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Age Changes in the Missing-Letter Effect Reflect the Reader's Growing Ability to Extract the Structure from Text

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Readers searching for a target letter in text are more likely to miss it in frequent function words than in less frequent content words, and the magnitude of this effect increases with age. While this increase has been taken to indicate that proficient readers process familiar words in terms of larger orthographic units, we propose that it reflects the reader's growing ability to extract the structure of text, resulting in a reduced emphasis on function than on content words. Indeed, comparing 2nd graders (7 to 7 1/2 years) and college students (Experiment 1) this increase was found even when function and content words were equated for frequency. Scrambling words within a sentence (Experiment 2) improved letter detection in function compared to content words among 7th graders (12 to 13 years) and college students, but not among 3rd graders (8 to 9 years). Although letter detection was also affected by word frequency, the age differences noted above are possibly due not to the increasing familiarity of words, but rather to the growing sensitivity to their structural role in text.

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One of the most replicated phenomena in reading research is that familiar words, such as *the, and,* and *for,* conceal their constituent letters (e.g., Corcoran, 1966; Drewnowski & Healy, 1977; Greenberg & Koriat, 1991; Healy, Oliver, & McNamara, 1987, Greenberg, Koriat, & Shapiro, 1992, Proctor & Healy, 1985). Thus, in reading a text, readers find it more difficult to detect the target letter *t* in *the* than in *rather.* Healy (1976) ascribed this missing-letter effect to the greater frequency of *the,* claiming that familiar words are more unitized, and hence conceal their constituent letters (see Drewnowski & Healy, 1980; Healy & Drewnowski, 1983). Specifically, the *unitization* model assumes that text is processed on several levels in parallel, e.g., letter, word, and phrase. Familiarity of higher-level units permits direct access to these units, thus preempting access to their constituent, lower-level units. Hence letter detection is more difficult with familiar than with less familiar words. More recently, Hadley and Healy (1991) revised the original model, suggesting that unitization is particularly critical during parafoveal processing of familiar words. Presumably, a complete and early identification of a familiar word in the parafovea allows readers to skip foveal processing of that word.

The unitization account of the missing-letter effect has recently been challenged by findings which suggest that it is the semantic-syntactic role of a word, rather than its familiarity, that is primarily responsible for the effect (Greenberg & Koriat, 1991; Greenberg et al., 1992, Koriat & Greenberg, 1991; Koriat & Greenberg, 1993, 1996; Koriat, Greenberg, & Goldshmid, 1991). Specifically, the missing-letter effect has been most consistently demonstrated for words such as *the, and,* and *for,* which carry little semantic content (Schindler, 1978). Hence, it is possible that the effect is due to the specific linguistic role of these words rather than to their familiarity or perceptual unitization. How might this occur? According to the alternative, *structural* account (see Greenberg & Koriat, 1991; Koriat & Greenberg, 1991, 1993, 1994), both structure and meaning are coded during reading, but analysis of structure leads the way to the processing of meaning (see Aaronson & Ferres, 1983; Bock, 1990). Function words are assumed to make a critical contribution to the process of establishing structure, for example, by signalling the onset of a new phrase (Kimball, 1973), and are therefore monitored early in text processing. However, as structure assumes its role in organizing the semantic pattern, the supports of structure become less available, resulting in a greater difficulty to detect letters in function words than in content words.

Evidence favoring the structural position comes from several sources (see Koriat & Greenberg, 1994, for a review). In brief, Koriat et al. (1991) used Hebrew because it offers some unique opportunities to disentangle the effects of frequency and structural role, which are confounded in English. In Hebrew, some function morphemes can be expressed as a one-letter prefix appended to a content word (e.g., LHAIFA means ''to Haifa,'' where the letter L, Lamed in Hebrew, represents the morpheme ''to''). Letter detection was more difficult for the initial

letter of a word when that letter was a function prefix than when it was part of a content word's stem, although the entire prefix word was no more frequent than control content words. Additionally, nonwords in both English and Hebrew yielded more errors when they appeared in functor slots than when they appeared in content slots in text. This effect was also found with English nonwords even when the same nonword, e.g., *fol*, was used to replace either a content word (e.g., *fog*) or a function word (e.g., *for*) in connected text (Koriat & Greenberg, 1991). Moreover, the same function word in English was found to reveal or conceal its letters depending upon its role within a phrase (Greenberg & Koriat, 1991). Thus, detection of the letter *n* in *on* was easier in the sequence *on switch* (where *on* is a modifier), than in *on my way* (where *on* maintains its typical function role). In the same vein, Moravcsik and Healy (1995) reported fewer errors in *the* when this word was used as a content word (referring to a thai spice) than when it was used as an article. They also found that letter detection for the word *in* is easier in phrases such as ''in clothes.'' Similarly, letter detection in the functor *for* was easier when *for* appeared at the end of a clause, and presumably contributed less to structure, than when it marked the onset of a phrase (Greenberg et al., 1992). In sum, there appears to be ample cause to assume that a word's structural role is crucial to the missing-letter effect.

The primary goal of the present research was to examine the missing-letter effect within a developmental context. This investigation gains impetus from several findings suggesting age changes in the magnitude of the effect. Drewnowski (1978) had first- through fifth-graders and college students perform the letter-detection task using four different types of passages. All but the first graders made an inordinately large number of errors on the function word *the*. Additionally, among first-grade readers, good readers were more likely to exhibit the missing-letter effect than were poor readers. Moreover, scrambling the words within a passage reduced the error rate for function words just for the good readers. Similar results were obtained in a subsequent study (Drewnowski, 1981), using *in* and *and*. Finally, Cunningham, Healy, Kanengiser, Chizzick, and Willitts (1988) found that detection of the letter *a* when it appeared by itself (as an article), was worse than when it was embedded in more familiar content words. This effect was obtained for children in third grade or above, but not for first graders. Thus, there is reasonable evidence that the missing-letter effect arises very early in reading, by the first or second grade, and that its magnitude increases with grade level. This evidence suggests that the occurrence of the missing-letter effect may be symptomatic of some developmental changes in text processing that occur during the acquisition of reading skills.

However, the interpretation of these developmental changes depends upon how the missing-letter effect itself is explained. If it is indeed due to the familiarity of function units, then the results could indicate that with increasing skill in reading, more unitized representations are formed for the frequently encountered units, so that readers can process text in terms of increasingly higher

level units. This is the interpretation offered by Drewnowski (1981). Consistent with this position is evidence suggesting that unitization at the phrase level begins later than that at the word level by the third grade in Cunningham et al. (1988) and by the fifth grade in Drewnowski (1981).

