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Detection errors on *the* and *and*: Evidence for reading units larger than the word

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In five experiments, subjects read 100-word passages and circled instances of a given target letter, letter group, or word. In each case subjects made a disproportionate number of detection errors on the common function words *the* and *and*. The predominance of errors on these two words was reduced for passages in which the words were placed in an inappropriate syntactic context and for passages in which word-group identification was disturbed by the use of mixed typecases or a list, rather than a paragraph, format. These effects for the word *and* were not found for the control word *ant*. These results were taken as evidence that familiar word sequences may be read in units larger than the word, probably short syntactic phrases or word frames. A tentative model of the reading process consistent with these results is proposed.

The present study employs a detection task to investigate the possibility that high-frequency words may be read in terms of units larger than the word: word frames, phrases, or syntactic groups. It has been observed that subjects searching for instances of a given target letter in printed text make a disproportionate number of errors on the word *the* (Corcoran, 1966; Healy, 1976). Healy (1976) found the high frequency of the word *the* to be critical, in support of the view that frequent words are read in terms of units larger than the letter, for example, spelling patterns (Gibson, 1965) or vocalic center groups (Spoehr & Smith, 1973). Here we extend that experimental paradigm by using words rather than letters as targets.

We propose to test a specific set of hypotheses that may enter into a model of the reading process. In common with other investigators, we shall assume that reading involves the use of a hierarchy of graphological, orthographic, lexical, and syntactic processing skills (Doehring, 1976; Estes, in press; Gibson, 1971; LaBerge & Samuels, 1974). We distinguish, in particular, between five separate levels of processing written text, which we define in terms of the units available at each level: letters, letter groups, words, phrases, and larger units such as clauses or sentences. We assume further that the completion of processing at a given level is tantamount to the identification of the unit at that level. Identification can be monitored through a detection task requiring subjects to circle every instance of a given target, which can be at any one of the processing levels. In previous studies (e.g., Corcoran, 1966; Healy, 1976) only letters were used as targets, but in the present study targets could be letters, letter groups, or words.

In the formulation of our model, we make the further assumption that, in the course of normal reading, subjects tend to process stimuli at the highest level available to them, in parallel with processing at lower levels. This assumption of parallel processing contrasts with that made by Gibson (1971), who postulates that subjects move through the linguistic hierarchy sequentially. We prefer the parallel assumption, or at least the weaker assumption (Estes, in press) that processing at higher levels can begin before processing at some lower level is complete, because we know from the study of Healy (1976) that subjects fail to detect letters when word units become available. This result also implies that once a unit has been identified at any given level, subjects will proceed to the next unit of text at that level without necessarily completing

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the processing at the lower levels. For example, once a word has been identified, the subject may move on to the next word without necessarily identifying all the letters and letter groups within the word. Consequently, when subjects are searching for targets at a given level, we should expect them to make more detection errors when they are able to identify units at a higher level than the level of the target than when they are able to identify only units at the target level or below.

The highest level of processing reached will no doubt partly depend on the subject's reading skill (Gibson, 1971; LaBerge & Samuels, 1974), but it will also depend on the nature of the stimulus materials used and the task demands (Estes, 1975; Gibson, 1971). In the present study, we therefore employ prose passages, where the highest level of processing is at least as large as the phrase, and we compare these to scrambled-word passages where the highest level of processing is the level of the word. Furthermore, we consider passages, such as the scrambled-letter passage of Healy (1976), where the highest level of processing is the level of the letter. In other words, in the detection tasks of the present study, we independently manipulate the level of the target and the processing levels available in the search passage.

If processing at a higher level is in some way impeded, processing at the lower levels will be more likely to proceed to completion, resulting in better detection of targets at the lower levels. Conversely, if processing at a higher level is in some way facilitated, processing at the lower levels should be less likely to proceed to completion. Familiarity with a unit at a given level will presumably facilitate processing of the unit at that level. Thus, the use of words of high frequency should facilitate processing, or identification, at the word level, and the use of commonly encountered syntactic phrases or word frames should facilitate processing at the phrase level. Thus, for example, subjects may be able to identify a familiar phrase before identification of the specific words in the phrase is completed. On the other hand, when phrases are not familiar, the subjects should not be able to complete processing at the phrase level before completing processing at the word level.

Consequently, we introduce variations in the search passage which impede or promote the formation of higher level units. In addition, we examine the detection of targets in frequent and infrequent words, and the detection of targets in syntactically correct phrases and in comparable syntactically incorrect word groups. We also introduce a modification of the detection task which requires the subjects to attend to the meaning of words, as in normal reading.

EXPERIMENT 1

The results of the study by Healy (1976) suggest, in accord with our proposed model, that subjects fail to complete processing at the letter level when processing at the word level is facilitated. This conclusion is based on the finding of a disproportionate number of detection errors on a given letter (*t*) when that letter was embedded in a frequent word (*the*). The present study aimed to determine whether, in analogy with this finding and in accord with our model, subjects fail to complete the processing at the word level when processing at the phrase level is facilitated. Specifically, we are led to predict that a disproportionate number of detection errors will occur on a given word when that word is embedded in a familiar phrase. In order to test this possibility, we used as targets both the letter *t* and the letter group *the*, and we employed search passages so constructed that the letter *t* was always part of the letter group *the*. This technique enabled us to make a direct comparison of performances on the letter and letter-group detection tasks. Since we expected subjects to make a disproportionate number of detection errors on the letter group *the* when it occurred as the word *the* contained in a familiar phrase, we examined two passages: a prose passage, where every instance of the word *the* necessarily occurred in a syntactically appropriate phrase, and a scrambled-word passage, so constructed that only half of the occurrences of the word *the* occurred within syntactically appropriate word phrases.

Method

Subjects. Sixty-four male and female students at Cornell Medical School, who were attending a neuroanatomy lecture, served as subjects in a group experiment conducted in the classroom. They were divided into two groups. Thirty-four of the subjects were in Group T and 30 were in Group The.

Design and materials. Two 100-word passages, typed on separate sheets of paper, were constructed for the present experiment. One passage, hereafter referred to as the "prose passage," contained 12 instances of the word *the*, 24 words which included the letter string *the* but no other instance of the letter *t* (e.g., *bathed* and *rather*), and 64 filler words chosen with the restriction that no word included the letter *t*. Every instance of the letter *t* in the passage was thus part of the letter string *the*. (See Appendix for a copy of the prose passage.)

