparison yielded no significant difference in error rate for the noncritical prepositional phrases, $F < 1$, but a significantly higher error rate for *for better or worse* than for *for or against*, $F(1, 46) = 7.99$, $p < .01$.

Table 1
Means and Standard Errors of Percentages of Omission Errors for the Word for *in Critical and Other Phrases and in Content Words in Experiment 1*

	For				Content words		All	
	Critical		Other					
Group	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
1	25.0	5.7	22.5	4.4	10.0	2.9	19.1	3.2
2	5.8	2.5	22.5	5.7	4.2	2.4	10.8	2.8
All	15.4	3.6	22.5	3.5	7.1	1.9	15.0	2.2

Note. The critical phrase for Group 1 was "For better or worse"; for Group 2, "For or against."

Discussion

The results of Experiment 1 indicate that word familiarity as such is not sufficient to produce a missing-letter effect. Letter detection for the exact same high-frequency word *for* differed according to its function within the phrase. Where *for* was placed in the context of *for or against*, and was more likely to be interpreted as a content word (or as an elliptical preposition), error rate was comparable to that obtained with moderate frequency content words. Thus, the sentential context in which the word was embedded was sufficient to wash out the missing-letter effect for *for*. Meanwhile, when *for* occupied a position one place removed from *or* in *for better or worse*, thus assuming its common functional status, error rate was much higher, closely matching that of *fors* elsewhere in the passage.

These results parallel the finding with Hebrew, where detection of the initial letter of an ambiguous word was more difficult when context supported interpretation of that word as a function prefix plus stem combination than as an unprefixed content word (Koriat et al., 1991; Experiment 4). It is also consistent with the observation that a nonword engendered more omission errors when placed in a syntactic slot that calls for a function word than when placed in a slot where a content word is expected (Koriat & Greenberg, 1991; Experiments 1 and 3). With a proofreading task, Abramovici (1983) also reported a similar effect using English verbs, where subjects detected fewer misspellings in the verb *have* in "I have found a book" (an auxiliary verb, i.e., a function role) than in "I have a book" (a full lexical verb, i.e., a content role).

Altogether, these results are not consistent with a simple version of the unitization model, which stresses the higher frequency of function words. However, that model also admits the possibility that the processing of text may take place in terms of units that are larger than a word (Drewnowski & Healy, 1977, 1980; Healy et al., 1987). Could the results of Experiment 1 be interpreted in terms of the assumption that *for better or worse* is more unitized at the phrase level than *for or against*? This possibility was examined in Experiment 4. First, however, we explore the generalizability of the effect found in Experiment 1.

Experiment 2

In Experiment 2 the critical function word was *on*. We contrasted contexts where *on* operates as a typical function

word with those in which it operates as an adjective or as part of a word compound (e.g., *on switch*. If the previous findings do generalize as hypothesized, then we should again see more errors for the critical word *on* in its typical function role than in its alternative role.

Method

Subjects. Twenty-nine Union College subjects were paid $1 for participation. None had participated in Experiment 1.

Design and materials. A passage was created where the letter *n* appeared in exactly 15 words. Ten of these were in the word *on* (frequency is 6,742 per million in Kucera & Francis, 1967), whereas the other 5 were in short content words with *n* as the final letter (mean frequency = 96 per million). In 5 of the 10 *on* appearances, *on* preceded a noun, acting as an adjective or as the leftmost part of a compound expression. Four such expressions were used, the first appearing twice: *on switch, on call doctor, on looker,* and *on side.*[2] In the remaining cases, *on* served in its typical functional role. The expressions used were "on a/the hospital bed," "on the remote," "on the table," and "on his clothes." Four *n*-content words were used, with the first repeated twice: *thin, gun, ton,* and *ten.* The three types of *n* contexts were evenly distributed throughout the one-page passage. No critical words occurred in the first or last sentences or at the beginning or end of lines or sentences.

Procedure. The task and instructions were the same as in Experiment 1, with the exception that subjects now searched for *n*s instead of *f*s.

Results and Discussion

Means and standard errors for the percentage of detection errors made in each context appear in Table 2 for the *on*-preposition, *on*-adjective, and content words. Overall, error rate was higher in Experiment 2 than in Experiment 1, perhaps due to the greater difficulty in detecting *n*s than *f*s. The *on*-adjectives and the content words yielded nearly identical error rates, whereas the error rate associated with *on*-prepositions was considerably greater. A one-way ANOVA comparing all three contexts yielded a strong effect of context, $F(2, 56) = 18.33, p < .001$. Subsequent analyses demonstrated a significantly higher error rate for the *on*-preposition than for the *on*-adjective, $F(1, 28) = 24.39, p < .001$, whereas error rate for the *on*-adjective did not differ from that of the content words, $F < 1$.