In contrast, according to the structural position, the missing-letter effect reflects primarily the differing structural roles of words in text. Presumably, then, an alternative interpretation of the developmental findings is that the magnitude of the missing-letter effect across ages reflects the changing ability of readers to extract the structure of phrases on-line during text processing. This ability requires identifying the structural role of different units in text, and using function units to build tentative structural frames. Consistent with this interpretation is that poor readers appear to be less sensitive to the syntactic properties of spoken and printed words than are normal readers (Vellutino & Scanlon, 1987). Moreover, developmental evidence indicates that function words are more difficult to encode and, thus, more difficult to learn to read, than are content words regardless of whether these words appear in context or in isolation (Blank, 1985). Finally, both children and adults have more difficulty handling function words in short-term memory and list-learning tasks (Paivio & Begg, 1971; Vellutino & Scanlon, 1985; Vellutino, Scanlon, & Spearing, 1995). A reasonable interpretation of this pattern of results is that function words are more abstract and linguistically more complex than are content words, and, unlike many content words, are devoid of referential imagery (Kintsch, 1972). Thus, it is possible that the developmental changes in the missing-letter effect are symptomatic of the reader's growing proficiency to process function units and use them as cues for the structure of text. Previous studies provided no basis for determining whether the alternative, structural explanation offers a viable account.

In an effort to determine whether increased unitization or increased ability to encode linguistic structure is responsible for the age changes in the missing-letter effect, Experiment 1 used a simple procedure to unconfound frequency and function. Passages were composed around pairs of short function and content words that were matched for length and contained the same target letter. In some of the pairs, the function word was considerably more frequent than the content word, as is typical, whereas in other pairs the two words were of equal frequency. Presumably, the unitization position would argue that when frequency is equated the functor disadvantage would disappear. In contrast, according to the structural position, the missing-letter effect should hold even when function and content units are matched on frequency, and furthermore, the developmental changes observed by Drewnowski should be found for such a condition as well.

A comparison of letter detection for the equal-frequency and different-frequency pairs should allow us to determine whether the age-changes in the magnitude of the missing-letter effect also stem from a greater unitization of familiar units. In one experiment, Healy (1976) obtained a higher rate of

detection errors for high-frequency than for low-frequency *content* words. Thus, it is of interest to see whether frequency too contributes to the age changes observed.

Experiment 1 also included a condition in which function and content words appeared either in their appropriate location in the sentence, or in inappropriate contextual slots. Placing a function word in a content slot has been previously shown to improve letter detection substantially among adults, consistent with the structural position (Koriat & Greenberg, 1991). If the age changes in the missing-letter effect are indeed due to increased sensitivity to the structural properties of text, then children's letter detection performance should be relatively unaffected by the misplacement of words in text.

EXPERIMENT 1

Method

Participants. Forty-eight Union College undergraduates were paid $3 each for participating in the experiment. Additionally, 55 second-grade pupils, with most students falling between the ages of 7 and 7 1/2 years, from Forts Ferry elementary school in Latham, New York participated, with the consent of their parents.

Design and materials. Initially, three different passages were constructed, one for each pairing of a function and content word. Each passage consisted of 34 sentences: Ten sentences contained one instance of the target function word, 10 contained one instance of the corresponding content word, 7 noncritical sentences presented the target letter in a short nontarget word, and finally 7 sentences contained no target letter. The location of target words within a sentence was the same for the matched function and content sentences.

Two additional ''anomalous'' passages were then derived from each of the above passages. In one version, in half of the function and content word sentences the function and content words exchanged locations, so that a function word occupied a content slot and vice versa. In a second version, the reversal of locations took place across the other pairs of five sentences, while the sentences involved in the exchange in the first version had the correct words restored. In this manner, each anomalous version presented half its target function and content words in an appropriate location, and half in an inappropriate location. Approximately half the participants in the experiment were presented the normal passages, whereas the other half received the anomalous versions, with approximately an equal number of each anomalous version used.

Three pairs of function/content words were used as targets, one pair assigned to each passage and its related versions. The three pairs were *at/it*, *in/it*, and *to/do*. The target letter for the *at/it* pair was *t*, for *in/it* it was *i*, and for *to/do* it was *o*. For adults, the frequency counts for the pairs were obtained from Kuçera and Francis (1967). According to this source, *at* and *it* have reasonably similar very high frequencies, with the function word *at* having the somewhat lower fre-

quency (5378 per million) than *it* (8756). *In* and *it* are substantially different in frequency, *in* having a count of 21,341 per million. *To* and *do* also differ substantially, *to* occurring 26,149 and *do* 1363 times per million.

For contrasts involving children, the frequency norms were based on 400 storybooks for beginning readers (Durr, 1985). We chose different norms for our children, and this resulted in a different word contrast in the equal-frequency condition for the two groups, because we wanted to insure that the function-content differences in familiarity that are called for by our design are maintained across the age groups studied. This was a particular concern in the equal frequency condition. Thus, the *at/it* passages were not used for children. Instead, *in* and *it* which are approximately equal in frequency for children, having frequencies of 311 and 345, respectively, were chosen. In contrast, *to* and *do* are substantially different in frequency, *to* with a count of 746 and *do* with one of only 99. For the *in/it* and *to/do* passages, constructed for children and adults, vocabulary never exceeded second grade level (Thorndike & Lorge, 1944). The *at/it* passage used only with adults was somewhat more difficult, but its style matched that of the other passages. Preliminary tests suggested that difficulty of a passage within this range has little effect on the missing-letter effect.

Finally, one other variable was manipulated in the case of the *in/it* passage. Adult participants tested first showed virtually no errors in their search for *i.* We surmised that this might be due to the distinctive appearance of the target *i,* i.e., the dot that appears above it. Therefore, we constructed a second set of *in/it* passages, identical to the first, but with the dots over the *i* removed. Subsequently, 10 additional adult participants were run using this new format, and because the children were tested later, we divided the dotted and no-dot version approximately equally among the children.

Procedure. Each participant was handed a booklet to read. The adult booklet contained three experimental target passages, one for each function-content target pair. The ordering of the critical passages was counterbalanced across participants. Half the adults received normal versions of each passage, whereas the other half received one of the two anomalous versions. As indicated above, ten adults received an *in/it* passage with *i* not dotted. The passages were in story format. Each target passage was preceded by a page indicating the appropriate target letter, and including a short practice passage in which participants were asked to search for that letter. Each experimental passage was followed by five true/false questions pertaining to that passage, so that readers would be encouraged to read for comprehension. There was also a page of general instructions, and a consent form at the beginning of each booklet.