The second passage, hereafter referred to as the "scrambled-word" passage, was derived from the prose passage. The 12 *thes* and the 24 words containing the letter string *the* were in the same locations as in the prose passage, and the punctuation marks remained the same. The order of the 64 filler words was random, with the single constraint that out of the 12 instances of the word *the*, 6 were followed by nouns ("appropriate context"), and 6 by other parts of speech ("inappropriate context").

Procedure. The subjects received written instructions which differed for the two groups. Subjects in Group T were asked to circle instances of the letter *t* as target, while subjects in Group The were asked to circle instances of the letter group *the*, either by itself, or embedded in another word. Both groups were told to read each passage at their normal reading speed, and to encircle each instance of the target with a pen or a pencil. The subjects were told that if they ever realized that they had missed a target, they should not retrace their steps to encircle it. They were told further that they were not expected to detect all targets, so they should not slow down

their normal reading speed in order to be overcautious about encircling the targets. Each subject was shown both passages. Half the subjects in each group were shown the prose passage first; the other half were shown the scrambled-word passage first. Subjects were told to read the two passages in the order in which they were stapled togather and to go on to the second passage as soon as they had finished the first.

Results

The results of the present experiment are summarized in Table 1, which includes for the two passages the means and the standard errors of the means for the total number of errors, for the number of errors on the word *the*, and for the conditional percentage of detection errors on the word *the* given an error. Means and standard errors were derived by computing scores for each subject and then averaging across subjects. All errors considered were omission errors (misses), since there were virtually no false alarm errors in any of the present experiments. Consequently, the mean total error score is the sum of the mean error score on the word *the* and the mean error score on the words containing the embedded letter string *the*. The conditional percentage of detection errors on the word *the* was derived for a given subject by determining the ratio of the number of errors on the word *the*, divided by the total number of errors. By chance alone the conditional percentage of errors on the word *the* should be 33.3%, since 12 of the 36 targets involve the word *the*. Healy (1976) found this conditional percentage to be the most sensitive index of performance in this situation, since it is not influenced by the speed-accuracy tradeoff typically found in such a task. Further, analyses of the present data revealed no significant difference in conditional percentages between subjects with high total error scores (10 or above) and subjects with low error scores. Because the conditional error percentages constitute the critical dependent variable, they are emphasized throughout our discussion of the results, although total error scores for all experiments are also shown in the tables below, along with error scores for the word *the*.

***T* and *the* detection tasks.** The conditional error percentages were not significantly lower for Group The than for Group T on either the prose [$t(60) = 1.54$, $p > .10$] or the scrambled-word passages [$t(51) = .46$, $p > .10$]. Both values for Group The were in fact significantly above chance level (33%) [prose: $t(29) = 4.58$, $p < .001$; scrambled word: $t(23) = 5.83$, $p < .001$]. This similarity between Group T and Group The indicates that even those subjects who were specifically instructed to search for instances of the letter group *the* made a disproportionate number of detection errors whenever *the* occurred on its own rather than as part of another word. Although these data, obtained with both prose and scrambled-word passages, appear counterintuitive, they are consistent with our proposed set of hypotheses. These data are equally consistent with Corcoran's (1966) hypothesis that the word *the*, being redundant (i.e., predictable from the prior word context), may not be scanned by the reader. However, the redundancy hypothesis would predict considerably fewer errors on the word *the* in the scrambled-word passage, where its occurrence cannot be predicted on the basis of prior context. This result was not obtained; hence, it seems unlikely that the word *the* is not scanned by the reader. We propose instead that the word *the* is scanned, but that the processing at the phrase level is completed before the word *the* itself can be fully processed and identified. Phrase-level units, which are clearly available in the prose passage, might also be formed in the scrambled-word passage whenever the target word *the* occurs in an appropriate syntactic context. An analysis of context effects, between and within passages, follows.

Prose vs. scrambled words. The conditional percentage of errors on the word *the* given an error was somewhat higher for the prose passage than for the scrambled-word passage for Group T, although not significantly so [$t(27) = 1.36$, $p > .10$]. For Group The, the conditional error percentages for the prose and scrambled-word passages were approximately equal. However, significantly more unconditionalized errors on the word *the* were made on the prose passage than on the scrambled-word passage by both Group T [$t(33) = 3.80$, $p < .001$] and Group The [$t(29) = 2.44$, $p < .05$]. These data are consistent with those of Healy

Table 1
Means and Standard Errors of Means (in Parentheses) for Error Frequencies and Conditional Percentages for Groups T and The of Experiment 1

Group	N	Passage	Total Errors	Errors on Word *the*			Errors on Word *the* Given Error	
				Total	Appropriate Context	Inappropriate Context	Percent	N′
T	34	Prose	7.44 (.90)	5.67 (.73)			72 (4)	32
		Scrambled Word	5.65 (.86)	3.88 (.67)	2.38 (.36)	1.50 (.34)	65 (5)	29
The	30	Prose	5.63 (.69)	3.56 (.52)			60 (6)	30
		Scrambled Word	4.50 (.77)	2.66 (.47)	1.53 (.30)	1.13 (.21)	61 (5)	24

Note—In this table and in the succeeding tables in this paper, the total number of subjects (N) does not necessarily equal the number of subjects on which the mean conditional percentages are based (N′), since not all subjects made errors on each passage.

(1976), who reported a significant difference in unconditionalized errors, but not in conditional percentages between comparable prose and scrambled-word passages.

It is important to consider the possibility that the prose passage employed is semantically odd in ways that might lead subjects to spend a disproportionate amount of processing time, and hence make disproportionately fewer errors, on embedded *thes*. Many of the content words involving the embedded *thes* are peculiar relative to the surrounding context. For example, mothers rarely discuss "psychotherapy" and "anesthesia." However, the fact that we obtained disproportionately fewer errors on the embedded *thes* for the scrambled-word passage as well as for the prose passage suggests that the semantic oddity of the prose passage was not critical to the present results, since all words would be unexpected, or peculiar relative to the surrounding context, in the scrambled-word passage. Furthermore, as we noted above, similar results were obtained by Healy (1976) for letter detection errors with another scrambled-word passage and a prose passage selected from Golding's *Lord of the Flies*.