Thus, as in Experiment 1, the role of the preposition dictated whether component letters were detected. The present findings add generalizability to Experiment 1, replicating the effect for a different preposition, a different target letter, a different letter location (final instead of initial), and a different type of contextual contrast.

Table 2
Means and Standard Errors of Percentages of Omission Errors for the Word on *in Prepositional and Adjectival Roles and for Content Words in Experiment 2*

Context	*M*	*SE*
On-Adjective	17.2	3.9
On-Preposition	42.0	5.6
N-content words	17.9	3.7
All	25.7	3.7

Experiment 3

The previous experiments indicated that error detection for the same word differs according to the phrase in which it is embedded. Experiment 3 was designed to clarify the process by which the embedding context exercises its influence.

In general, the effects of local context on letter detection may be understood in terms of phrase unitization. According to Drewnowski and Healy (1977), common function words tend to be processed in terms of units that are larger than the word. This explains the finding that word scrambling improves letter detection in *the*. In a recent formulation of this idea, Healy et al. (1987) specifically argued that the word *the* is more likely to be included in a reading unit that also contains its preceding word than in one that also contains its following word. This is because *the* is more likely to form a familiar two-word sequence with its preceding word (see Umeda & Kahn, 1982). Consistent with this idea, they observed that an asterisk placed in the interword space before *the* reduced letter detection errors more than one placed after *the*. Thus, the effects of context may be understood in terms of familiar supraword units that include *the*.

If these ideas are extended to the results of Experiment 1, perhaps what should determine letter detection errors for *for* is not the context that follows *for* but the context that *precedes* it. Thus, the higher percentage of errors for *for* in *for better or worse* than in *for or against* might be due to the possibility that the preceding word and *for* tend to form a more familiar two-word sequence in ____ *for better or worse* than in ____ *for or against.*

Thus, Experiment 3 was designed to test whether the different roles played by prepositions matter when the preceding context is held constant. Once again we used the expression *for or against,* but this time it was pitted against the presumably familiar word pair, *for abortion.* The change was made so it would be easier to construct sentences where the words preceding the critical expressions are identical. Note that as in Experiment 1, *for or against* alters the standard functional role for *for,* whereas *for abortion* maintains it.

If Experiment 3 indicates a higher percentage of errors for *for abortion* than for *for or against,* this would provide additional support for the structural account of the missing-letter effect. According to this account, the missing-letter effect does not arise from the process by which different reading units contact their representations in long-term memory. Rather, it occurs in a postlexical, postparsing stage, when accessed representations are integrated into an overall schema for the

[2] *Onlooker* appears generally as a single word. However, a brief survey of students indicated that 6 out of 13 thought that the two-word version (*on looker*) was acceptable, whereas 10 of 13 thought a single-word version was acceptable. All other expressions used in this experiment appear as two words in *Webster's Third International Dictionary of The English Language,* although *on side* appears also as a single word.

phrase or the sentence. Thus, if the context that follows *for* is found to affect detection errors for *for* under conditions where preceding context is held constant, this would constitute strong support for the late-stage view of the missing-letter effect (see Koriat & Greenberg, 1991; Koriat et al., 1991).

Method

Subjects. Seventy subjects from Union College were paid $1 to participate in Experiment 3. None had participated in the earlier experiments.

Design and materials. Two passages were constructed in much the same manner as in Experiment 1. Each passage contained three *f* contexts: a critical phrase containing *for*, various prepositional phrases containing *for* ("other"), and content words beginning with *f* (mean frequency is 163 per million; Kucera & Francis, 1967). There were five exemplars of each condition in a passage. Both passages were about the abortion controversy. In one passage the critical phrase was *for abortion*, and in the other passage it was *for or against*. The two critical phrases were matched for the preceding context. Five preceding contexts were used, each of which preceded one presentation of *for or against* in one passage, and one presentation of *for abortion* in the other passage. These were "Everybody wants to know whether you are (for abortion/for or against)," "whether they are," "you can be," "they can enjoy asking whether you're," and "so next time you are asked whether you're."