The booklet for children contained only two experimental target passages: *in/it* and *to/do,* which were presented in a counterbalanced order across participants. In addition, there was an instruction page, two practice pages, and two sets of three true/false questions. Consent forms for children were obtained in advance of testing. The instructions in the booklet were supplemented by oral instructions

TABLE 1
Means and Standard Errors of Percentages of Omission Errors for Content and Function Words

Frequency condition	Word class	Age group			
		Children		Adults	
		M	*SE*	*M*	*SE*
Unequal	Function	41.4	3.0	52.1	3.0
	Content	12.3	1.6	1.6	0.4
Equal	Function	25.5	2.4	55.5	2.5
	Content	14.6	1.5	13.8	1.4

Note. The results are presented separately for a condition where the function word's frequency is greater than that of the content word (''unequal''), and where both are of equal frequency (''equal'').

with examples delivered by the experimenter, with the aid of the second grade teachers. As was the case with the adults, half the children received normal passages, and half received anomalous passages. Furthermore, the children were evenly divided between dotted and undotted *i* passages.

Participants were instructed to read at their normal speed and to circle any instance of the target letter. They were asked to read for comprehension, and were told that they would be asked to answer several true/false questions after completing each passage. As is typical in this task, participants were told not to retreat and circle targets that initially were missed.

Results

The analyses to be reported below were confined to the unequal-frequency condition of *to/do*, and to the equal-frequency comparisons of *in/it* for children, and *at/it* for adults. Preliminary analyses indicated that children were unaffected by dots above the *i* (and we report on some evidence of that later). Also, adults in the undotted *in/it* condition responded similarly to all adults in the *at/it* condition, so for simplicity we focused our analyses on the latter data which were more plentiful.

Table 1 presents mean percentage of detection errors as a function of age for both the unequal-frequency condition (in which the function word was more frequent than the content word), and in the equal-frequency condition (in which the two words were matched on frequency). Focusing first on the former condition, which is representative of previous comparisons, it can be seen that the present results are generally consistent with earlier findings in two respects. First, the more frequent function words engendered more errors than their corresponding content words across both groups. Second, the size of the missing-letter effect i.e., the difference between the error percentage for content and function words, increased with age from 29 to 50%. A two-way analysis of variance (ANOVA),

Age × Word Type (Content vs. Function), yielded $F < 1$ for age; $F(1,99) = 109.37$, $p < .001$ for word type; and $F(1,99) = 8.06$, $p < .01$, for the interaction, supporting the above observations.

The second, equal-frequency condition, allows us to determine whether the two effects just noted derived from the greater frequency of the function words, or from their syntactic role within the sentence. A similar two-way ANOVA on the results for this condition yielded $F(1,99) = 9.45$, $p < .005$, for age; $F(1,99) = 102.81$, $p < .001$, for word type; and $F(1,99) = 32.92$, $p < .001$, for the interaction. Thus, first, the missing-letter effect is found even when frequency is equated, suggesting that this effect depends, to a large degree, upon syntactic role. Second, the interaction suggests that the sensitivity to the syntactic role of words in text increases with age. These results are consistent with the structural view according to which the developmental changes in the magnitude of the missing-letter effect reflect increased sensitivity to the structural role of words, and increased tendency to utilize them in building structural frames for the sentence.

Does word frequency also exert an effect over and above that of syntactic role? To examine this question, a three-way ANOVA was conducted, with frequency condition (equal vs. unequal frequency) as the third factor. As expected, this analysis revealed a significant main effect for word type, $F(2,98) = 161.62$, $p < .001$; and an Age × Word Type interaction, $F(2,98) = 24.64$, $p < .001$. In addition, significant effects were found for the Age × Frequency Condition interaction, $F(1,98) = 7.72$, $p < .01$; and for the Frequency Condition × Word Type interaction, $F(1,98) = 11.91$, $p < .001$. The Age × Frequency Condition interaction reflects the observation that adults exhibited more detection errors with the equal-frequency than with the unequal-frequency passages, whereas the reverse was true for children. More important, the Frequency Condition × Word Type interaction derives from the fact that the magnitude of the missing-letter effect was stronger when the function word was also more frequent than the content word. This interaction indicates that frequency too may contribute to the missing-letter effect. Note that the triple interaction was not significant, $F(1,98) = 1.19$, suggesting that the effects of frequency do not increase with age.

While the missing-letter effect was strongest among adults in both the equal- and unequal-frequency conditions, inspection of Table 1 clearly indicates that it was also evident among second graders. As was true for the adults, the children made more errors on function than content words, both in the unequal-frequency condition, $F(1,52) = 31.31$, $p < .001$; and in the equal-frequency condition, $F(1,51) = 10.46$, $p < .005$. As far as the age changes in the missing-letter effect are concerned, the Age × Word Type interaction noted earlier appears to stem, curiously enough, from the fact that the older participants made *more* errors than children on function units. This was true both in the equal-frequency condition, $F(1,99) = 21.00$, $p < .001$; as well as in the unequal-frequency condition, though in this latter case the effect was not significant, $F(1,99) = 1.89$, $p < .10$.

TABLE 2
Means and Standard Errors of Percentages of Omission Errors for Unequal-Frequency and Equal-Frequency Content and Function Words in Appropriate and Inappropriate Text Slots

Frequency condition	Word class	Age group: Child *M*	Child *SE*	Adult *M*	Adult *SE*
		Appropriate slot			
Unequal	Function	24.2	2.7	31.6	2.2
	Content	4.2	1.0	0.8	0.8
Equal	Function	15.8	2.3	35.8	2.6
	Content	5.0	1.2	9.2	1.4
		Inappropriate slot			
Unequal	Function	15.8	1.9	15.0	1.7
	Content	5.8	1.1	0.0	0.0
Equal	Function	18.3	2.2	11.6	2.4
	Content	7.1	1.4	9.2	2.2

Table 1 also suggests that the role of frequency in the missing-letter effect was less clear for adults than children. Although both groups show a stronger effect in the unequal- than in the equal-frequency condition, the stronger effect for adults was due primarily to a drop in content errors rather than to an increase in function errors. Nevertheless, frequency affected performance in both groups. Thus, a Frequency Condition $\times$ Word Type ANOVA for the adult group yielded $F(1,47) = 4.52$, $p < .05$, for frequency condition; $F(1,47) = 110.81$, $p < .001$, for word type; and $F(1,47) = 4.47$, $p < .05$, for the interaction. A similar ANOVA for the children indicated $F(1,51) = 3.31$, *ns*, for frequency condition; $F(1,51) = 46.53$, $p < .001$, for word type; and $F(1,51) = 7.85$, $p < .01$, for the interaction. Thus, although the interaction is indeed somewhat stronger for the children than for the adults, both groups exhibited a more pronounced effect in the unequal-frequency condition.