Within-passages context effects. In the scrambled-word passage, both Group T and Group The subjects made more detection errors on instances of the word *the* which were immediately followed by nouns than on those which were followed by other parts of speech. This difference between the "appropriate context" and "inappropriate context" *thes* was highly significant for Group T [$t(33) = 4.04$, $p < .001$], and was in the right direction, although not significant, for Group The [$t(29) = 1.65$, $p > .10$]. These findings of local-context effects provide further support for the hypothesis that under appropriate circumstances phrase-level units may be identified in scrambled-word passages and may impair identification, and hence detection, of lower level units.

EXPERIMENT 2

In Experiment 1, subjects searching for both types of targets (*t* and *the*) made more errors on the word *the* whenever it appeared in an appropriate context. However, the appropriateness of the context was confounded with such variables as the location of the target in the search passage and the nature of the words surrounding each target. The present experiment addressed the question of context effects more systematically. The nature of the context was manipulated by altering the sequence of two filler words around each of the 12 *the* targets in two newly constructed scrambled-word passages. Whereas in one passage all instances of the word *the* occurred in what was deemed an "appropriate" context, in the other passage all instances of the word *the* occurred in an "inappropriate" context. If processing at the phrase level impairs processing at the letter and word levels, we would expect more errors and higher conditional error percentages on *thes* in an appropriate context than in an inappropriate context.

Method

Subjects. Forty-eight male and female students at the Mount Sinai Medical School, who were attending a biochemistry lecture, served as subjects in a group experiment conducted in the classroom. Twenty-four subjects were in Group T and 24 subjects were in Group The.

Design and materials. The scrambled-word passage used in Experiment 1 was used again in the present experiment. In this passage, six instances of the word *the* were followed by nouns and six by other parts of speech. Two new passages, referred to as the "local-context" and "no-context" passages, respectively, were derived from the scrambled-word passage. Both contained the same 36 targets, including 12 instances of the word *the* and 24 target words containing *the*. The same filler words and the same punctuation were used as in the scrambled-word passage. The no-context passage differed from the scrambled-word passage in one respect only: The sequence of words was partially rearranged so that no instance of the word *the* was followed by a noun. In contrast, each of the 12 *the* targets in the local-context passage was part of a meaningful syntactic group, typically a prepositional phrase. We accomplished this effect by reversing the sequence of the two filler words on either side of each target word *the*, so that a meaningless sequence of words in the no-context passage (e.g., "air the of") would effectively become a syntactic group in the local-context passage (e.g., "of the air"). The word *the* thus always appeared in an appropriate context in the local-context passage, and in an inappropriate context in the no-context passage.

A fourth passage, also 100 words long and constructed according to similar principles as the scrambled-word passage, was included in the present experiment. We used this passage largely to provide variety, and the results obtained will not be reported here.

Procedure. All subjects were shown all four passages, with the order of presentation being roughly counterbalanced across subjects. As in Experiment 1, subjects received written instructions, which differed for the two groups. Subjects in Group T were instructed to circle instances of the letter *t*, while subjects in Group The were to circle instances of the letter group *the*. The procedure was otherwise identical to that used in Experiment 1.

Results

The results are summarized in Table 2, which includes for the three passages the means and the standard errors of the means for the total number of errors, for the number of errors on the word *the*, and for the conditional percentage of errors on the word *the* given an error.

The conditional percentage of errors on the word *the* given an error was substantially higher for the local-context passage than for the no-context passage for subjects in both Group T [$t(19) = 2.60$, $p < .05$] and Group The [$t(20) = 5.18$, $p < .001$]. For the local-context passage, the conditional error percentage was significantly above chance level for both groups [Group T: $t(21) = 6.59$, $p < .001$; Group The: $t(21) = 2.40$, $p < .05$], whereas for the no-context

Table 2
Means and Standard Errors of Means (in Parentheses) for Error Frequencies and Conditional Percentages for Groups T and The of Experiment 2

Group	N	Passage	Total Errors	Errors on Word *the*	Errors on Word *the* Given Error	
					Percent	N'
T	24	Scrambled Word	5.95 (.85)	4.16 (.65)	69 (5)	24
		No Context	5.00 (1.05)	2.79 (.81)	46 (8)	20
		Local Context	6.83 (.94)	5.00 (.78)	69 (5)	22
The	24	Scrambled Word	5.12 (.78)	3.12 (.60)	61 (7)	19
		No Context	2.95 (.62)	1.04 (.51)	18 (6)	21
		Local Context	5.16 (.86)	3.21 (.52)	51 (8)	22

passage, it was not different from chance level for Group T [$t(23) = 1.54$, $p > .10$] and was significantly below chance level for Group The [$t(20) = 2.51$, $p < .05$]. Detection errors on the word *the* are thus substantially decreased whenever the word *the* is removed from its habitual context. This effect is observed regardless of whether the subjects are searching for the letter *t*, or for the word *the*. As both passages used were scrambled-word passages, the context effects observed do not depend on the presence of larger syntactic or semantic units such as clauses or sentences.

As for the scrambled-word passage, the conditional percentage of errors on the word *the* given an error was significantly above chance level for both Group T [$t(23) = 7.13$, $p < .001$] and Group The [$t(18) = 4.17$, $p < .001$]. More detection errors on the word *the* were made by subjects in both Group T [$t(23) = 3.49$, $p < .01$] and Group The [$t(23) = 7.03$, $p < .001$] when the word *the* preceded a noun than when it did not. The mean number of errors on the word *the* was 2.70 for *thes* in an appropriate context and 1.46 for *thes* in an inappropriate context for subjects in Group T and 2.20 and .91, respectively, for subjects in Group The. These results for the scrambled-word passage essentially replicate those obtained for the same passage and different subject population in Experiment 1.

EXPERIMENT 3

Experiments 1 and 2 demonstrate the effects of word context on the detection of the target *t* as well as on the detection of the target *the*. Subjects make more errors on the word *the* when it appears in an appropriate context than when it appears out of context, and we have suggested that the word *the* may be processed as part of a phrase-level unit. We now attempt to impede the formation of phrase-level units by using purely perceptual variables, instead of syntactic or semantic variables, such as were used in Experiment 2. For this purpose, we employed two types of manipulations: one involving the use of mixed typecases (see Fisher, 1975, and McClelland, 1976, for other examples of the use of this variable), and the second involving a change in the passage layout. Two mixed typecase passages were constructed. In the first passage (mixed letter), every other letter was typed in capitals in order to disturb word identification and make it more difficult for the subjects to process units at levels higher than the letter. In the second passage (mixed word), every other word was typed in capitals in order to disturb phrase identification and make it more difficult for the subjects to process units at levels higher than the word. We changed the passage layout by typing the words in five vertical columns, which the subjects were instructed to read from top to bottom. This final manipulation (list passage) not only disturbs the identification of units larger than the word, but also forces the subjects to abandon their usual left-to-right reading pattern. The processing at levels higher than the word should, therefore, be virtually eliminated by the list passage. In each of the passages where the formation of units larger than the word was disturbed, our hypotheses led us to expect a decrease in the conditional error percentages on the word *the* relative to the standard scrambled-word passage.