The first and last sentences in each passage contained no target letters, and sentences with targets alternated with filler sentences that contained no *f*s. The same filler sentences were inserted in the same locations in the two passages. Also the sentences containing the *f*-content words were identical across the two passages. In essence, the two passages were virtually identical except for the differences in the critical phrases. Again, words with an *f* did not appear at the beginning or end of sentences or lines in the text.

Procedure. Half the subjects were randomly assigned to read the *for abortion* passage (Group 1), and the remaining subjects were assigned the *for or against* passage (Group 2). In all other respects the procedure matched that of Experiment 1.

Results

Table 3 displays the means and standard errors for the percentages of errors associated with the three different *f* contexts for the two passages. It can be seen that subjects made fewer detection errors in the content words than in all but one of the *for* conditions. Thus, in Group 2, subjects missed considerably fewer *f*s in *for or against* (3%) than in the prepositional phrases (22%). Note that these error rates were quite similar to those found in Experiment 1 for the comparable conditions. Moreover, the error rate for *for* embedded in *for or against* was very close to that found for the content words. Meanwhile, in Group 1 the error rates were high in both *for abortion* (27%) and the other prepositional phrases (35%).

Planned comparisons confirmed these observations. First, an ANOVA comparing error rates for the "other" *for* phrases (29%) and the content words (5%) yielded $F(1, 69) = 60.29$, $p < .0001$, replicating the typical missing-letter effect. A significant effect was also observed for Group 1 between *for abortion* and content words, $F(1, 34) = 16.79$, $p < .0005$. In contrast, error rate for *for* in *for or against* was not significantly higher than that found for content words, $F < 1$. Finally, an ANOVA contrasting detection rates in the two critical *for* phrases yielded $F(1, 68) = 23.10$, $p < .0001$, indicating that the availability of *f* is greater in *for or against*, where it acts more like an adjective, than in *for abortion*, where it is a clear preposition.

We also compared the results of Experiment 3 with those of Experiment 1 with regard to detection errors in *for*. Note that the two experiments differed in the critical prepositional phrase (*for better or worse* vs. *for abortion*). More importantly, they differed in that preceding context was kept constant across both critical *for* phrases in Experiment 3 but not in Experiment 1. A three-way ANOVA, Experiment × Passage Type (*for or against* vs. *for better or worse/for abortion*) × Phrase (critical vs. other) yielded $F(1, 114) = 13.64$, $p < .0005$, for passage type; $F(1, 114) = 23.97$, $p < .0001$, for phrase; and $F(1, 114) = 12.02$, $p < .001$, for the Passage Type × Phrase interaction. No other effects were significant. Thus, it appears that controlling for preceding context did not reduce the size of the *for* advantage for *for or against*.

Discussion

The results of Experiment 3 clearly indicate that the lower error rate observed for *for* in *for or against* is not because *for* is less likely to be included in familiar word sequences that also contain its preceding word(s). Rather, even when preceding context was held constant across the two critical phrases, a missing-letter effect was found only for *for abortion* but not for *for or against*. The failure of the preceding context to effectively join with the function word *for* to form an equally impenetrable perceptual unit regardless of *for*'s role undermines the proposition of a unitized word frame composed of a high-frequency word and the preceding space and word (see Healy et al., 1987). It is apparent that the collective evidence supports the structural hypothesis that the missing-letter effect for common function words is due to their specific linguistic roles. Neither the familiarity of the function words themselves nor the familiarity of their embedding phrases, defined by the immediately surrounding context, can account for the effects obtained here.

The results of Experiment 3 are also inconsistent with the redundancy position, which appears to place the missing-

Table 3
Means and Standard Errors of Percentages of Omission Errors for the Word for *in Critical and Other Phrases and in Content Words in Experiment 3*

	For				Content words		All	
	Critical phrase		Other phrases					
Group	*M*	*SE*	*M*	*SE*	*M*	*SE*	*M*	*SE*
1	27.0	4.8	35.0	4.6	6.0	2.3	23.0	3.2
2	3.0	1.2	22.0	3.7	4.0	1.6	10.0	1.7
All	15.0	2.9	29.0	3.1	5.0	1.4	16.5	2.0

Note. The critical phrase for Group 1 was "For abortion"; for Group 2, "For or against."

letter effect at a prelexical stage. According to this position, letters are missed in common function words because the predictability and high redundancy of these words permit subjects to skip over them during reading (e.g., Corcoran, 1966). However, in Experiment 3, the missing-letter effect for the function word *for* was found to depend on the words that *follow* it in the text, when preceding context was held constant, suggesting that the effect occurs *after* the representation of *for* has been accessed. This finding agrees with previous results with Hebrew prefix words, which also place the missing-letter effect at a postlexical, postparsing stage (Koriat et al., 1991). Thus, taken together, the results of this and the previous studies concur in supporting the claim of the structural position that the missing-letter effect occurs at a relatively late stage in the reading process, after the meanings of individual words have been accessed and their linguistic roles in the sentence have been defined. This contrasts with the redundancy account, which placed the missing-letter effect at a prelexical stage, and with the unitization model, where the effect is relegated primarily to the process of relating orthographic units to their internal representations.

