Memory & Cognition
1979, 7 (2), 77-85

Mechanisms of sentence context effects in reading: Automatic activation and conscious attention

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In Experiment 1 subjects named target words that were preceded by a congruous sentence context, an incongruous sentence context, or no sentence context, under stimulus conditions that were either normal or degraded by contrast reduction. Under normal stimulus conditions, a contextual facilitation effect, but no contextual inhibition effect, was observed. When the target word was degraded, both contextual facilitation and inhibition were observed. Experiment 2 replicated the increase in contextual inhibition under degraded conditions and also demonstrated that inhibition increased as the interval between contextual processing and target-word onset was lengthened. The results were interpreted within the framework of the Posner and Snyder two-process theory of expectancy. Thus, when target-word recognition is rapid, only the fast-acting automatic activation component of context effects has time to operate. When target-word processing is delayed, the conscious-attention mechanism, which is responsible for inhibition effects, becomes operative. The relevance of these results to developmental investigations of the interaction of word recognition and contextual processing is discussed.

In a recent study, West and Stanovich (1978) had subjects of three ages name a target word that had been preceded by an incomplete sentence that was congruent with the word, by an incomplete sentence that was incongruent with the word, or simply by the word "the" (i.e., a no-context condition). Compared to the reaction times obtained in the no-context condition, naming was faster when the target word was preceded by a congruous context. This contextual facilitation effect did not differ statistically across the three age groups in the study (fourth-graders, sixth-graders, and adults). In fact, correlations involving a standardized reading measure indicated a tendency for poorer readers to show a greater contextual facilitation effect, a result consistent with previous research (Biemiller, 1977-1978; Schvaneveldt, Ackerman, & Semlear, 1977). In addition, a significant contextual inhibition effect (longer naming times in the incongruous context condition than in the no-context condition) was found for both fourth-grade and sixth-grade subjects, but not for adults. In the latter group, mean naming times were virtually identical in the no-context and incongruous conditions.

The pattern of results in the West and Stanovich (1978) study fits rather nicely within the framework of the two-process theory of expectancy developed by Posner and Snyder (1975a, 1975b). Their theory has been applied to the semantic context effect in lexical decision tasks (Fischler, 1977; Neely, 1976, 1977) and is rather easily generalized to sentence context effects of the type studied by West and Stanovich (1978). Briefly, Posner and Snyder (1975a, 1975b) proposed that semantic context affects recognition via two processes that act independently and have different properties. The automatic activation process occurs because when stimulus information activates a memory location, some of the activation automatically spreads to semantically related memory locations that are nearby in the network. The automatic spreading-activation process is fast acting, does not use attentional capacity, and does not affect the retrieval of information from memory locations unrelated to those activated by the context (see Neely, 1977, for a more complete discussion). Thus, the automatic activation process

This research was supported by an Oakland University faculty research grant. The authors would like to thank Mike Seiler, Ann Cunningham-DiPaolo, and Dale Hansen for assistance in data collection. James H. Neely made extensive and insightful comments on an earlier version of this manuscript and the authors are grateful for his contribution. The authors also wish to thank Paula J. Stanovich for providing technical assistance. Requests for reprints should be sent to Keith E. Stanovich, Department of Psychology, Oakland University, Rochester, Michigan 48063.

0090-502X/79/020077-09$1.15/0

quickly results in a contextual facilitation effect, but does not cause an inhibitory effect when a word is incongruous with its preceding context. In contrast, the conscious-attention mechanism responds to a preceding context by directing the limited-capacity processor to the memory location of the expected stimulus. The conscious-attention mechanism is slow acting, utilizes attentional capacity, and inhibits the retrieval of information from unexpected locations because the limited-capacity processor must be "shifted" to a location some distance away in the memory network so that information can be read out. Several recent studies of semantic context effects using the lexical decision task have provided some support for the two-process theory of Posner and Snyder (Fischler, 1977; Neely, 1977; Tweedy, Lapinski, & Schvaneveldt, 1977).

The results obtained by West and Stanovich (1978) can be interpreted as indicating that word recognition in adults is so fast that the target word can be named before the slow-acting conscious-attention mechanism can have an inhibitory effect (i.e., can direct the limited-capacity processor to a memory location far from the target word when it is preceded by an incongruous context). Instead, only the automatic spreading-activation component of contextual processing has time to operate before the word is recognized, thus resulting in contextual facilitation, but no corresponding inhibition in the reaction times of the adults. The word recognition processes of children, however, may be slow enough to allow the conscious-attention mechanism to have an effect. This results in both contextual facilitation and inhibition in the reaction times of the children. The two-process expectancy theory of Posner and Snyder (1975a, 1975b) can also account for the results of several recent studies indicating that poorer readers show greater contextual facilitation effects (Biemiller, 1977-1978; Doehring, 1976; Schvaneveldt et al., 1977). This occurs because poorer readers have slower word recognition times (Mackworth & Mackworth, 1974; Perfetti & Hogaboam, 1975), and as word recognition is slower, there is a greater tendency for contextual facilitation to result from the conscious-attention, as well as the automatic-activation, mechanism.