The present study investigated one additional question. It may be that subjects presented with scrambled-word passages do not read them in the same manner as they would a prose passage. In particular, it may be that the detection task predominates over the reading task so that subjects do not attend to the meaning of words. In order to insure that subjects do attend to word meanings, the subjects in the present experiment were given the task of underlining every name of a living thing in each passage, in addition to their tasks of reading and circling instances of the target letter or target letter group.

Method

Subjects. One hundred and thirty-seven male and female undergraduate students of Yale University, who were taking a course in introductory psychology, served as subjects in a group experiment conducted in the classroom. The subjects were divided into two groups, with 71 subjects in Group T and 66 subjects in Group The.

Design and materials. We employed five passages of scrambled words. Four of the five passages were identical in terms of the words used; they differed only in the format in

which they were typed. The first passage (scrambled-word passage) was identical to that used in Experiments 1 and 2. The second passage (mixed-letter passage) differed from the scrambled-word passage only in that every other letter was typed in uppercase. There were two versions of the mixed-letter passage. In Version A the first letter in the passage was typed in lowercase, whereas in Version B the first letter in the passage was typed in uppercase. Thirty-six subjects in Group T and 31 subjects in Group The were shown Version A of the passage, and 35 subjects in Group T and 35 subjects in Group The were shown Version B. The third passage (mixed-word passage) differed from the first in that every other word was typed in uppercase. There were two versions of the mixed-word passage. In Version A, the first word in the passage was typed in lowercase, and in Version B, the first word in the passage was typed in uppercase. Thirty-six subjects in Group T and 32 subjects in Group The were shown Version A, and 35 subjects in Group T and 34 subjects in Group The were shown Version B. The fourth passage (list passage) contained the same words as the other passages, but they were typed in five vertical columns, with each word typed flush left. The order of the words and the typecase of the letters were the same as in the scrambled-word passage, but all commas, periods, and quotation marks were removed. The fifth passage resembled the scrambled-word passage in both construction and layout, but different sets of words were used in the two passages. This passage was employed to provide variety, so that the subjects would be less likely to realize that the four critical passages contained the same words. The results for the fifth passage will not be discussed in the present paper.

Procedure. All subjects were shown all five passages with the fifth passage always shown in the third position. The order of the other four passages was roughly counterbalanced across subjects. Subjects received written instructions to circle instances of the letter *t* (Group T) or to circle instances of the letter group *the* (Group The). In addition, unlike in previous experiments, subjects in both groups were told to underline every name of a living thing in each passage. The subjects were also told to note that one passage (list passage) would consist of five vertical columns of words and that they were to read each column of words from top to bottom. The procedure was otherwise analogous to that used in Experiments 1 and 2.

Results

The results of the present experiment are summarized in Table 3, which includes for each of the four critical passages and each of the two groups the means and the standard errors of the means for the number of total errors, the number of errors on the word *the*, and the conditional percentage of errors on the word *the* given an error.

Subjects in Group T, who were instructed to search for *ts*, showed a similar pattern of results to those in Group The, who were instructed to search for *thes*. As in Experiments 1 and 2, the conditional error percentages for the scrambled-word passage were significantly above chance [Group T: $t(66) = 5.63$, $p < .001$; Group The: $t(61) = 3.95$, $p < .001$]. In comparison to the scrambled-word passage, the conditional percentages for the mixed-letter passage, where every other letter was capitalized, were significantly reduced for Group T [$t(56) = 3.41$, $p < .01$], although not significantly changed for Group The [$t(50) = 1.86$, $.10 < p < .05$]. The results for Group T suggest that when the processing of units at levels higher than the letter is impeded, the percentages of letter detection errors on the word *the* are reduced to near chance level. Furthermore, the conditional error percentages for the mixed-word passage, where every other word was capitalized, were significantly reduced relative to the scrambled-word passage in Group T [$t(58) = 2.56$, $p < .05$], and reduced but not significantly so in Group The [$t(58) = .98$, $p > .10$]. In both groups, however, the conditional percentages in the mixed-word passage remained significantly above chance [Group T: $t(62) = 2.42$, $p < .05$; Group The: $t(60) = 2.05$, $p < .05$]. The conditional error percentages for the list passage fell below chance level and were significantly lower than those in the scrambled-word passage for both groups of subjects [Group T: $t(51) = 4.35$, $p < .001$; Group The: $t(47) = 5.69$, $p < .001$]. These observations for the mixed-word and list passages indicate that, when the processing of units at levels higher than the word is impeded, the percentage of detection errors on the word *the* is reduced.

An analysis of the underlining task revealed both a high level of performance and no significant differences in performance levels between the two groups of subjects or among the four passages. Excluding the word *I*, there were six instances of names of living

Table 3
Means and Standard Errors of Means (in Parentheses) for Error Frequencies and Conditional Percentages for Groups T and The of Experiment 3

Group	N	Passage	Total Errors	Errors on Word *the*	Errors on Word *the* Given Error	
					Percent	N′
T	71	Scrambled Word	5.18 (.45)	2.94 (.32)	55 (4)	67
		Mixed Letter	3.44 (.43)	1.48 (.23)	40 (4)	59
		Mixed Word	4.85 (.51)	2.04 (.25)	42 (4)	63
		List	2.51 (.39)	.70 (.15)	28 (5)	54
The	66	Scrambled Word	5.47 (.64)	2.45 (.26)	48 (4)	62
		Mixed Letter	3.68 (.48)	1.61 (.19)	54 (5)	54
		Mixed Word	4.42 (.46)	1.73 (.21)	42 (4)	61
		List	2.66 (.32)	.45 (.10)	17 (4)	51

things in each passage. The mean percentage of misses on these targets was 19.1%, and the mean percentage of false alarms was 1.0%. Consequently, we are satisfied that subjects did consider the meaning of the words during the detection task. The results for the scrambled-word passage suggest, therefore, that a large preponderance of detection errors on the word *the* is found even when the subjects consider the meaning of the words. In addition, the results for the scrambled-word passage compared to those for the other three passages suggest that the majority of detection errors on the word *the* is due to the processing at levels higher than words. Impeding the processing at these higher levels results in the observed decrease in conditional percentages of errors on the word *the*. The present experiment used perceptual variables to achieve this result. Note that Corcoran's (1966) redundancy hypothesis, which postulates that the word *the*, being redundant, is not scanned, cannot give a simple account of the present pattern of results. The predictability of the word *the* does not change with a change in typecase or passage layout; nevertheless, changes were found in the percentages of detection errors on the word *the* with such changes in passage format.