Experiment 4

The aim of Experiment 4 was twofold. First, a tighter control was imposed on the *content* and *function* phrases to help sharpen the contrast between them. Thus, whereas the earlier experiments in this series compared phrases that varied in meaning, the present experiment held meaning constant across its critical phrases. We approximated equality by manipulating only the *location* of the object term for *for*. To illustrate, consider the contrast between the following two sentences: "Are you for abortion or against it?" versus "With regard to the issue of abortion, are you for or against?" Both sentences convey the same general meaning. However, whereas in the former expression *for* refers to an object term that follows immediately within the same phrase, in the latter expression it refers to an object mentioned earlier (sometimes a few sentences earlier in the passage). Thus, although in both sentences it is clear to what *for* refers, in the latter sentence the object term is implicit when *for* is interpreted, whereas in the former sentence it is explicitly stated. If letter detection is more difficult in the explicit than in the implicit sentences, this can help specify the critical factor distinguishing between the prepositional and content phrases used in the previous experiments.

Thus, in Experiment 4 we used the phrase *for or against* with the object of *for* either appearing after *for*, or as an implicit, elliptical reference of *for* embedded in an earlier part of the sentence. In the implicit case, as in the explicit case, it was always obvious to what *for* was referring. Moreover, the words directly preceding *for* were the same for matched pairs of implicit and explicit phrasing (presented in different passages). If explicit phrasing engenders a higher error rate than implicit phrasing under conditions where meaning is equated, this should strengthen the proposition that the missing-letter effect for function words depends on their specific syntactic role within the phrase, thus adding to the structural model (see Koriat & Greenberg, 1991; Koriat et al., 1991).

The second aim of Experiment 4 was to rule out an explanation of the results of the previous experiments in terms of differences in phrase-level unitization. Essentially, the results of our previous experiments agree with those of previous work by Healy and her associates (e.g., Drewnowski & Healy, 1977, 1980; Healy, 1976) in demonstrating the importance of local context in producing the missing-letter effect. The two sets of studies, however, differed in methodology. Whereas we contrasted different types of meaningful contexts (e.g., *for or against* vs. *for better or worse*), Healy and her associates focused on the presence of local meaningful context as such, comparing letter detection for normal and scrambled phrases. The finding that word scrambling improves letter detection in highly familiar words like *the* was taken as evidence that familiar word sequences are more unitized at the phrase level, thus concealing their constituent letters more than unfamiliar word sequences. Perhaps, then, the reduced error rate for *for or against* in the previous experiments is because this phrase is *less* unitized than phrases representing *for* in its normal prepositional role.

This possibility, however, appears unlikely: When our results are compared with those of the scrambling studies, an intriguing pattern emerges. In the studies by Healy and her associates, scrambling was found to reduce, but not entirely eliminate, the missing-letter effect. In fact, in some of these experiments (e.g., Drewnowski & Healy, 1977; Experiment 1), scrambling had a very marginal effect on the size of the missing-letter effect. In contrast, in our previous experiments, the embedding of *for* in *for or against* not only reduced the size of the missing-letter effect, but eliminated the effect altogether, yielding equivalent error rates for *for* and *f*-content words. If phrase unitization were responsible for the effects observed in our previous experiments, then even if *for or against* were assumed to be no more unitized than a random sequence of words, it should have still engendered a larger error rate for *for* compared with the matched content words by virtue of the presumed unitization of *for*. However, the results suggest that the embedding of *for* in *for or against* does not diminish phrase unitization, but rather instantiates a content role for *for*. Thus, in Experiment 4 we examined the possibility that although letter detection is worse for *for* appearing in its typical prepositional role (explicit sentences), than in corresponding scrambled sentences, it may actually be better for *for* embedded in implicit sentences than when it appears in corresponding scrambled sentences. This is because in the latter case destroying context eliminates most support for the atypical content role of *for* in the implicit sentences.