The above account of the West and Stanovich (1978) results implies that the lack of a contextual inhibition effect in the data of the adults was not due to any qualitative difference in their comprehension processes, but was simply the result of adults' word recognition mechanisms being faster than the one of the parallel-acting contextual expectancy processes (the conscious-attention mechanism) that leads to inhibition effects. This speculation on the age differences in contextual processing can be put in the same framework that Cromer (1970) used to distinguish two types of poor readers. One group (the deficit group) reads poorly because of inadequate word recognition skills, although their comprehension skills are adequate. On the other hand, the second group (the difference group) has adequate word identification skills, but reads poorly because of difficulties in using syntactic and semantic cues (see Isakson & Miller, 1976). The explanation of the West and Stanovich (1978) results described above amounts, in Cromer's (1970) terms, to hypothesizing that the general age-related differences in reading performance are due to a deficit in word recognition skills rather than to differences in syntactic and semantic processing.

It follows that if the lack of a contextual inhibition effect in the reaction times of the adults was due to their rapid word recognition skills rather than to a difference in syntactic and semantic processing, then the performance of adults should approximate that of children under conditions that slow word recognition. This prediction is tested in Experiment 1, where adults read target words in congruous, incongruous, and neutral sentence contexts under both normal and degraded stimulus conditions. Stimulus degradation was produced by contrast reduction and was designed to increase word recognition time.

EXPERIMENT 1

Method

Subjects. The subjects were 24 undergraduate psychology students recruited through a subject pool at Oakland University.

Stimuli and Apparatus. The sentences used in this experiment were 60 of the sentences employed in the West and Stanovich (1978) study. These sentences were constructed so that their last two words were the words "the" and a noun that was highly predictable from the preceding context (e.g., "the car rolled down the hill"). The 60 sentences were organized into 30 sentence pairs (e.g., "the boy swam underneath the bridge" was paired with "the clothes hung inside the closet"). The terminal word of each sentence was then deleted, and the resulting incomplete sentences were used as contexts and the deleted nouns were used as word targets. A sentence context and a target word were considered to be congruous when they were derived from the same original sentence (e.g., "the boy swam underneath the" was congruous with the target "bridge"). A sentence context and a target word were considered to be incongruous when they had been derived from opposite members of the original sentence pairs (e.g., "the clothes hung inside the" was incongruous with the target "bridge"). A no-context condition was created by presenting only the word "the" before the target. As a whole, the sentences were of a low level of reading difficulty. They were composed of simple high-frequency words (based on the Kučera & Francis, 1967, count) and could all be read by fourth-graders.

The stimuli were typed in lowercase Courier 72 font with an IBM Selectric II typewriter. The stimuli were then photographed with Kodalith high-contrast film and the negatives were mounted in double-glass mounts. The slides were back-projected onto a translucent screen by two Kodak Carousel 760H slide projectors. One projector contained the context slides and the other contained the target slides. The images of the two projectors were aligned so that when a sentence context and a target word were simultaneously projected, the subject seated in front of the screen saw what looked like a single complete sentence. The size of the image projected onto the screen by a single five-letter word was approximately .6 cm high and 3.5 cm wide.

Since subjects sat approximately 108 cm from the screen, the five-letter words subtended a horizontal visual angle of approximately 1.86 deg. Degradation was produced by placing four neutral density filters between the translucent screen and the lens of the projector containing the target words. These filters reduced the intensity of the stimulus by 1.4 log units, thus reducing the contrast between stimulus and background.

Target onset was controlled by a Vincent Associates Uniblitz shutter that was positioned over the lens of the projector that contained the target slides. When the experimenter pushed a control button, the shutter was electronically opened and the projected image of the target word appeared. A Lafayette Instruments electronic clock (Model S4419-A, accurate to the millisecond) was started by the same push of the control button. When the subject responded verbally to the target, a voice-activated relay stopped the clock and closed the shutter. The microphone that led to the voice-activated relay was held by the subject.

Procedure. Subjects were individually tested in a session that lasted approximately 20 min. They were told to read aloud the sentence contexts that appeared on the screen in front of them. Approximately .3 sec after the subjects pronounced the last word of the context, which was always "the," a target word appeared. Subjects were instructed to read the target word as rapidly as possible when it appeared. In addition, the subjects were told that only the reading of the target word was timed, so they were free to read the contexts at a comfortable pace. Targets were read under the following three conditions: (1) with the prior display of a congruous sentence context, (2) with the prior display of an incongruous sentence context, and (3) without the prior display of a sentence context (only the word "the").