The next series of analyses concerned the effect of switching function and content units within text. The results are presented in Table 2 for the appropriate and inappropriate slots. Note that the means reported in Table 2 for the appropriate slots differ from the means in Table 1, because in Table 2 we display only data obtained from participants in the condition in which they had both appropriately and inappropriately slotted target words. Inspection of Table 2 reveals several trends. First, the results for the appropriate-slot condition generally replicate those reported earlier: The missing-letter effect is evident for both adults and children, but it is stronger for adults. However, unlike the results reported earlier, here we find little indication of a frequency effect for either

children or adults. Thus a three-way ANOVA, Age × Word Type × Frequency Condition yielded neither a main effect for frequency condition, $F < 1$, nor any interaction involving condition. These analyses, however, did yield significant effects for age, $F(1,46) = 4.68$, $p < .05$; for word type, $F(1,46) = 75.52$, $p < .001$; and for the Age × Word Type interaction, $F(1,46) = 6.88$, $p < .05$.

Second, the comparison between the appropriate-slot and the inappropriate-slot conditions indicated that the placing of content and function units in inappropriate syntactic slots reduced the size of the missing-letter effect. However, this reduction was clearly evident only in the adult group, and in this group, misplacement affected letter detection in function words, but not in content words. Thus, letter detection in function units improved considerably when these units were placed in a slot that was appropriate for a content word in text. In contrast, detection errors in content words were generally indifferent to location.

The following analyses support these conclusions. In these analyses the data from both the equal- and unequal-frequency conditions were collapsed, because the previous analysis failed to yield any effect for frequency. First, a three-way ANOVA, Age × Word Type × Location (appropriate vs. inappropriate) yielded $F < 1$ for age, $F(1,46) = 67.03$, $p < .01$, for word type; and $F(1,46) = 19.68$, $p < .001$ for location. In addition, the Word Type × Location interaction was significant, $F(1,46) = 12.59$, $p < .001$; as was the Age × Location interaction, $F(1,46) = 16.77$, $p < .001$. Furthermore, the triple interaction was also significant, $F(1,46) = 4.53$, $p < .05$. Inspection of Table 2 reveals the source of these interactions: Whereas the placing of words in inappropriate syntactic slots generally improves letter detection, the beneficial effect appears to be confined primarily to function words, and to adult readers.

Two analyses were conducted to substantiate these conclusions. First, focusing only on function units, an Age × Location ANOVA yielded significant effects for location, $F(1,46) = 19.78$, $p < .001$; as well as for the Age × Location interaction, $F(1,46) = 11.13$, $p < .005$. In contrast, a similar ANOVA conducted for content words yielded $F < 1$ for both main effects and for the interaction.

Second, a Word Type × Location ANOVA for adult participants produced significant effects for word type, $F(1,23) = 52.99$, $p < .001$; location, $F(1,23) = 46.22$, $p < .001$; and the interaction, $F(1,23) = 12.55$, $p < .002$. In contrast, the same ANOVA for children yielded only a main effect for word type, $F(1,23) = 20.04$, $p < .001$, and no effect for location, $F < 1$, or the interaction, $F(1,23) = 1.41$.

Finally, because the previous analysis collapsed data for the *in/it* passages from both dotted and undotted *i*, some of the above analyses were repeated using only children in the undotted condition. The results of these analyses left the conclusions unchanged. In particular, the analysis comparing children and adults in the equal-frequency condition, again showed an effect of word type, $F(1,70) = 65.09$, $p < .005$; and a Age × Word Type interaction, $F(1,70) = 5.45$, $p < .05$. Furthermore, as before, a separate analysis of the children data revealed a word-type effect, $F(1,23) = 8.06$, $p < .01$.

Discussion

Past work evaluating developmental changes in letter detection in function and content words compared high frequency function words with content words of considerably lower frequency (Cunningham et al., 1988). Consequently, it was not possible to discern whether these changes reflect increased unitization of familiar words with reading practice, or rather increased capacity to use function words as a guide for sentence structure. The structural account of the missing-letter effect invites a reexamination of the age differences observed in letter detection. According to that account, these differences reflect an increasing capacity to extract the structure of text on line during reading, and to build tentative structural frames that can help integrate each processed reading unit into a general meaning schema. In order to contrast the predictions of the unitization and structural views it was necessary to disentangle the effects of frequency from those of function. Thus, in addition to comparing the performance of children and adults under the typical conditions in which function words are of considerably higher frequency than their content word counterparts, we included a condition in Experiment 1 in which the frequency of the function and content words was equated. Indeed, with the typical condition in which the function unit is the more frequent, our results replicated previous findings. First, the missing-letter effect was demonstrated for both adults and children. Second, the magnitude of the effect increased with age. These findings are consistent with both the unitization and structural approaches. However, the missing-letter effect was also obtained when function and content words were matched for frequency. As was the case with the unequal-frequency condition, the missing-letter effect was exhibited by early readers as well as by adults, and the effect increased with increasing reading experience. Curiously, adults made more errors in function words than did children. Thus, it would seem that the increased magnitude of the missing-letter effect with age is associated with increased attention to the structural role of words in connected text. Additionally, we found evidence that children are somewhat less affected by the slot occupied by a function word than are adults: Whereas the misplacement of a functor helped reveal its target letter to adults, children benefited little from this manipulation. This finding too suggests that the bulk of the age difference in the differential processing of content and function words is due to the greater sensitivity of adults to the structural role of functors in a sentence.