Method

Subjects. Forty-four subjects from Union College were paid $1 to participate in Experiment 4. This experiment was conducted immediately after subjects had completed another experiment involving searches for *t* and *e* in the word *the* and content words.

Design and materials. Two versions of the same passage were constructed. The first version was a coherent paragraph that contained 15 experimental sentences, evenly divided between *f*-content (mean frequency is 301 per million in Kucera & Francis, 1967), *for*-explicit,

and *for*-implicit sentences. The *f*-content sentences contained a three- or four-letter *f*-content word. The *for*-explicit sentence always included the phrase *for or against*, with a noun embedded between the words *for* and *or* in the phrase (e.g., *for law or*). Finally, the *for*-implicit sentences always contained *for or against* neither interrupted nor followed by an explicit reference. Nevertheless, it was clear that *for* was referring to a particular noun appearing earlier in the sentence. The critical words (*for* and *f*-content words) never appeared at the beginning or end of lines or sentences.

In addition to the experimental sentences, the passages also contained ten filler sentences that did not include the target letter *f*. These were evenly distributed throughout the passage with one filler sentence at the beginning and end of a passage.

Version 2 was a near replica of Version 1. In fact, the only difference between the two versions was that all the implicit sentences in Version 1 were rewritten in the explicit form in Version 2, whereas the explicit sentences of Version 1 were implicit in Version 2. Explicit and implicit target sentences were matched for most words across the two passages, and the words (at least two) that immediately preceded the *for* phrase were identical in each sentence's implicit and explicit construction. The specific preceding contexts were "trying to decide whether it is," "it doesn't matter that you are," "could be strongly," "speaking out," "indicate our attitude either," "should you be," "be they," "whether it is," "views are demonstrated," and "stand either." Positioning of the critical words was reasonably maintained across the two passages. Finally, Version 1 of normal text was scrambled in a way that destroyed most potential phrases, including the critical *for or against* phrases. However, the positions of the critical *for* and *f*-content words were held relatively constant across the normal and scrambled passages.

In addition to the experimental passages, two practice passages were constructed, one normal text and the other scrambled. Both passages contained short *f*-content words and the function word *for*.

Procedure. Half the subjects were assigned to read Version 1 of normal text, and the remaining subjects read Version 2. Subjects in both groups also read the scrambled passage. Within each group, half the subjects received the scrambled passage first, and half received the normal text first. The two practice passages were administered before the experimental passages in the same sequence as a subject's experimental passages. Subjects were instructed to search the passages for the letter *f*. They were told in advance that two passages would be scrambled, but that they should do their best to read them.

Results

Table 4 presents mean percentage of omission errors for the content, explicit, and implicit phrases in the normal and scrambled passages. The scrambled phrases were defined as explicit or implicit according to the status of the normal phrases from which they were derived.

The results for the normal passage indicate a higher percentage of errors for *for* phrases where an explicit object followed the function word *for* than for those where the object was implicit, $F(1, 43) = 8.20$, $p < .01$. Only explicit phrases yielded a larger proportion of errors than did the content phrases, $F(1, 43) = 4.24$, $p < .05$, whereas the implicit phrases, if anything, produced slightly fewer errors than the content phrases. Thus, the results of the previous experiments have been replicated despite the fact that the only difference between the two types of *for* phrases involved the location of the object term within the sentence.

Table 4
Means and Standard Errors of Percentage of Omission Errors for Content, Implicit, and Explicit Phrases in Normal and Scrambled Passages (Experiment 4)

	Passage			
	Normal		Scrambled	
Phrase	*M*	*SE*	*M*	*SE*
Content	15.5	2.4	10.5	2.1
Explicit	22.3	3.3	16.4	2.9
Implicit	14.1	2.8	18.2	3.3

The scrambled passage yielded a somewhat different pattern of results than the normal passage, as indicated by a significant Phrase × Passage interaction, $F(2, 86)$ 3.22, $p < .05$. Although scrambling tended to reduce percentage of errors for the content and explicit phrases, it increased errors slightly for the implicit phrases. A two-way Passage × Phrase ANOVA including only the two types of *for* phrases also yielded $F(1, 43) = 6.66$, $p < .02$ for the interaction.