Each subject completed one block of 33 trials under normal stimulus conditions and one block of 33 trials under conditions where the target word was degraded. Order of stimulus conditions was counterbalanced across subjects. Within each block, two practice trials were given under each of the three context conditions. The practice trials were followed by nine experimental trials given under each of the three context conditions. The ordering of the three context conditions within the 27 experimental trials was random, with the constraint that each context condition occur three times in every 9 trials. In the experimental trials, all subjects saw the same set of 54 target words, but the assignment of the words was counterbalanced across subjects so that each word was preceded equally often by a congruous context, an incongruous context, and no context. Additional counterbalancing insured that each context and target was equally often in a degraded and nondegraded block and equally often in the first and second blocks of trials. No subject saw the same target word or sentence context more than once in the course of the experiment.

Results

Across all subjects, approximately 5% of the trials were dropped from the data analysis due to some type of experimental malfunction (e.g., the vocal response was too soft for the relay setting, the subject triggered the voice key by coughing or handling the microphone). These trials were fairly evenly distributed among the six experimental conditions. Trials on which the subject articulated the wrong word or had a response time longer than 2,000 msec were scored as subject errors and dropped from the analysis. This type of error never occurred under normal stimulus conditions. Under degraded conditions, there were 7 subject errors on congruent context trials, 8 subject errors on no-context trials, and 10 subject errors on incongruent context trials.

The mean reaction times to name the target words in all six experimental conditions are displayed in Table 1. All of the analyses that follow are based on the mean reaction times for each subject. Additional analyses that were carried out on the median reaction times yielded results highly consistent with the analyses done on the means. A two-way analysis of variance on the mean reaction times from all six experimental conditions indicated that the effects of stimulus quality [$F(1,23) = 126.88$] and context condition [$F(2,46) = 14.07$] and the Stimulus Quality by Context Condition interaction [$F(2,46) = 9.81$] were all significant at the .001 level. Additional one-way analyses indicated that there was a significant effect of context condition in both the nondegraded [$F(2,46) = 4.61$, $p < .025$] and degraded [$F(2,46) = 12.86$, $p < .001$] conditions. Planned comparisons indicated that in the nondegraded condition, the 15-msec contextual facilitation effect (faster reaction times in the congruous condition than in the no-context condition) approached statistical significance [$F(1,46) = 3.78$, $p < .06$], but the 8-msec contextual inhibition effect (slower reaction times in the incongruous condition than in the no-context condition) did not [$F(1,46) = 1.10$]. In the degraded condition, planned comparisons indicated that the 49-msec contextual facilitation effect approached significance [$F(1,46) = 3.18$, $p < .09$] and that the 88-msec contextual inhibition effect was highly significant [$F(1,46) = 10.36$, $p < .005$].

DISCUSSION

The results from the normal stimulus condition approximated those obtained from the West and Stanovich (1978) study. The contextual facilitation effect was somewhat smaller (15 msec vs. 28 msec) and was only marginally significant. However, there was no indication of a reliable contextual inhibition effect. Quite a different picture emerged from the degraded stimulus condition. Here, a 49-msec contextual facilitation effect was obtained. More importantly, a highly significant 88-msec contextual inhibition effect was observed when the target stimulus was degraded. This result supports the Posner and Snyder (1975a, 1975b) two-process theory of context effects. Under normal stimulus conditions, word recognition is so fast that it occurs before the slower acting conscious-attention

Table 1
Mean Reaction Times in Milliseconds

Stimulus Condition	Context Condition		
	Congruous	No Context	Incongruous
Normal	451	466	474
Degraded	687	736	824

process can have an effect, hence, contextual facilitation without inhibition. When word processing is slowed the conscious-attention mechanism has time to act, and inhibition results. The lack of contextual inhibition under normal conditions that distinguishes adult performance from that of children appears to stem from the relative speed of the adult word recognition process rather than from a difference in the use of semantic and syntactic cues.