While we interpret these results as support for the structural position, some concern might be raised regarding our choice of target words in Experiment 1. First, the target word *it*, which was used in the equal-frequency comparison, may be technically classified as a function word (see e.g., Clark and Clark, 1977). However, what matters in terms of the structural view is not the technical classification of the word as a function word, but rather the extent to which it contributes more to the structure of a phrase or to its content. Both Moravcsik and Healy's (1995) work and our own research (e.g., Greenberg & Koriat, 1991) have

yielded evidence that letter detection for even the same word varies with its role in a sentence. Even prepositions and articles (e.g., *in, on, for,* and *the*) produce no more errors than standard content words when they do not assume a structure supporting role. For example, Moravcsik and Healy showed that letter detection in *it* varies with its specific role in a sentence. Thus, while it is more convenient to stress the function/content contrast, what matters in terms of the structural model is the specific role assumed by a word in a sentence. Indeed, the present study demonstrates that a pronoun such as *it,* in its role as the subject or object of a phrase, in fact, yields better letter detection than do the prepositions to which it was compared, and this was the case even though *it* and the comparison prepositions were matched on frequency. This result is perfectly consistent with the structural model's emphasis on sentential role.

One other potential concerns arises from the target letters in the equal frequency conditions being different for adults and children. Koriat and Greenberg (1991) and Schneider, Healy, and Gesi (1991) observed that the strength of the missing-letter effect can vary across target letters. However, these differences cannot explain why moving a function word to a content location would enhance letter detection for adults only. Presumably, a change of slot ought not to be of greater consequence for one group than another if the observed differences in the appropriate slot condition were simply a function of which letter was being detected. In total, the more parsimonious explanation of these findings is one that emphasizes a target word's role in the sentence.

EXPERIMENT 2

The results of Experiment 1 supported the proposition that the age changes that occur in the missing-letter effect reflect increased sensitivity to the structural organization of the sentence. At the same time, however, there was some support for the unitization hypothesis, in that word frequency also affected letter detection. In Experiment 2 we sought to obtain further support for the structural position while also attempting to clarify the relative contribution of structure-driven versus unitization-driven processes to the developmental changes in letter detection.

Experiment 2 differed from Experiment 1 in several respects. First, three age groups were included, third graders, seventh graders, and college students. The inclusion of seventh graders was intended to help specify in somewhat greater detail the developmental changes that occur in letter detection.

Second, Experiment 1 capitalized on the availability of some function words whose frequency could be matched with that of frequent content words. As noted, though, there is an artificial element in this matching. The word *it,* the content match in the equal-frequency condition, is considered by some a functor. To further strengthen our contention that young readers are less attentive to the structural role of functors than are adults, Experiment 2 , avoids such a comparison, and instead focused on the more standard comparison between the definite

article *the* and ordinary content words. Third, in Experiment 2, the same target letter is used for adults and children for both content and function words.

Finally, because frequency was not equated in Experiment 2 (i.e., *the* occurs more frequently than any other word in English) the methodological strategy implemented was similar to that used by Drewnowski (1978) who compared the missing-letter effect between two types of passages, normal and scrambled. In that study, word scrambling, i.e., reordering words randomly, with some constraints on target word placement, reduced the magnitude of the missing-letter effect for adults, but not for children below the fourth grade. Whereas the effect of scrambling on the missing-letter effect for adults has been replicated in a number of studies (e.g., Drewnowski, 1978; Drewnowski & Healy, 1977; Koriat et al., 1991), the effect of scrambling on children's letter detection has received more limited attention (e.g., Drewnowski, 1978).

In Experiment 2, then, we used the high-frequency functor *the* as well as matched high and low frequency content words. The target words were embedded either in a normal or a scrambled passage. It may be proposed that the contribution of sentence structure to the missing-letter effect should be observed for the normal text, and much less so for the scrambled text in which structure is largely destroyed. The contribution of word-level unitization, in contrast, should be equally found for both types of passages. Although this simple proposal would encounter the objection of proponents of both the unitization and structural positions, as will be discussed shortly, it can serve as a rough guideline for our predictions.

From the results of Experiment 1 it appears that both the structural role of functors as well as their high frequency contribute to their inordinately high rate of letter omissions. The question then is how unitization and structural contributions combine. One simple hypothesis, the additivity hypothesis, is that the two types of contributions are independent, but whereas the contribution of frequency (unitization) to letter omission is constant across different levels of reading proficiency, the effects of structural role, increase with reading proficiency, resulting in the observed age-increase in the magnitude of the letter-detection effect.

An alternative, interactive hypothesis, is that the effects of unitization on letter detection in function words actually diminish as these words are increasingly utilized as cues for structure. If this hypothesis is correct, then the overall magnitude of the missing-letter effect may or may not change with age depending on the relative contribution of unitization-driven and structure-driven processes to letter detection in function words. The key to these contributions should be found in comparing normal and scrambled passages: According to the interactive hypothesis, much of the missing-letter effect for children is due to the unitization of function words, and hence should be revealed with scrambled passages as well, whereas that for adults is primarily due to the structural role of these words, and hence will be found mostly for normal passages.

A comment about the effects of scrambling is needed in order to clarify how the scrambled sentences were generated in Experiment 2. Previous work comparing letter detection in scrambled and normal text has found scrambling to reduce the size of the missing-letter effect. While this finding seems, on the face of it, to accord better with the structural position, proponents of the unitization position (Drewnowski & Healy, 1977; Healy, 1994) argued that scrambling improves letter detection in function words because it destroys unitization of the integral phrase patterns in which these words are embedded. For example, the word *the* occurs very often in frequent, multi-word combinations, such as *on the* or *from the,* and these, allegedly perceptually unitized combinations are disrupted by scrambling. Elsewhere, we have offered arguments and data to suggest why a structural interpretation of the effects of scrambling is more plausible (see Greenberg, Koriat, & Shapiro, 1993; Koriat et al., 1991; Koriat & Greenberg, 1994) and we review those arguments later in the discussion section. Nevertheless, precautions were taken in Experiment 2 to reduce the likelihood of attributing the effect of scrambling to a greater phrase-level unitization in the normal passage. First, we avoided using *the* in phrases in which there was an adjacent high frequency functor, such as *on the* (see Drewnowski, 1978). Second, the critical content words in Experiment 2 appeared in word sequences that in the majority of cases contained a highly familiar functor (e.g., *a* or *and*) immediately preceding or following it, thereby presumably increasing the cohesiveness of the phrase. Finally, it might be assumed that high-frequency content words are more likely to enhance phrase-level unitization than lower frequency content words. Therefore, to assess the effect of scrambling that might be due to the destruction of familiar multiword units, and also to examine the possible effects of word frequency, both high- and low-frequency content words were used.