Discussion

Although the results of Experiment 4 did not yield pronounced effects, their pattern on the whole was generally consistent with the two predictions advanced. First, error rate for the same function word *for* differed depending on whether reference was overt or elliptical. Where *for* was immediately followed by its overt reference, it presumably filled its typical syntactic role, and consequently percentage of errors was higher than when it was followed by *or*. In the latter case the reference did not appear in the same phrase with *for*, and the word *for* was apparently interpreted more like a content word than as a preposition. These results are all the more impressive in view of the fact that the two types of phrases were closely matched with regard to their general meaning as well as the words immediately preceding *for*.

Second, the interactive pattern between type of passage and type of phrase is consistent with the proposition that the reduced percentage of errors for *for* in *for or against* is not due to the latter phrase being less unitized than such phrases as *for abortion*. If that were so, the error rate should have been even lower when *for* is embedded in a nonsense, scrambled passage. Rather, it appears that the phrase *for or against* instantiates a particular interpretation of *for*, resulting in a proportion of omission errors similar to what is found for content words.

General Discussion

Although our previous work (Koriat & Greenberg, 1991; Koriat et al., 1991) left the strong indication that the missing-letter effect was intimately tied to the word's function, support came primarily from work with Hebrew words and Hebrew and English nonwords. However, work by Healy and her colleagues (Cunningham, Healy, Kanengiser, Chizzick, & Willitts, 1988; Healy, 1976; Drewnowski & Healy, 1977, 1980), which examined English function words, led to a

different impression. We noted that the confounding that exists in English between word frequency and word function makes it difficult to separate the contributions of these two factors. Thus, in our previous studies we adopted two different approaches for disentangling frequency and function. The first involved the use of Hebrew, where function morphemes can be expressed optionally as single letters prefixed to content words, thus producing orthographic strings that are not necessarily more frequent than content words (Koriat et al., 1991). The second approach involved the use of nonwords that were placed either in function or content slots, thus allowing us to eliminate the contribution of word frequency altogether (Koriat & Greenberg, 1991). The present study utilized still a third approach, taking advantage of English prepositions that appear in text in roles where their explicit function status is challenged. These words enabled us to examine the contribution of linguistic function directly, by comparing letter detection for the same word placed in different contexts.

The present results can be summarized as follows. First, letter detection in highly familiar function words varied significantly depending on their specific linguistic role within the phrase. In all four experiments a function word placed in a sentential slot that instantiated its prepositional role engendered a typical missing-letter effect relative to its matched content word. In contrast, the same function word yielded no more detection errors than its matched content word when it assumed a less typical, content-like role. These findings are inconsistent with the unitization account and implicate structural contributions to the missing-letter effect.

Second, the aforementioned effects of context on letter detection survived in Experiments 3 and 4 even where the immediately preceding words were kept constant across the two usages of the function word. Furthermore, whereas word scrambling generally reduced letter detection errors for the prepositional *for*, it tended to increase errors for the adjectival (or elliptical) *for*. Thus, the differential effects of context do not seem to derive from a greater unitization of the prepositional phrases.

Third, the differential effect of context was obtained in Experiment 4 when the prepositional and adjectival sentences conveyed essentially the same meaning, further supporting the dominant role of syntactic structure in the missing-letter effect.

Taken together, these results strengthen our thesis that the missing-letter effect for high-frequency function words does not simply arise from their greater unitization, but reflects their role in the particular sentential context. Thus, the effect could not have emerged from the processes leading up to and including lexical access, but apparently occurred at a stage where the individual words were integrated into an overall meaning schema for the phrase as a whole. Our findings indicate that the missing-letter effect is sensitive to very subtle contextual features, such as the location of the reference in the text. It follows that this effect results from a process that is finely tuned to the structural aspects of the sentence.

Also, the effect was sensitive to the organization of the sentence even where meaning was held constant. Thus, it would appear that the missing-letter effect is independent of both the lexical entries of individual target units and the meaning of the encompassing sentence. This is consistent with our contention (Koriat & Greenberg, 1991; Koriat et al., 1991) that the locus of the effect is at the stage where the individual units are integrated into an overall meaning representation (see Rayner & Frazier, 1989).