Although a conceptualization of the results of Experiment 1 in terms of the Posner and Snyder (1975a, 1975b) theory is elegant and parsimonious, objections could be raised against such an interpretation. One problem centers around the statistical marginality of some of the results. For instance, in the normal stimulus condition, the predicted contextual facilitation effect is only marginally significant and is not much larger in absolute magnitude (15 msec vs. 8 msec) than the presumably nonexistent inhibition effect. In addition, the contextual facilitation effect in the degraded stimulus condition did not reach accepted levels of statistical significance. Of course, only replication can establish the reliability of the results. However, several points should be noted. First, the predicted Context by Stimulus Quality interaction was observed and was highly significant. Second, the statistical marginality of the facilitation effects should not be of great concern, since several demonstrations of facilitation effects in related paradigms (e.g., Fischler, 1977; Fischler & Goodman, 1978; Neely, 1976; Schuberth & Eimas, 1977) and the large and highly reliable facilitation effects to be reported in Experiment 2 leave their existence hardly in doubt. Finally, a comparison of the inhibition effects in the two conditions (88 msec vs. 8 msec) clearly confirms the most important prediction that Experiment 1 was designed to test.

Schuberth and Eimas (1977) obtained results that apparently contradict an explanation of sentence context effects in terms of the Posner-Snyder (1975a, 1975b) theory. Using a lexical decision task, Schuberth and Eimas found contextual facilitation and inhibition effects that did not change with variations in the frequency of the target word. Based on the process-time explanation given above, one would expect greater contextual effects with low-frequency words, since low-frequency words take longer to recognize. However, the magnitude of the frequency effect in the Schuberth and Eimas experiment (only 71 msec in the isolated word control condition) might not have been great enough to cause a detectable increase in inhibition. It took a 270-msec degradation-induced increase in word recognition time to produce the effects observed in Experiment 1. It is also not clear whether the fact that Schuberth and Eimas observed a significant inhibition effect conflicts with the results of Experiment 1 and those of the West and Stanovich (1978) study. Since Schuberth and Eimas presented their contexts for fixed intervals during which subjects read the contexts silently (rather than having the subjects read the context aloud, as in Experiment 1), it is unknown how much time elapsed between the reading of the context and the appearance of the target word. Thus, it is not clear how much time the attentional mechanism had to operate and, consequently, it is impossible to say whether or not inhibition should be expected.

A more important objection to Experiment 1 concerns the fact that the amount of time that the word recognition process would need to run to its completion and the amount of time that the attentional mechanism was given to exert its inhibitory influence were not independently manipulated (both being affected by the degradation manipulation). This leaves the results open to alternative explanations. Specifically, the explanation that we have given is based solely on the amount of *time* available to the two expectancy processes. However, since the attentional mechanism is assumed to be under the subject's control, it is possible that only in difficult tasks (e.g., the degraded condition of Experiment 1) will the subject be motivated to utilize the attentional mechanism to generate expectancies. Thus, under this explanation, it was the task characteristics, specifically the level of difficulty, rather than processing time per se, that led to the pattern of results observed in Experiment 1.

Alternative explanations such as the one outlined above can be tested by independently manipulating word recognition difficulty and the amount of time available to the expectancy processes. This is done in Experiment 2, where stimulus quality and the response-stimulus interval (RSI) (the amount of time between the response to the last word of the context and the onset of the target word) are varied orthogonally. The task-difficulty explanation would predict that only the degraded conditions will produce inhibition and that the amount of inhibition will not depend on the RSI (which, in the range manipulated, should not affect the difficulty of target-word naming). The processing-time explanation would predict that it is the total time interval (regardless of how produced) between the response to the context and the beginning of lexical retrieval that is important. Thus, the amount of inhibition should increase with increases in both stimulus degradation (which increases the duration of the encoding stage that precedes lexical retrieval) and the RSI.

EXPERIMENT 2

Method

Subjects. The subjects were 36 undergraduate students recruited through a subject pool at Oakland University.

Stimulus and Apparatus. The sentences were the same as those in Experiment 1. The stimuli were typed on 6 x 9 in. (15.2 x 22.9 cm) cards in lowercase Prestige Elite font with an IBM Selectric II typewriter. One set of cards contained the

sentence contexts and another contained the target words. The stimuli were presented via an Iconix tachistoscope at a viewing distance of 88.9 cm. Five-letter words subtended a horizontal visual angle of approximately .62 deg. The contexts and the target words were presented in separate fields of the tachistoscope and were aligned so that when both were presented the subject saw what looked like a complete sentence. Degradation was produced by inserting into the target-word field a neutral density filter that reduced the intensity of the stimulus by .3 log units. Target-word onset was controlled by a button pushed by the experimenter. This button started a trial sequence that displayed the target word after a predetermined time interval and simultaneously started a millisecond clock. When the subject responded verbally to the target, a voice-activated relay stopped the clock.