EXPERIMENT 4

We aim to extend the generality of the results obtained in the preceding experiments and in the study by Healy (1976) to another target letter and another high-frequency word. The word *and*, the third most frequent word in the English language (Kučera & Francis, 1967) and the target letter *n* were accordingly selected for study. We constructed a new scrambled-word passage in which every instance of the letter *n* occurred within the letter group *and* and an equivalent control passage in which all occurrences of the word *and* and of words containing the embedded letter string *and* were replaced by the word *ant* and by words containing the embedded letter string *ant*, respectively. The control passage provides a powerful test both of the frequency hypothesis (Healy, 1976) and of the hypothesis that the subject may decide not to scan fully a given word on the basis of its global features as detected in peripheral vision (e.g., Hochberg, 1970). Both trigrams (*and* and *ant*) are equal in length, share the initial two letters, and have a similar word shape. Additional advantages of this comparison are the virtually identical embedded trigram frequencies of the two letter strings (Underwood & Schulz, 1960) and the fact that the letter *n* occurs in the same location and is pronounced similarly in both cases. The word *ant* has the further advantage of not being archaic, unlike the word *thy* employed by Healy (1976) in an equivalent control condition. The two words (*and* and *ant*) differ only in frequency, with *and* being by far the more frequent, and in part of speech, with *ant* being a concrete noun rather than a function word.

In addition, the importance of the location of the target letter (Corcoran, 1966) was tested by the use of a control passage of scrambled letters analogous to that employed by Healy (1976). Finally, the processing of text at levels higher than the word was impaired by the use of a list passage analogous to that employed in Experiment 3.

Following the earlier results, we expect conditional error percentages to be above chance on the *and* passage and at chance level on the *and* list, the *ant* passage, and the scrambled-letter passage.

Method

Subjects. Twenty-four male and female students at Mount Sinai Medical School, who were attending a biochemistry lecture, served as subjects in a group experiment conducted in the classroom.

Design and materials. We constructed four new 100-word passages. One passage, hereafter referred to as the "scrambled-word *and* passage" included 12 instances of the word *and*, 24 words which included the letter string *and* but no other instance of the letter *n*, and 64 filler words chosen from an article in *The New York Times*, with the restriction that no word included the letter *n*. These constraints insured that every instance of the letter *n* in the passage was part of the letter string *and*. The order of the words within the scrambled-word passage was random, with the single constraint that 6 out of the 12 instances of the word *and* occurred between like parts of speech ("appropriate context"), whereas the remaining 6 occurred between unlike parts of speech ("inappropriate context"). Punctuation marks were inserted arbitrarily.

The second passage, hereafter referred to as the "scrambled-letter passage," was derived from the scrambled-word passage described above. In order to form the scrambled-letter passage, the scrambled-word passage was divided into 20 consecutive five-word groups, and the letters within each of the 20 groups were randomized. A given letter thus did not necessarily remain within the same word but did remain within the same word group. The *n*s, punctuation marks, and "interword" spaces were kept in the same locations as in the scrambled-word passage.

The third passage, referred to as the "scrambled-word *ant* passage," was also derived from the first. It was identical to the scrambled-word *and* passage in every respect, except that every instance of the word *and* was replaced by the word *ant*, and every target word containing the letter string *and* was replaced by another target word containing the letter string *ant*. The two classes of words containing the target letter string (those containing *and* and those containing *ant*) were roughly matched for number of letters, number of syllables, number of vocalic center groups, frequencies according to Kučera and Francis (1967), and position of the letter string within the word. (For example, the word *handle* was replaced by the word *pantry*.) Since the locations of *ant* targets precisely matched those of *and* targets, the "appropriateness" of the context of the *ant* targets did not match that of *and* targets. In fact, all *ant* targets probably were in "inappropriate" contexts. The two scrambled-word passages therefore differed not only in the frequency and the nature of the target, but also in the "appropriateness" of the context surrounding that target.

The fourth passage, hereafter referred to as the "list passage," was also derived from the first. The 100 words were typed in five vertical columns of 20 words each. The order of the words and the typecase of the letters were the same as in the scrambled-word *and* passage, but all commas and periods were removed.

Procedure. The procedure was similar to that used in Experiments 1 and 2. Subjects received written instructions

Table 4
Means and Standard Errors of Means (in Parentheses) for Error Frequencies and Conditional Percentages of Experiment 4

Passage	Total Errors	Errors in *and/ant* Locations	Errors at *and/ant* Locations Given Error	
			Percent	N'
Scrambled Word *and*	7.12 (1.06)	5.75 (.79)	84 (2)	20
Scrambled Letter	5.20 (1.03)	2.54 (.55)	55 (5)	21
Scrambled Word *ant*	3.25 (.62)	.71 (.22)	24 (7)	19
List	1.96 (.50)	.91 (.34)	34 (9)	13

Note—*Total N = 24.*

to read each passage and encircle each instance of the letter *n*. Each subject was shown all four passages, with the order of the four passages counterbalanced across subjects.

Results

The results of the present experiment are summarized in Table 4, which includes for the four passages the means and the standard errors of the means for the number of total errors, for the number of errors in "*and/ant* locations," and for the conditional percentage of errors in "*and/ant* locations" given an error. An error in an *and/ant* location is defined as an error in the word *and* in both the scrambled-word *and* passage and the list passage, the word *ant* in the scrambled-word *ant* passage, or in the corresponding locations in the scrambled-letter passage. (Recall that the *n*s were in the same locations in the scrambled-word and scrambled-letter passages.) As in Experiments 1-3, the chance conditional percentage of errors in *and/ant* locations was 33%, since 12 of the 36 *n*s were in the words *and* or *ant* in each scrambled-word passage and in the list passage.