Method

Participants. Twenty-three Union College undergraduates were either paid $3 for participating or given credit toward fulfilling a course option for out-of-class activity. In addition, 19 third-grade students, almost all between the ages of 8 and 9 years, and 14 seventh-grade students, almost all between the ages of 12 and 13 years, from the Hebrew Academy of the Capitol District of Albany, New York participated (with the consent of their parents) and were rewarded with age appropriate gifts for their service.

Materials and design. Each participant was presented with a booklet containing six passages, arranged in two sets, three normal passages and three scrambled passages. The first two passages in each set were for practice, and the third was the experimental passage. The order of the two sets was counterbalanced across participants within each age level so that approximately half the participants received the normal passages first, and the other half received the scrambled passages first.

The passages for all three age levels were basically equivalent except that a few noncritical words in the third-grade passages were changed to more sophis-

ticated words for the seventh-grade and adult passages (e.g., *liked* changed to *admired*). The scrambled passages were rewritings of the normal passages in which the structural cohesion of each sentence was destroyed.

Each experimental passage contained 33 words in which the target letter *t* appeared as the initial letter. Only 15 of these words were target words—five *the*s, five short high frequency content words—*tree, two, try, turn* and *time* (no less than a frequency count of 3772 in the Harris and Jacobson norms, 1982), and five short low-frequency content words—*tour, tan, tub, tame,* and *trim* (frequency no higher than 94 in the Harris and Jacobson norms). The Harris and Jacobson norms were used to assure that the target words were familiar to children at the third-grade level. The high- and low- frequency content words were matched on length. The critical target words were matched across sentences for location. Finally, the critical target words never appeared at the beginning or end of a sentence or of a line of text, and were never preceded or followed by another word containing the letter *t.*

Procedure. Standard letter detection instructions were given (see Experiment 1). In addition, as in Experiment 1, readers were told that they would be asked a few questions following the readings. The questions were three brief true/false questions.

Results

Table 3 presents mean percentage of detection errors for function words, and high- and low-frequency content words as a function of age and passage type (normal vs. scrambled). The data of one third-grade participant who failed to mark any *t*s were eliminated. The results presented in Table 3 exhibit four trends that can be summarized as follows. First, a missing-letter effect is clearly observed for all age groups, including the youngest, with *the* producing almost 10 times more errors than content words.

Second, scrambling improves letter detection for function words but not for content words, thus reducing the magnitude of the missing-letter effect. Of primary importance, however, is the observation that this effect is exhibited by all age groups except the youngest. This group, in fact, yielded no effects of scrambling whatsoever. Thus, omission errors in *the* dropped from about 46% in normal passages to about 27% in scrambled passages for the seventh grade and college students combined, whereas the respective error rates for the third graders were 57 and 55%.

Third, a missing-letter effect, although of a smaller magnitude, is evident even for the scrambled passages.

Finally, the results for content words exhibit a frequency effect, with high-frequency words producing more errors than low-frequency words. This effect is generally observed for all age groups and for both normal and scrambled passages.

Several analyses confirm these observations. The first series of analyses

TABLE 3
Means (*M*) and Standard Errors (*SE*) of Percentages of Omission Errors for Function Words and High-Frequency (HF) and Low-Frequency (LF) Content Words for Normal and Scrambled Passages

Passage type	Word type		Grade			
			Third	Seventh	College	All
		Normal passage				
Normal	Function	*M*	56.8	41.2	49.2	49.5
		SE	6.7	9.0	6.0	4.1
	HF Content	*M*	17.9	10.0	8.3	11.9
		SE	5.7	3.6	2.9	2.4
	LF Content	*M*	11.6	2.5	7.5	7.5
		SE	3.8	2.5	2.0	1.7
		Scrambled passage				
Scrambled	Function	*M*	54.8	23.8	29.2	35.9
		SE	8.4	5.8	5.5	4.2
	HF Content	*M*	14.7	13.8	7.5	11.5
		SE	4.0	4.3	3.8	2.3
	LF Content	*M*	8.4	8.7	8.3	8.5
		SE	3.2	5.2	2.7	2.0

collapsed the data for the low- and high-frequency content words, and focused on the contrast between *the* and content words. A three-way ANOVA, Grade (3) $\times$ Passage Type (2) $\times$ Word Type (Content vs. Function) yielded significant main effects for both passage type, $F(1,56) = 10.44$, $p < .005$; and word type, $F(1,56) = 103.61$, $p < .0001$. In addition, the Passage Type $\times$ Word Type interaction was significant, $F(1,56) = 12.25$, $p < .001$. These effects, however, were further moderated by a three-way interaction, $F(2,56) = 3.54$, $p < .05$.

To clarify the source of this interaction, separate three-way ANOVAs were conducted, comparing each pair of age groups. As expected, the triple interaction reached significance when comparing third graders with either college students, $F(1,41) = 5.99$, $p < .02$; or seventh graders, $F(1,33) = 4.89$, $p < .05$; but not when seventh graders were compared with college students, $F < 1$.

Thus, the developmental transition seems to occur between the third and the seventh grade. For the third grade, a two-way ANOVA, Passage Type (2) $\times$ Word Type (Content vs. Function) yielded a significant effect only for word type, $F(1,18) = 49.95$, $p < .0001$, but not for passage type, $F < 1$, or the interaction, $F < 1$. In contrast, collapsing data across seventh graders and college students, a similar two-way ANOVA yielded significant effects for word type, $F(1,39) = 59.63$, $p < .0001$; passage type, $F(1,39) = 16.55$, $p < .0001$, and the interaction between them, $F(1,39) = 19.35$, $p < .0001$. Additional one-way ANOVAs

confirmed that for each of the age groups, *the* exhibited more omission errors than content words in both the normal and the scrambled passages.

Note that unlike in Experiment 1, there was no indication in Experiment 2 of a weaker missing-letter effect for the youngest group than for the other groups. Thus, focusing only on the normal format, a 2 × 2 ANOVA comparing the effects of word type (content vs. function) for the third graders with those for the seventh graders and college students combined, yielded $F(1,57) = 105.27$, $p < .0001$, for word type; and $F < 1$ for the interaction.

We turn next to the comparison between the high- and low-frequency content words. A three-way ANOVA, Grade (3) × Passage Type (2) × Word Frequency (2) yielded a significant effect for word frequency, $F(1,56) = 5.63$, $p < .05$, but no interactions. In fact, neither the Passage Type × Word Frequency interaction, nor the Passage Type × Word Frequency × Age interaction were statistically significant, $F < 1$. Furthermore, no systematic pattern emerges apart from the fact that across all age groups error rate in both high- and low-frequency content words was actually somewhat higher in the scrambled than in the normal passages. Thus, there is no suggestion, whatsoever, that manipulation of passage structure affects letter detection in familiar content words as it does in familiar function words.