Prior to the collection of the data, the experimenter was given extensive practice in synchronizing the pushing of the control button with the articulation "the." Thus, RSI was manipulated by altering, via the trial-sequence setting of the tachistoscope, the time between the button activation and the presentation of the target word. In each trial of Experiment 2, this interval was set at either 100 or 700 msec. Since something on the order of 50 msec usually elapsed between the end of the articulation of the word "the" and the pressing of the control button (had the experimenter pushed the button before the end of the pronunciation of "the," that articulation would have activated the voice key and stopped the trial immediately), the effective RSI in the experiment was either 150 or 750 msec. Of course, there was some variability in the response of the experimenter, so that it would be more accurate to call these RSI values mean intervals. However, it should be emphasized that the experimenter had extensive practice in synchronization before the experiment began, and that the same experimenter operated the control button throughout the experiment. It is possible that, due to the articulation of the word "the" being more unpredictable in the no-context condition, synchronization was more difficult, and thus resulted in a longer effective RSI in the no-context condition. The experimenter was, of course, aware of this potential problem and tried to minimize it by attempting, on all trials, to initiate her buttonpress with the articulation of "the" such that the button was activated as soon as possible after the end of the articulation of "the." The experimenter was instructed to develop a criterion so stringent that it occasionally resulted in her pressing the button during the articulation of "the," thus aborting the trial. The fact that this type of experimenter error occurred with approximately equal frequency in all three context conditions suggests that any RSI differences between the three conditions were probably not large. It was, however, probably the case that the RSI variability was greater in the no-context condition. In summary, it is unlikely that any lengthening of RSI in the no-context condition was of sufficient magnitude to have resulted in significant reaction time changes in this condition, and even more unlikely that any changes so created would have worked in such a way as to produce the pattern of results predicted by the Posner-Snyder (1975a, 1975b) theory.

Procedure. Subjects were individually tested in a session that lasted approximately 30 min. They were told to look into the tachistoscope and read aloud the sentence contexts that appeared. Subjects were instructed to read the target word as rapidly as possible when it appeared. In addition, the subjects were told that only the reading of the target word was timed, so they were free to read the contexts at a comfortable pace. Targets were read under congruous, incongruous, and no-context conditions as in Experiment 1.

Each subject completed one block of 33 trials under normal stimulus conditions and one block of 33 trials under conditions where the target word was degraded. Order of stimulus conditions was counterbalanced across subjects. Within each block, one practice trial was given under each of the three context conditions. The practice trials were followed by a random ordering of 30 experimental trials consisting of 5 trials given under each of the six conditions formed by the factorial combination of context (congruous, incongruous, no context) and RSI (150 msec, 750 msec). In the experimental trials, each subject saw the same set of 60 target words, but the assignment of words was counterbalanced across subjects so that each word was preceded equally often by a congruous context, an incongruous context, and no context. Additional counterbalancing insured that each context and target was equally often in a degraded and nondegraded block, equally often in the first and second blocks of trials, and equally often presented under RSIs of 150 msec and 750 msec. No subject saw the same target word or sentence context more than once in the course of the experiment.

Results

Across all subjects, approximately 7% of the trials were dropped from the data analysis due to some type of experimental malfunction. These trials were fairly evenly distributed among the 12 experimental conditions. Trials on which the subject articulated the wrong word or had a response time longer than 2,000 msec were scored as subject errors and dropped from the analysis.

The mean reaction times to name the target words and the mean percentage of errors in all 12 experimental conditions are displayed in Table 2. All of the analyses that follow are based on the mean reaction times for each subject. Additional analyses that were carried out on the median reaction times yielded results consistent with the analyses done on the means. A three-way analysis of variance on the reaction times from all 12 experimental conditions indicated that the main effects of stimulus quality [$F(1,35) = 58.75$, $p < .001$] and context condition [$F(2,70) = 43.80$, $p < .001$] were highly significant. The effect of RSI did not reach statistical significance [$F(1,35) = 2.61$, $.10 < p < .15$]. None of the interactions was significant, although the Stimulus Quality by Context Condition [$F(2,70) = 2.26$, $p < .12$] and RSI by Context Condition [$F(2,70) = 2.19$, $p < .12$] interactions both approached significance.

More illuminating are the planned comparisons used to test the significance of the facilitation and inhibition effects in the four conditions formed by the factorial combination of stimulus quality and RSI. These analyses indicated that under normal stimulus conditions with

Table 2
Mean Reaction Times in Milliseconds and Mean Percentage of Errors (E)

		Context Condition					
		Congruous		No Context		Incongruous	
RSI	Stimulus Condition	Mean	E	Mean	E	Mean	E
150	Normal	674	0.0	785	.6	793	.6
150	Degraded	827	2.8	951	5.0	967	8.3
750	Normal	685	0.0	738	1.1	769	0.0
750	Degraded	814	1.1	910	6.7	962	6.7

a RSI of 150 msec, there was a highly significant 111-msec contextual facilitation effect ($p < .001$), but the 8-msec contextual inhibition effect did not approach significance ($p > .25$). Under degraded stimulus conditions with a RSI of 150 msec, there was a highly significant 124-msec contextual facilitation effect ($p < .001$), but the 16-msec contextual inhibition effect was not statistically significant ($p > .25$). In the normal stimulus condition with a RSI of 750 msec, both the 53-msec contextual facilitation effect and the 31-msec contextual inhibition effect were significant ($p < .005$ and $p < .05$, respectively). Finally, in the degraded stimulus condition with a RSI of 750 msec, both the 96-msec contextual facilitation effect and the 52-msec contextual inhibition effect were significant ($p < .001$ and $p < .05$, respectively).