Altogether, these results are consistent with the structural model advanced by Koriat et al. (1991) and Koriat and Greenberg (1991). We propose that although the coding of structure and the coding of meaning go hand in hand during reading, the coding of structure generally leads the way: Readers try to establish a tentative structural frame for the phrase and then use it to guide the interpretation and integration of the constituent units into a meaning representation. The establishment of these frames appears to occur at a relatively early stage in text processing, on the basis of a cursory and shallow visual analysis that utilizes a parafoveal preview of information (see Rayner & Pollatsek, 1989). The missing-letter effect reflects a kind of figure-ground organization of the sentence, where the structure-supporting units recede to the background as the meaning of the text unfolds. Therefore, letter detection is more difficult in function words, which normally serve to anchor and support phrase structure, than in the semantically informative content words. However, when function words are forced into a content role, thus presumably contributing less to structural specification, their constituent letters remain available. Furthermore, inasmuch as tentative structural frames are apparently established at the local level before all relevant constraints have been consulted (see Frazier, Clifton, & Randall, 1983), it is these local frames rather than the more encompassing frames that are presumably responsible for the missing-letter effect. This can explain why letter detection for *for* was affected by changes in the location of its object in text, although these changes did not modify the overall meaning (Experiment 4).

The structural account sketched above differs from both the redundancy and the unitization accounts in that it attributes the missing-letter effect to a relatively late stage in text processing. Thus, the redundancy account relegates the effect to a prelexical stage, assuming that subjects merely skip function words during reading, whereas in the unitization account the effect is seen to ensue from the process by which orthographic entries contact their internal representations. The structural account, in contrast, assumes the effect to occur at a relatively late stage, after the meanings of individual words have been accessed and their role in the phrase has been defined.[3]

[3] We should note that in all of the experiments reported in the present article, manipulation of the syntactic function of the critical function word was accompanied by a change in stress. For example, *for* was more stressed in *for or against* than in *for abortion*. Thus, perhaps the missing-letter effect for a function word is mediated by its relative stress within the phrase. We are currently exploring this possibility, among others, within a general conceptual framework where both prosodic structure (see Gee & Grosjean, 1983), and detection errors are seen to reflect the processes underlying the extraction of structural frames during reading.

If the structural account of the missing-letter effect is accepted, it follows that this effect could be diagnostic about the process underlying the establishment of structural frames during reading. We should now discuss some specific findings of the present study and their possible implications regarding the extraction of structural frames.

First, consider the finding that letter detection in a target word can be affected by its trailing context. This finding constitutes strong support for the late-stage account of the missing-letter effect. In both Experiments 3 and 4, context preceding the appearance of the target word *for* was held constant. In fact, in Experiment 4, the equated preceding context extended for as many as eight words. Nevertheless, the typical function-disadvantage effect was found, implying that letter detection for *for* depends on the words that *follow* it in text. Of course, it is possible that *or* (in *for or against*) is registered concurrently with *for*. However, the point to emphasize is that the missing-letter effect is "late" in the sense that the letters are not lost immediately on encountering the familiar visual pattern *for*. Rather, the word that follows *for* must be properly interpreted and integrated so that it can specify *for*'s role before the constituent letters of *for* are lost. Of course, it might be argued that the visual pattern *for or*, being very familiar, is registered and processed as a unitized pattern. However, according to the unitization principle, this pattern should have produced more, not fewer, detection errors than less familiar word sequences.

More work is needed, perhaps utilizing eye movement methodology (see Rayner & Pollatsek, 1989) to help clarify how information that occurs to the right (in English) of a target word assists the establishment of a structural frame that affects letter detection in the target word itself. If *or* is found to improve letter detection in *for* even when *or* is not fixated, this would support the proposition that the extraction of phrase structure occurs on the basis of a shallow visual analysis that utilizes a parafoveal preview. This proposition was advanced by Koriat and Greenberg (1991) to explain the finding that the size of the function-disadvantage effect for nonwords varied with their visual similarity to the words they replaced in text (e.g., replacing *for* with either *fom* or *fol*). The effect of trailing context in the present study may similarly suggest the operation of a fast-moving, structure-building process that is based on a shallow processing of text (including parafoveal preview) and that leads the way to a more detailed analysis that focuses on meaning.

Second, the effects of trailing context in the present study contrast with the absence of such effects in a previous Hebrew experiment (Koriat et al., 1991, Experiment 4), and this contrast may be instructive about the size of the structural frames that are responsible for the missing-letter effect. In that experiment, ambiguous Hebrew words were used that could be interpreted either as a function prefix plus stem combination or as an unprefixed content word. These words were either preceded or followed by a *disambiguating* context in the sentence. Although the preceding context affected detection of the initial letter of the ambiguous word, the following context did not.