Discussion

The results of Experiment 2 yielded a missing-letter effect for all age groups and for both normal and scrambled passages. The determinants of this effect, however, appear to differ for the three groups, as suggested by the interaction between word type and age level. For seventh graders and college students, the results replicate previous findings indicating that scrambling improves letter detection in function words but not in content words (e.g., Drewnowski, 1978; Drewnowski & Healy, 1977; Healy, 1976; Koriat & Greenberg, 1991). For third graders, in contrast, there was no effect of scrambling whatsoever. The results for the older participants suggest that the missing-letter effect for proficient readers is primarily due to the structural role of *the.* For third graders, in contrast, the indifference of the missing-letter effect to scrambling strongly suggests that this effect is not due to structural extraction, but to other factors, possibly the greater familiarity of *the*, as suggested by Healy (1994).

Consider first the effects observed for the older participants. The improved letter detection that ensued from scrambling could be attributed to unitization at the phrase level. In Experiment 2, however, we took special precautions to prevent that *the* would be the only target word appearing in higher order units. If the effects of scrambling were due primarily to the destruction of the encompassing perceptual integrity of phrase units, a similar reduction, though perhaps less dramatic, ought to have been found also for content words. This, however, was not the case. Along those lines, Koriat et al. (1991) found that scrambling produced opposite effects on letter detection in function and content words

(somewhat similar to what we found here). Scrambling reduced the size of the missing-letter effect both by improving letter detection in function words and by impairing it in content words. This pattern is difficult to reconcile with the notion that the effects of scrambling are due to the disruption of familiar phrase units. Recently, in fact, Koriat and Greenberg (1996) reported an enhancement effect in which letter detection in content words was better when these words followed a functor than when they followed another content word, suggesting that the juxtaposition of function and content words produces opposite effects in the two types of words. Finally, Koriat and Greenberg (1993) showed that when a series of function morphemes appears in succession (e.g., *and for the*) usually only the initial functor engenders a particularly high error rate (greater *than* that of comparable content morphemes). The exception to this finding was the word *the*, presumably because *the* immediately instructs readers that a noun phrase is beginning (see Koriat & Greenberg, 1993). Altogether, though, it appears doubtful that the effect of scrambling on the missing-letter effect is due to destruction of unitization at the phrase level.

The structural interpretation of the scrambling effect observed for adults and older children is that function words are particularly important for establishing a semantic/syntactic framework for a phrase. Therefore they should be more sensitive to the removal of local context. Content words, in contrast, tend to maintain a semantic independence in or out of context. The question, of course, is why function words evidence more omission errors than content words even in scrambled text? Two alternatives exist. The first is that indeed the missing-letter effect observed for scrambled text is due to the greater unitization of *the*. The second is that readers can build local frames around function words even for sequences that are devoid of meaning, and these frames are responsible for the missing-letter effect.

Turning next to the results for third graders, these are consistent with the idea that beginning readers are not skilled in extracting the overall structure of the phrase or the sentence, and are less sensitive to the structural role of functors than are proficient readers. Therefore, their letter detection performance is generally indifferent to scrambling. This implies that the missing-letter effect evidenced by the youngest group both here and in Experiment 1, presumably derives from the greater familiarity, and unitization of function words. Indeed, the results of Experiment 2 suggest that word frequency contributes to letter omissions even for content words, and this contribution occurs for all age levels alike. Thus it may be argued that familiarity has an additive effect over that of structural role for all participants. If this were so, however, we would have expected third graders, who are presumably unaffected by structural role, to exhibit a reduced missing-letter effect as compared with that of older readers. However the magnitude of this effect was not smaller for third graders. This pattern leads us to speculate that as the structural role of functors becomes more dominant, the familiarity of these functors becomes less critical in affecting letter detection. Presumably, beginning readers are more attentive to the perceptual features that

are important for word identification, and less so to deeper linguistic features that define the structural relationships between words.

Note that Experiment 2 failed to replicate the increase in the magnitude of the missing-letter effect with age. Perhaps because *the* is still more frequent than the functors used in Experiment 1, and as indicated earlier, familiarity may have a stronger impact on children's letter detection. In addition, Experiment 2 used somewhat older children, and consistent with earlier studies, the difference between third graders and adults is less dramatic than that between still younger children and adults (e.g., Drewnowski, 1978). In Drewnowski's work, error rates for the for third graders was also nearly identical to that of adults for normal passages. Drewnowski's first and second graders, though, showed a less powerful missing-letter effect than did his adults, as was also the case here. Thus, the findings here are consistent with those of Drewnowski's.

GENERAL DISCUSSION

The missing-letter effect has been taken by Healy and her associates (e.g., Healy & Drewnowski, 1983) to reflect the size of the unit used in reading. Specifically, it was proposed that because function units are highly frequent in text, they tend to be processed at the word level, thus concealing their constituent letters. This assumption underlies some of the studies attempting to track the development of unitization with age (Cunningham et al., 1988; Drewnowski, 1978, 1981). Previous results indicated that indeed the magnitude of the missing-letter effect increases with age, consistent with the idea that reading processes are controlled by larger units as readers gain experience. The more frequently a word is encountered, the more it tends to be processed as a whole unit.

However, in view of the recent work of Koriat and Greenberg on the missing-letter effect, it was important to reconsider the developmental findings with an alternative perspective in mind. According to the structural interpretation of the missing-letter effect, function words play a central role in supporting the establishment of the syntactic structure of the sentence before receding into the background as meaning unfolds (see also Aaronson & Ferres, 1983; Bock, 1990). It is the central contention of the model that the missing-letter effect that detection errors reflect the varied roles of morphemes in the cognitive representation of a sentence. Function words are assumed to be processed early and quickly by a reader in order to establish the structure of sentence into which meaning units are enrolled. The retreat of function words early on into the background of the representation leads to high error rates in such units. Thus, young readers apparently do not suffer from the ability to distinctively process structurally dedicated and content dedicated units as do adults. It follows, then that the less mature reader is either not as efficient as the more mature reader at rapidly identifying and using the structural units, or they have not yet completely mastered the conceptual distinction between structural and content items. We assume

that pattern of cognitively casting structural items into the background requires that the reader discerns the difference between the structural and content words.