The processing-time hypothesis derived from the Posner-Snyder (1975a, 1975b) theory makes the prediction that the amount of inhibition should increase as the interval between contextual processing and the target-word retrieval stage is lengthened, regardless of how the lengthening is produced (i.e., by increasing the RSI, slowing the target-word encoding stage, or both). Figure 1 displays the data of Experiment 2 in a way that allows this prediction to be evaluated. The amount of inhibition and facilitation is represented on the ordinate. The abscissa represents the interval between the articulation of the last context word and the completion of the encoding stage of target-word processing. Thus, assuming a 100-msec stimulus encoding stage, the total interval in the 150-RSI normal stimulus condition is 250 msec. Plotted next is the 150-RSI degraded condition, where the 166-msec degradation effect makes the total interval 416 msec. The interval is 850 msec in the 750-RSI normal condition and 1,022 msec in the 750-RSI degraded condition. Figure 1 shows a steady increase in the inhibition effect as the time interval available for contextual processing increases. The facilitation effect is on the order of 100 msec for three of the conditions, but shows a dip to 53 msec in the 750-RSI normal condition. The contextual inhibition effect behaved as predicted by the Posner-Snyder theory. It increased monotonically as the processing interval was lengthened, was negligible and nonsignificant in the two conditions with the shortest interval, and attained an appreciable magnitude and statistical significance only at the two longest intervals.

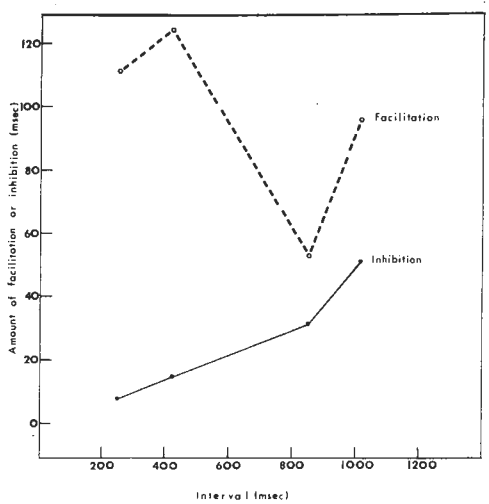

Figure 1. Amount of facilitation and inhibition as a function of the interval between the articulation of the last context word and the completion of the encoding stage of target-word processing.

GENERAL DISCUSSION

The results of Experiments 1 and 2 are generally consistent with an explanation of sentence context effects derived from the Posner-Snyder (1975a, 1975b) two-process theory of expectancy. It appears that word recognition can be so fast that it allows time only for the operation of the automatic activation component of the expectancy generated by a sentence context. In such a situation, contextual facilitation without inhibition was observed. However, when subjects were given longer to process the sentence context, either by delaying the presentation of the target word or by lengthening the time needed to process the target word, significant contextual inhibition effects became evident. This was presumably due to the operation of the conscious-attention mechanism.

It should be noted that the Context by Stimulus Quality interactions observed in the present experiments could be looked on as replications of a result previously reported in the literature on single-word priming effects (Becker & Killion, 1977; Meyer, Schvaneveldt, & Ruddy, 1975). These experiments did not, however, contain a no-context control condition and thus could not separate contextual facilitation from inhibition. Instead, the preferred explanation (see Meyer et al., 1975) utilized Sternberg's (1969) additive factors logic and interpreted the interaction as indicating an encoding locus for context effects. In the conceptualization of the present authors, it is not the encoding locus of stimulus quality that is important, but instead the simple fact that stimulus degradation slows target-word recognition and increases the amount of time that the expectancy processes (initiated by the sentence context) have to act. Thus, the effect of RSI should logically not be any different from that of stimulus quality, and this is in fact what the results show.