The discrepancy between these results and those of Experiments 3 and 4 may be due to the positioning of the disambiguating information. In the latter experiments, the disambiguating context immediately followed the target word (*for*). Specifically, the word *or* that immediately follows *for* in *for or against* tips the balance in favor of the adjectival interpretation, because *or* normally establishes a relationship between two content words. Such was not the case in the Hebrew experiment. It appears, then, that although the meaning of the ambiguous Hebrew words was made clear by its subsequent disambiguating context, the effects of context on letter detection were confined to the locations immediately surrounding the target word (see Drewnowski & Healy, 1977; Healy, Oliver, & McNamara, 1987; Koriat & Greenberg, 1991). Thus, the discrepancy noted above is consistent with the proposal that although readers may establish structural frames of different sizes (story, passage, sentence, phrase), the missing-letter effect is most sensitive to local frames, possibly at the phrase level only. This proposal is also supported by the finding from Experiment 4 that the missing-letter effect is stronger when the object of *for* is explicitly included in the same phrase as *for* than when it is not.

Third, the present results illuminate the process by which local context exercises its influence on letter detection in function words. As indicated earlier, Healy and her associates reported that word scrambling reduced the size of the missing-letter effect for function words and interpreted this finding in terms of a greater unitization of the phrases surrounding the function words. In contrast, our results suggest that local context exerts its effect not merely through increasing the unitization of the phrase as a whole, but by instantiating a particular role for the function word. Although *for or against* is a common phrase, it nevertheless engendered no more detection errors than did the scrambled phrases.

We are not entirely clear about the process by which function words come to assume their specific roles within the evolving frame of the phrase. However, the results of the present study suggest that the critical factor underlying the missing-letter effect lies in the extent to which a morphemic unit contributes to structural specification relative to its contribution to meaning. Presumably, when *for* is embedded in *for or against*, it takes on a heavier semantic burden than it normally does when it is used in its typical function role. The same is true for *on* when embedded in *on switch*, where it essentially conveys semantic rather than syntactic information. Furthermore, the results of Experiment 4 suggest that what matters is the role of the morpheme within its circumscribed local context. Presumably, when a function word is used elliptically to refer to an object mentioned earlier, it takes on more semantic content within the phrase than when the object is explicitly stated in the same phrase. In summary, we envision a system where morphemes recede to the background when they serve to define the structural frame of the phrase, but are brought to the foreground when they are found to contribute to the evolving meaning of the phrase.

Finally, the results of the present study lend further support to the general claim (see Koriat & Greenberg, 1991) that the structural frames that are responsible for the missing-letter effect are established on the basis of a delicate interplay between syntactic, lexical, and semantic factors. This interplay may be illustrated by contrasting the results of the present

study with those of the previous study (Koriat & Greenberg, 1991). In that study, function and content words were placed in syntactic slots that called either for a function or a content word in a sentence. Error rate was of course highest where the function words appeared in their proper function slots. Placing function words in content slots reduced their error rate markedly, although it remained relatively high in comparison with content words. Content words, in contrast, yielded few omission errors whether they were placed in a content or a function slot. These results were interpreted to suggest that readers monitor text for function words as potential syntactic cues for the phrase's structural frame. When these words effectively mark a phrase's structure, they are likely to engender an inordinately high percentage of errors. However, even when they are misplaced, readers can often succeed in building tentative frames around them. Although such frames might be superseded by subsequent constructions, they may still produce the missing-letter effect to a modest degree.

In the present study, in contrast, function words embedded in content locations yielded no evidence for a missing-letter effect. This is probably because these content phrases provided a structural frame specifically instantiating a content interpretation of the function word. Such was not the case in the previous study, where placing a function word in a content slot generated an embedding context that failed to articulate a precise role for the function word. Thus, although readers generally focus on common function words in an attempt to derive a useful structure, where the phrase instantiates a clear content interpretation of the function word, the tendency to utilize that word as a syntactic anchor is diminished, resulting in reduced detection errors.

Other results of the previous study (Koriat & Greenberg, 1991) also suggest that in the same way that contextual factors may constrain the establishment of a structural frame around a function word, so can lexical factors counteract the effects of contextual–syntactic factors. Thus, although nonwords generally produced less detection errors than words, a nonword placed in a function slot tended, in fact, to produce more detection errors than a content word placed in the same slot. Apparently, a nonword can be assimilated more readily into the evolving frame than a content word whose lexical entry is incompatible with a function interpretation.

In summary, the present results, along with those of our previous work, pose profound difficulties both for the unitization account of the missing-letter effect as presently constituted and for the redundancy explanation. Meanwhile, they further the support for an emerging structural account, which emphasizes the contribution of syntactic structure to the early stages of text processing.

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