Scrambled word vs. scrambled letter. The mean conditional percentage of errors on the word *and* in the scrambled-word *and* passage was significantly above chance level [$t(19) = 19.69$, $p < .001$] and significantly above the conditional error percentage for the scrambled-letter passage [$t(19) = 5.89$, $p < .001$].

These data, which confirm the results obtained by Healy (1976, Experiment 1), are inconsistent with the hypothesis that the location of the target letter may account for the preponderance of errors on the word *and*, since the *n*s are in the same locations with respect to the word boundaries in the two passages. However, whereas Healy found the conditional percentage of errors at *the* locations to be significantly less than chance in the scrambled-letter passage, the conditional percentage of errors in *and* locations in the present scrambled-letter passage was significantly greater than chance [$t(20) = 3.78$, $p < .01$]. A possible explanation for this discrepancy is suggested by Corcoran's (1966) finding that the position of the letter in the word does have some effect on detection probability, and that later letters (in his case, *e*s) are more likely to be missed than early ones.

***And* vs. *ant* passage.** Whereas the conditional percentage of errors at *and/ant* locations given an error was significantly above chance for the *and* passage, it was not significantly different from chance [$t(18) = 1.25$, $p > .10$] for the *ant* passage. This observation, which is inconsistent with the location and pronunciation hypotheses since the location and pronunciation of the letter *n* are the same in both passages, provides support for the hypothesis that the frequency of a unit at a given level facilitates processing at that level. The results also support the hypothesis that the high frequency of the word *and*, or its role as a function word, or both, facilitate processing at levels higher than the letter.

Context effects. Word frequency is not the only variable of importance, however. Manipulations of the surrounding word context also prove to be critical. More detection errors on the word *and* were made by subjects reading the scrambled-word *and* passage when the word *and* occurred between two like parts of speech, or in "appropriate context," than when it occurred between unlike parts of speech, or in "inappropriate context" [$t(23) = 3.12$, $p < .01$]. The mean number of errors on the word *and* was 3.29 for *and*s in appropriate contexts and 2.46 for *and*s in inappropriate contexts. These results suggest that when the word *and* occurs as part of a syntactically correct word group, it may be processed as part of a phrase-level unit.

List passage. The processing of phrase-level units should be disrupted or eliminated by the use of the list passage, which not only removes the words from their adjoining spatial positions but also alters the usual left-to-right reading pattern. As expected, the conditional error percentage for the list passage was at chance level and was significantly below that observed for the scrambled-word *and* passage [$t(31) = 5.37$, $p < .001$].

EXPERIMENT 5

In Experiment 5, we independently manipulated the level of the target and the highest level of processing available in the search passage. As in Experiment 4, scrambled-word passages in which phrase-level units were available were compared to list passages in which the processing of phrase-level units was impaired and the highest available processing level was the level of the word. Letter

groups *and* and *ant*, both alone and embedded in other words, were used as targets in the first ("trigram search") experimental condition, and the words *and* and *ant* were used as targets in the second ("word search") condition.

According to our proposed set of hypotheses, detection of targets both at the letter-group level and at the word level should be impaired by processing at the phrase level. Consequently, we should expect to continue to find more errors on the word *and* for the scrambled-word passage than for the list passage under both experimental conditions. Further, since we predict that the word *ant* in the scrambled-word passage is less likely than the word *and* to enter into phrase-level units, whether by virtue of its low frequency, its role as a content word, or the "inappropriateness" of its contexts in the passage used, we should expect to find substantially fewer errors on the word *ant* than on the word *and* in the scrambled-word passages. Moreover, we should expect to find no differences in detection errors on the word *ant* between the *ant* scrambled-word passage and the *ant* list, since phrase-level units are unlikely to be formed in either case.

We also investigated two plausible alternative hypotheses that could account for the preponderance of detection errors on the word *the* that was observed for subjects instructed to search for the *the* trigram. First, the word *the* is shorter, and therefore may be less conspicuous, than the necessarily longer target words containing the embedded *the* trigram. If the word *and*, like the word *the*, was missed because of its length, there should be no difference in the pattern of errors between the scrambled-word passage containing the target *and* and the analogous passage containing the target *ant*, since the two targets are of equal length. The disproportionate number of detection errors on the word *the* in the previous experiments could also be explained by postulating that a letter-group target might be easier to locate when it is embedded within a word than when it constitutes an entire word. Under these assumptions, we would expect to find a different pattern of results when subjects search for targets at the word level than when they search for targets at the letter-group level. In particular, we would not expect to find a difference in the frequency of detection errors between *and* and *ant* word targets. As we shall demonstrate below, these two hypotheses seem to be ruled out by the present results.

Method

Subjects. The present experiment was conducted at the Mathematical Psychology Laboratory of the Rockefeller University. Forty-eight male and female young adults recruited from a newspaper advertisement served as subjects in the two experimental conditions: Twenty-four subjects served in the trigram search condition, and 24 subjects served in the word search condition.

Design and materials. We employed four passages of scrambled words. Three of the passages, the scrambled-word *and* passage, the scrambled-word *ant* passage, and the *and* list, were the same as those used in Experiment 4. The fourth passage was the *ant* list, which consisted of the same words as the *ant* passage, typed in five vertical columns. The order of the words and the typecase of the letters were the same as in the *ant* passage, but all punctuation marks were removed. The *ant* list was thus comparable to the *and* list.

Procedure. Subjects in the trigram search condition were asked to circle the letter group *and*, both alone and embedded in other words, in the *and* passage and list, and to circle the letter group *ant*, alone and embedded in other words, in the *ant* passage and list. Subjects in the word search condition were instructed to search for the words *and* and *ant*. As in the previous experiments, the subjects were told to read each passage at their normal reading speed and to read each list of words from top to bottom. The orders of presentation of *and* vs. *ant* circling tasks and of the two passages within each task were counterbalanced across subjects. The reading time for each passage was determined with a stopwatch by the experimenter.