Although the results of Experiments 1 and 2 are generally supportive of the Posner-Snyder (1975a, 1975b) theory, some inconsistencies in the results of the two experiments (which differed primarily in experimental apparatus) suggest that there is still much to be learned about the operation of the processes that mediate sentence context effects and the time course of

these processes. First of all, the contextual inhibition effect in the degraded condition of Experiment 1 was larger than that observed in any of the conditions of Experiment 2. Also, the contextual facilitation effect in both conditions of Experiment 1 was less than what would be expected on the basis of the results of Experiment 2. The most important difference between the two experiments concerns the nature of the stimulus conditions. In Experiment 1 the subject read a white word on a dark background, whereas in Experiment 2 the subject read a black word on a white background. Perhaps more relevant for studies of word recognition was the rather large difference in the horizontal visual angles of the words in the two experiments. In Experiment 1 a five-letter word subtended 1.86 deg, compared with .62 deg in Experiment 2. Purcell, Stanovich, and Spector (1978) demonstrated that differences of such a magnitude can have a large influence on the mechanisms that mediate the word superiority effect. However, rather than engage in blatantly post hoc speculation on whether such a variable could possibly interact with contextual effects to influence target-naming time, we simply point to this variable as potentially relevant.

Although the magnitude of the inhibition effect in Experiment 2 increased monotonically as expected, the form of the contextual facilitation function is problematical. Three of the conditions show facilitation effects of a similar magnitude (about 100 msec). However, there is a dip to 53 msec in the 750-RSI normal stimulus condition (see Figure 1). One might speculate that the time course of sentence context effects is such that the facilitation due to attentional control does not reach its maximum until after a substantial decay of the automatic pathway activation. Thus, it is possible that the processing interval of the 750-RSI normal condition falls in a range where there has been decay of the automatic activation, but not enough time for the full effect of the attentional facilitation component, which is presumably the main cause of the facilitation effect in the 750-RSI degraded condition. Neely (1977) also found a drop in contextual facilitation in a single-word priming experiment and offered a similar explanation.

The results of Experiment 2 do indicate that the data of Schuberth and Eimas (1977) might not be inconsistent with the Posner-Snyder (1975a, 1975b) theory. Schuberth and Eimas found that the magnitude of the contextual inhibition effect in a lexical decision task did not change as the frequency of the target word was manipulated. However, given the inhibition function displayed in Figure 1, it is clear that a 70-msec word-frequency effect would probably not make a detectable difference in the amount of inhibition.

Although the details of how the two expectancy mechanisms operate in producing sentence context effects remain to be worked out, there now appears to be enough evidence generally supportive of the Posner-Snyder (1975a, 1975b) theory (Fischler & Goodman, 1978, using a single-word priming paradigm, adopted a research strategy similar to that of the present authors and found that changes in the speed of word identification had the predicted effect on the amount of automatic facilitation) that its use as a framework for understanding sentence context effects certainly seems warranted. The theory has proven useful in studies of other types of context effects, and its application to the study of the development of the component processes of reading could help to explain some apparently anomalous results in the area. For example, the Posner-Snyder theory provides a framework for understanding the developmental change in the effect of sentence context observed in the West and Stanovich (1978) study. The age differences observed can be explained without hypothesizing qualitative changes in syntactic and semantic processing across an age range (Grade 4 through adult) that current work on language development would make an unlikely candidate for such a change. Rather, the seemingly discontinuous disappearance of the contextual inhibition effect between Grade 6 and adulthood appears to be due, instead, to the gradual increase in word recognition speed (Biemiller, 1977-1978; Doehring, 1976) that sometime during this age range results in word retrieval that is accomplished before the conscious-attention expectancy mechanism can have an effect.

The explanation outlined above has at least two important implications that are relevant for current work on the development of reading fluency. First, it is perhaps the case that many theories that have placed great emphasis on the use of context (e.g., Goodman, 1970; Smith, 1971) have unduly ignored the importance of rapid word recognition. Indeed, several recent studies and theoretical statements (Biemiller, 1977-1978; Rozin & Gleitman, 1977; Shankweiler & Liberman, 1972; West & Stanovich, 1978; Perfetti, Bell, Hogaboam, & Goldman, Note 1) have, in contrast to previous theorizing, emphasized the importance of rapid word recognition in the development of reading fluency. In particular, recent results suggest the possibility that rapid individual word recognition rather than superior contextual processing may be the key to fluent reading. The time course of mental events for the fluent reader may be such that only the automatic activation component of contextual expectancy can operate before an individual word is recognized. Thus, the conscious-attention mechanism may be short-circuited in the more fluent reader and the developing efficiency of this mechanism may not be a causal factor in age-related changes in reading ability beyond a certain level. Of course, this conceptualization is more relevant to a situation where the words and concepts in the text are fairly familiar to the children (the West & Stanovich, 1978, study insured this

condition by using sentences that were well within the capabilities of the fourth-graders). The reason for this is that the explanation assumes that children have the words organized in semantic memory in such a way that automatic pathway activation can operate. Contextual facilitation might show more of a tendency to increase with age if more difficult sentences were used. This might be the case because, for the younger reader, the words of more difficult sentences probably are not organized in an efficient way in semantic memory, or because the words have occurred together so infrequently in the child's experience that automatic pathways have not yet developed.