Presumably, then, the missing-letter effect occurs, in part, at a postlexical stage, after the word has been identified and its linguistic role has been specified. If this interpretation is correct, then the developmental changes observed previously may be symptomatic of the increasing role played by structure during text analysis, rather than of the increased unitization of reading segments. We proposed that an important component of reading proficiency is the ability to extract the structure of a sentence on line, and it this ability that contributes in a large measure to the developmental changes in the missing-letter effect.

Three different approaches were used in Experiments 1 and 2 to evaluate this idea. First, we examined the age changes in the missing-letter effect both when function words were far more frequent than their content word counterparts, as is typical, and when function and content words were equated for frequency. Second, we placed content and function words in inappropriate syntactic slots, and examined the effects that this misplacement had on letter detection in different age groups. Finally, we compared the magnitude of the missing-letter effect for normal and scrambled passages for different age groups. Taken together, these three approaches yielded evidence favoring the structural account of the developmental changes in letter detection, but also supported the possible contribution of unitization-driven processes.

First, in Experiment 1, the magnitude of the missing-letter effect was found to increase with age. This was true for the typical condition in which the frequency of functors is much higher than that of content words, consistent with previous findings. However, the same pattern of results was observed even when the frequency of function and content words was equated. These results support the view that the increased magnitude of the missing-letter effect with age is associated with increased sensitivity to the structural role of functors in text.

Second, in Experiment 1, we found that the placing of function and content words in inappropriate locations in otherwise normal sentences improved letter detection in function words. This effect, however, was obtained for adults (see also Koriat & Greenberg, 1991), but not for 2nd graders. In the same vein, Experiment 2 established that the scrambling of words within the sentence improved letter detection in function words for both seventh graders and college students but not for third graders, who manifested equally strong missing-letter effects with both types of text (see Drewnowski, 1978). It should be noted that both manipulations, misplacement and scrambling, did not produce a similar improvement in letter detection in content words. These observations suggest that beginning readers are less sensitive to the structural role of sentences than are proficient readers.

Finally, frequency effects were observed in both Experiment 1 and 2. Thus, in Experiment 1, the typical condition in which functors were more frequent than

content words produced a stronger missing-letter effect than the matched-frequency condition. Also in Experiment 2, high-frequency content words produced more omission errors than low-frequency content words. Both of these findings suggest that familiarity or unitization also contribute to letter detection and thus are one of the causes for the relatively high error rate observed for function words. It should be noted that with the exception of pronouns (see Moravcsik & Healy, 1995), heretofore frequency effects on letter detection in content words have been demonstrated only for scrambled passages or nonparagraph forms (see Healy, 1976) and here we provide evidence of a frequency effect in connected text as well. It is important to note that frequency effects were equally observed for all age groups alike in both Experiment 1 and 2, suggesting that familiarity or unitization cannot account for the increase in the magnitude of the missing-letter effect with age. Cunningham et al. (1988) showed that reducing the visually familiarity of target words by misspelling them reduces letter detection errors, and this reduction is more profound for more skilled readers. The present results are consistent with the proposition of Healy and her associates that the familiarity of an orthographic pattern affects letter detection. However, they do not support the contention that the increased missing-letter effect with age derives from increasing unitization of familiar orthographic patterns. An examination of Cunningham et al. most comparable grade groupings (4, 7, and college in Experiment 3) shows that while the misspellings of content words increasingly reduced the missing-letter effect with age, the same was not true for the target word *the*. It would appear then, that at least when it comes to function words, impairing a familiar pattern is no more effective for mature than less mature readers. Instead, as the present study suggests, scrambling the text has more impact on letter detection in *the* for the older reader, as compared to the younger reader, indicating that while all readers may unitize familiar words, the older readers respond more to the structural role of *the* in a sentence.

What does this pattern of results tell us about the processes underlying the developmental changes in the missing-letter effect? Possibly, the origin of this effect differs for children and adults. Exactly how, however, is not clear. One possibility, is that the missing-letter effect in beginning readers is entirely due to the greater familiarity and unitization of function words. Among more proficient readers, in contrast, both unitization-driven and structure-driven processes contribute to the missing-letter effect for function words. If this interpretation is accepted, we must assume first, that the increase in the magnitude of the missing-letter effect with age is due to the greater ability to utilize functors as cues for structure, and second, that the contribution of unitization does not increase, and may even decrease with reading proficiency.

Another possibility is that the difference between beginning readers and advanced readers parallels that between scrambled and normal text. Thus, in addressing the question of why the missing-letter effect is observed even for scrambled text, Koriat and Greenberg (1991) proposed that proficient readers

may be able to use function words as kernels around which to build rudimentary local structures even when these occur in a nonsense sentence. A good example is Lewis Carroll's (1900) poem Jabberwocky. Although nonsense, this poem imparts structure and rhythm through the strategic placement of function morphemes (see Koriat & Greenberg, 1994). The detection of local structures within a nonsense context may explain why letter detection in function units is inordinately difficult even when these are misplaced in text. Perhaps, the structures extracted by beginning readers are also rudimentary and local in nature, even with normal text. Thus, an enticing hypothesis that can help link the unitization and structural hypotheses, is that proficient readers are able to extract structures which integrate information across a larger number of reading units than beginning readers. In this sense, children may be said to process text in smaller structured linguistic ''units'' than do adult readers. This may explain why children exhibit a missing-letter effect that is less sensitive to contextual changes.

In sum, the present evidence suggests that the structural role of a word contributes largely to the missing-letter effect, and importantly that is the reader's increasing sensitivity to structurally informative items during text analysis that accounts for some of the developmental changes in the magnitude of the missing-letter effect. Therefore, the missing-letter effect can serve as a useful vehicle for tracking the development of structural analysis with age. Of course, more work is needed to specify whether such changes reflect increased sensitivity to the syntactic role played by different words in text, and/or increased utilization of function units to establish structural frames in reading. In addition, however, the results also support the contribution of unitization to letter detection, although it does not seem likely that the changes in the missing-letter effect with age are due to increased unitization of familiar function words.

More generally, the study is perhaps the first demonstration that both familiarity and structural role must be taken into account in explaining letter detection errors in reading. Apparently, then, the missing-letter effect reflects factors that impact on prelexical identification processes as well postlexical linguistic analysis. The suggestion is that neither the factors involved, nor the models explaining how these factors contribute to the missing-letter effect, exclude the other from consideration. Thus, we concur with Moravcsik and Healy's (1995) assessment that ''it is likely that no single explanation could account for the full range of factors influencing letter detection performance'' (p. 92).

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