Results

Trigram search. The results of the trigram search condition are summarized in Table 5, which includes for the four passages the means and the standard errors of the means for the total number of errors, the number of errors in *and/ant* locations, the conditional percentage of errors in *and/ant* locations given an error, as well as the reading times in seconds. An error in an *and/ant* location is an error on the word *and* in the *and* passage and list, and in the corresponding locations on the word *ant* in the *ant* passage and list.

There were no significant effects involving reading times. The mean conditional error percentage was significantly above chance for the scrambled-word passage [$t(21) = 6.30$, $p < .001$] and was at chance level for the *and* list. The difference in error percentages between the scrambled-word *and* passage and the *and* list was significant [$t(13) = 2.55$, $p < .05$], whereas

Table 5
Means and Standard Errors of Means (in Parentheses) for Error Frequencies, Conditional Percentages, and Reading Times for Passages With *and* or *ant* Targets in the Trigram Search Condition of Experiment 5

Target	Passage	Total Errors	Errors in *and/ant* Locations	Errors at *and/ant* Locations Given Error		Reading Times (in Seconds)
				Percent	N'	
and	Scrambled Word	7.54 (1.31)	4.66 (.68)	69 (5)	22	58.3 (2.7)
	List	2.21 (.44)	.83 (.23)	37 (8)	15	58.1 (2.5)
ant	Scrambled Word	3.37 (.73)	.79 (.34)	16 (4)	18	58.9 (3.1)
	List	1.79 (.51)	.29 (.12)	20 (8)	13	58.4 (2.9)

Note—Total $N = 24$.

that between the corresponding scrambled-word *ant* passage and list was not [$t(10) = .71$, $p > .10$]. These results are consistent with our previous findings for the word *the* and provide further evidence that subjects may process frequent words in the scrambled-word passage in terms of phrase-level units. The increased accuracy on the list passage cannot be attributed to an increase in processing time on that passage, since reading times were equal for the two passages. Instead, a difference in reading strategy is implicated.

Further results rule out the possibility that subjects miss the word *and* solely because of its length: The conditional error percentage for the scrambled-word *ant* passage was significantly less than that of the scrambled-word *and* passage [$t(38) = 7.41$, $p < .001$] and was significantly below chance level [$t(17) = 4.02$, $p < .01$].

Word search. The results of the word search condition are summarized in Table 6, which includes for the four passages the means and the standard errors of the means for the total number of errors and for the reading times in seconds. Since the subjects were asked to search for the words *and* and *ant* only, the conditional error percentages cannot be derived for the present data.

The subjects made more errors on the scrambled-word *and* passage than on any other passage. The difference between the *and* passage and the *ant* passage, in which every occurrence of the word *and* had been replaced by the less frequent word *ant*, was significant [$t(23) = 4.06$, $p < .001$], as was the difference between the *and* passage and the *and* list [$t(22) = 3.40$, $p < .01$]. In contrast, the difference between the *ant* passage and the *ant* list was not significant [$t(22) = 1.09$, $p > .10$]. More errors in the scrambled-word *and* passage were made when the word *and* appeared in its usual context, between two similar parts of speech, than when it occurred out of context [$t(23) = 2.62$, $p < .05$]. The mean number of errors on the word *and* was 1.25 for *and*s in appropriate contexts and .75 for *and*s in inappropriate contexts.

No difference was found between the *and* and *ant* lists [$t(22) = .94$, $p > .10$]. Our hypotheses specify that word frequency will facilitate processing of a given word. On that basis, we might have expected to find a difference between errors on the *and* and *ant* lists. However, since the level of the target in the word search condition and the highest level permitted by the list passage are both the level of the word, we should expect subjects in that condition to process all targets up to the word level. According to this line of reasoning, few errors are anticipated and any variation in the pattern of errors is due to random factors.

No significant differences in reading times were observed between the *and* passage and the *and* list or between the *ant* passage and the *ant* list. The reading times were in fact shorter for the two lists than for the two passages, although not significantly so.

These data show that subjects make a large number of errors on the word *and* relative to the less frequent word *ant* in scrambled-word passages, even when they are directed to search only for the word itself and not for any of the embedded trigrams. The fact that more *and*s were missed when the word *and* occurred in an appropriate context suggests that word context as well as word function or frequency play a major role in this phenomenon.

Table 6
Means and Standard Errors of Means (in Parentheses) for Error Frequencies and Reading Times for Passages With *and* or *ant* Targets in the Word Search Condition of Experiment 5

Target	Passage	Total Errors	Reading Times (in Seconds)
and	Scrambled Word	2.00 (.44)	38.4 (3.2)
	List	.39 (.15)	31.2 (2.7)
ant	Scrambled Word	.41 (.15)	33.8 (3.0)
	List	.21 (.08)	30.2 (2.4)

Note—Total $N = 24$.

DISCUSSION

Subjects searching for instances of a given target letter in printed text make substantially more errors on the words *the* and *and* than on words containing embedded *the* and *and* trigrams (e.g., *thesis, handle*). This effect is not due to word length, or to the pronounceability or the location of the target letter within the word. The contribution of the global word features of the frequent function words *the* and *and* is also unlikely. Rather, we show that the frequency or the function of the target words may be critical (Experiment 4).

Healy (1976) interpreted similar data by postulating that highly frequent words such as *the* may be read in terms of units larger than the letter. We now propose that under some circumstances highly frequent word sequences including the words *the* and *and* may be read in terms of units larger than the word. Specifically, we propose that text may be processed at various levels, each of which involves units of a specific size, and that processing at these various levels occurs in parallel. We further propose that successful completion of processing at a higher level will terminate processing at all lower levels.

Evidence for these hypotheses comes from the observation that a disproportionate number of detection errors occur on the words *the* and *and* when subjects are searching for a given target letter and persist even when subjects are searching for the entire trigram (Experiments 1, 2, 3, and 5). Three alternative explanations of this effect can be ruled out:

(1) Subjects fail to scan the words *the* and *and* because of their high predictability based on prior context (Corcoran, 1966). This alternative is ruled

out by the finding that alterations in typecase and passage format reduce detection errors on the words *the* and *and*, although these alterations should not influence the contextual redundancy of those words (Experiments 3 and 5). Furthermore, the similar notion that a combination of prior context and global features is sufficient to alert the subject to the presence of a function word, which is consequently not fully scanned (e.g., Hochberg, 1970), can be eliminated by the finding that virtually no errors are made on the word *ant* whenever it replaces *and* in similar passages and in identical contexts (Experiment 5), even though *and* and *ant* have very similar global features.