The second important implication derived from the present work concerns how deficiencies in word recognition affect the operation of the processes that generate semantic and syntactic expectancies. Many models of reading that hypothesize a series of processing stages (e.g., Gough, 1972; LaBerge & Samuels, 1974) predict that inefficient word recognition processes will lead to less use of contextual constraints, either because little capacity is left over for contextual processing or because the higher level expectancy processes are receiving degraded information from the lower level recognition processes. This prediction rests entirely on the assumption of a strict processing hierarchy, such that word recognition follows letter recognition and semantic processing follows word recognition. However, much current work in cognitive psychology (see Rumelhart, 1977) seems to contradict the seriality assumption in indicating that the initiation of a higher level process must not necessarily await the completion of all lower ones. Instead, interactive models of the type outlined by Rumelhart seem to be more consistent with the experimental data. In such a conception, a pattern is synthesized based on information provided simultaneously from several information sources (e.g., feature extraction, orthographic knowledge, lexical knowledge, syntactic knowledge, semantic knowledge). An interactive model thus leaves open the possibility that higher level processes could actually compensate for deficiencies in lower level processes. Thus a reader with poor word recognition skills may actually be prone to a greater reliance on contextual factors because these provide additional sources of information. An extrapolation of the results reported here suggests more specifically how this compensatory interaction between different levels of processes might work. If word recognition is slow, conscious-attentional expectancies combine with automatic activation to provide another source of contextual facilitation.

The compensatory notion outlined above would explain why several studies have failed to confirm the prediction of the serial-stage models that more skilled readers would show greater semantic context effects (Allington & Strange, 1977; Biemiller, 1977-1978; Doehring, 1976; Samuels, Begy, & Chen, 1975-1976; Schvaneveldt et al., 1977; West & Stanovich, 1978; Perfetti et al., Note 1). In fact, several of these studies have actually found a decrease in contextual facilitation as reading ability increases. This finding can be explained by a compensatory model of reading skills based on an interactive processes conceptualization (e.g., Rumelhart, 1977). Thus, as regards more global theories of the reading process, the present results can be seen as generally supportive of, but indicating limitations in, the positions of theorists such as Goodman (1970) and Smith (1971). Their position that word recognition and contextual processing go on in parallel, are highly interactive, and involve tradeoffs is supported. However, the exact nature of the tradeoffs between the two types of processes (relatively "bottom-up" word recognition and relatively "top-down" contextual facilitation) appears to be unlike that conceptualized by Smith (1971). Increases in reading ability seem to be more dependent on increases in word recognition speed than on greater use of semantic and syntactic cues. Instead, the slower word recognition of poorer readers leads to greater use of context. Top-down processes can compensate for slow word recognition processes, both when the slowness is due to developmental immaturity and when it is due to degrading the stimuli presented to adults. A conceptualization in terms of the two-process theory of Posner and Snyder (1975a, 1975b) provides a mechanism that accounts for this effect.

Finally, the results presented here have implications for a widely used technique in developmental investigations of context utilization, the cloze task (see Bickley, Ellington, & Bickley, 1970). Basically, the subject is presented with a sentence that has a word removed and is asked to produce the missing word. Accuracy is the performance measure, and the subject is under no time pressure. Obviously, performance on the cloze task is dependent on the ability to consciously generate a word consistent with the sentence. The question raised by the present study is how this conscious prediction process is related to the processes that cause contextual facilitation in actual reading. If, as has been argued, the conscious-attention process is less implicated in contextual facilitation as reading proficiency develops, then performance on cloze tasks may be less indicative of actual context usage at the higher reading levels. The correlation between proficiency and cloze performance (Bickley et al., 1970; Ruddell, 1965) may not be indicative of a causal relation. Older and better readers may respond more accurately on cloze tasks due to their larger stores of linguistic and general knowledge. This does not necessarily mean that greater conscious contextual prediction is implicated in their more rapid reading speeds. In fact, if they are reading rapidly enough, it is likely that any effect of context on recognition is due to automatic spreading activation rather than conscious prediction. Perhaps reaction time

measures similar to those used in the present study might be better indicators of context use in the actual reading situation than are cloze tasks. Several recent investigators (e.g., Doehring, 1976; LaBerge & Samuels, 1974) have emphasized the diagnostic value of speed measures.

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(Received for publication September 29, 1978;
revision accepted February 1, 1979.)