(2) Subjects make errors on the words *the* and *and* because of their short length, which makes them less conspicuous than the longer words containing the embedded letter strings. This second alternative is ruled out by the finding that subjects do not make a disproportionate number of detection errors on the less frequent word *ant* (Experiment 5), even though *and* and *ant* are of equivalent lengths.

(3) Subjects make errors on the words *the* and *and* when searching for trigrams because a trigram is easier to locate when it is embedded within a word than when it constitutes an entire word. This third alternative is ruled out by the finding that subjects continue to make a large number of errors on the word *and* relative to the number on the word *ant* in scrambled-word passages, even when they are instructed to search for the target words *and* or *ant* but not to respond to the *and* and *ant* letter groups embedded in longer words (Experiment 5).

There are three manipulations that reduce the conditional percentages of detection errors to, or close to, chance level, and each of these manipulations seems to be effective because it impairs phrase-level processing and hence disturbs the formation of reading units larger than the word. The most powerful manipulation is the change from the standard paragraph to a vertical list format. This procedure prohibits the natural left-to-right reading pattern and necessarily precludes the use of reading units larger than words (Experiments 3, 4, and 5).

The second manipulation, which does preserve the normal reading pattern, is the variation in context: The conditional percentages fall at chance level when syntactic units larger than the word are eliminated by placing the word *the* in syntactically inappropriate contexts (Experiment 2). Similarly, more errors are made on the word *the* when it is followed by a noun (Experiments 1 and 2) and on the word *and* when it is placed between two like parts of speech (Experiments 4 and 5). These results hold whether the subjects are instructed to search for a given target letter (Experiments 1, 2, and 4), trigram (Experiments 1 and 2), or word (Experiment 5).

The third manipulation, which involves changes in typecase, preserves both the normal reading pattern and the syntactic context but alters the perceptual global features of either the words or word groups. In particular, when passages are typed with every other letter (mixed letter) or every other word (mixed word) in capitals, the percentage of detection errors on the word *the* is reduced relative to that for passages with standard typing. The mixed-letter and mixed-word passages have similar effects; they both attenuate but do not reduce to chance levels the conditional percentages of detection errors on the word *the*.

Since all three manipulations disrupt processing at levels higher than the word, these results provide converging evidence that leads us to propose that familiar word sequences that often include the words *the* or *and* are read in terms of units larger than the word. We specifically suggest that these units are at the phrase level. In particular, they may be short syntactic phrases such as "boy and girl" or word frames such as "on the _____." Alternatively, the frequent function words, although separated from other words by word boundaries, may be read as prefixes or suffixes of the neighboring word. In any case, there is no evidence for processing of units much greater in size than the phrase, say on the order of the clause or sentence, since the preponderance of errors on the word *the* is no larger in a prose passage than in a standard scrambled-word passage (Experiment 1; Healy, 1976).

It should also be made clear that the phrase-level units in question must be of high frequency. Otherwise, it would be difficult to explain why embedding the word *the* in a word unit such as *weather* leads to few detection errors, whereas embedding it in a phrase unit such as "on the _____" leads to many detection errors. These two types of situations differ in two respects. There is a difference between the levels of the units in question (word vs. phrase), and there is a difference between the frequency of the units in question (low for words vs. high for phrases). According to the hypotheses outlined above, it is the frequency of the given unit rather than its level that is critical in determining the likelihood of detecting embedded lower level units.

As Healy (1976) has remarked, it is important to keep in mind that the reading units in question may be one of two possible types: perceptual units or response units. The perceptual units would be visual and the response units would be acoustic, presumably formed by phonetic recoding. The involvement of response units is suggested by the possibility that subjects searching for a target scan an acoustic image of the text rather than a visual image. This possibility seems reasonable on the basis of the evidence by Corcoran (1966) that subjects searching for the letter *e* are likely to miss those instances that are not pronounced, and evidence by Krueger (1970) that acoustic confusability retards letter detection. On the other hand, the effective manipulations of perceptual variables in the present

study (Experiment 3) suggest the involvement of visual units. At present we are, therefore, unable to choose between these two classes of units.

The present results, which are consistent with our set of hypotheses, are less clearly consistent with other models of the reading process. Serial processing theories are incompatible with the finding that subjects fail to detect a target at a given level when higher level units become available. Contextual redundancy theories are ruled out by the data from Experiments 3 and 5. Furthermore, explanations based on the notion of a speed-accuracy tradeoff cannot account for our observed results because our measure of conditional error percentages is independent of the subjects' absolute accuracy levels on this task.

It should be emphasized that we should not expect the particular results we obtained with the common function words *the* and *and* to generalize to less frequent words. Indeed, we have shown that the results for *and* do not apply to *ant*. The special properties of the frequent function words make them particularly likely to be joined to other words in reading. However, although the specific results for *the* and *and* may not generalize to other words, the results for these words do throw light on how subjects read other words. In particular, the identity of the words surrounding the function words proves to be critical. When the function words are surrounded by appropriate neighbors, and only then, a preponderance of detection errors occurs on the function words. These results suggest that in appropriate syntactic contexts, neighboring words are read in conjunction with function words. Thus, whereas the earlier results of Healy (1976) demonstrated the critical role of the frequency of a given word in determining the occurrence of target detection errors, our present results demonstrate the critical role of the familiarity of a given word sequence.

In conclusion, although the relevance of the detection task to normal reading may be questioned, we argue that the present detection paradigm approaches the normal reading situation more closely than do many of the other letter detection paradigms in the literature (e.g., Johnson, 1975; Wheeler, 1970). The occurrence of the same pattern of results when subjects are forced to process semantic characteristics of the words (Experiment 3) as when the task does not specifically make such demands strongly suggests that subjects may typically perform the detection task using processes employed in normal reading for meaning.

Appendix
Prose Passage of Experiment 1

All week the weather was amazing. Even flowers in the park withered and became leathery under the sun's thermal rays. Children wearing no clothes bathed near the southern shore of the lake, while their mothers discussed other problems of psychotherapy and anesthesia. Panthers in the zoo surveyed the scene in a fatherly manner. As shadows lengthened, the air became ethereal and clouds began gathering on the horizon. "Bother," mumbled Alice, who was one of the sunbathers, "I've hardly begun my thesis on the theory of medieval atheism, and I'd rather go and buy the earthenware jug I saw on Friday."

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