Children's Word Recognition in Context: Spreading Activation, Expectancy, and Modularity

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STANOVICH, KEITH E.; NATHAN, RUTH G.; WEST, RICHARD F.; and VALA-ROSSI, MARILYN. *Children's Word Recognition in Context: Spreading Activation, Expectancy, and Modularity.* CHILD DEVELOPMENT, 1985, **56**, 1418–1428. Both third-grade children (mean age 9-6) and fifth-grade children (mean age 11-6) performed like adults in that they named a word (e.g., "tractor") just as fast when it was preceded by a related but incongruous incomplete sentence context (e.g., "the farmer planted the") as when it was preceded by a neutral context (e.g., "they said it was the"). The results support the assumption of the 2-process interactive-compensatory model that context effects on children's word recognition are caused by a spreading-activation process and an expectancy-based attentional process that operate simultaneously. The findings indicate that the word recognition input system of children as young as third graders displays some modular properties. The conclusion that word recognition is modular for adults and that it displays considerable modularity even in children as young as third graders has implications for global theories of the reading process because other recent developmental/individual difference findings are more easily accommodated by modular models of reading than by hypothesis-testing models that do not as clearly demarcate the word level of processing.

During the years when reading theory was dominated by analysis-by-synthesis and hypothesis-testing models, most reading theorists posited a word recognition stage that was heavily contextually driven. However, as the result of a spate of recent studies (most appearing since 1980; see Ehrlich & Rayner, 1981; Forster, 1979; Gough, 1983; Henderson, 1982; Mitchell, 1982; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Seidenberg, Waters, Sanders, & Langer, 1984; Stanovich, 1981; Stanovich & West, 1983a, 1983b), a new and very different consensus is emerging. Most researchers now seem to agree (for reviews, see Henderson, 1982, and Stanovich & West, 1983a) that for fluent adults reading normal text, word recognition is not directed by contextual expectancies.

A reconceptualization of the developmental component of reading theories is also currently under way, again resulting from the fact that the findings of a flurry of recent studies have contradicted long-held theories. Several of the classic "top-down" theories in the reading literature (e.g., Goodman, 1976; Smith, 1971) contain the assumption that reading performance becomes more contextually driven at all levels in the processing hierarchy as reading skill develops. Recent evidence has indicated that at the level of word recognition this assumption is false. It appears that context effects on word recognition, particularly those due to conscious expectancies, are more salient in the younger or less skilled reader (e.g., Perfetti, Goldman, & Hogaboam, 1979; Schvaneveldt, Ackerman,

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& Semlear, 1977; Schwantes, 1981, 1982; Simpson, Lorsbach, & Whitehouse, 1983; Stanovich, West, & Feeman, 1981; West & Stanovich, 1978; West, Stanovich, Feeman, & Cunningham, 1983). For example, several studies of developmental changes in the effects of context on word recognition have been designed to compare the time to recognize a target word (e.g., "corn") in a congruous context (e.g., "the farmer planted the") to recognition time in a neutral context (e.g., "they said it was the"). Unrelated-incongruous sentences (e.g., "the musician played the") are often used to measure contextual inhibition. Larger facilitation effects (faster congruous times than neutral times) and inhibition effects (slower incongruous times than neutral times) are often shown by the younger and/or less skilled subjects in these experiments, thus contradicting an important prediction of the top-down models.

The results from the developmental and individual differences research have been conceptualized within the interactive-compensatory model of reading (Stanovich, 1980, 1984). This model supplements the basic interactive idea that recognition is accomplished via the simultaneous amalgamation of information from many different sources (e.g., Rumelhart, 1977) with one critical assumption: deficiencies at a particular level of the processing hierarchy can be compensated for by a greater use of information from other levels, and this compensation takes place irrespective of the level of the deficient process. The specific model of compensatory processing employed by Stanovich (1980, 1984) was the two-process model of expectancy developed by Neely (1977) and Posner and Snyder (1975a, 1975b). The two-process model assumes that contextual effects can be mediated by two contextual mechanisms that have very different properties. One is an automatic spreading-activation process operating in semantic memory. This mechanism is fast acting, uses little cognitive capacity, and causes facilitatory but not inhibitory context effects. The other mechanism is a process of specific contextual prediction (sometimes called the conscious expectancy, or attentional, mechanism) that operates more slowly, utilizes attentional capacity, and causes facilitation and inhibition (see Neely, 1977; Stanovich & West, 1983a).

The two-process interactive-compensatory model postulates that both contextual processes operate simultaneously and that both can result in a compensatory interaction (larger context effects being displayed by the less skilled reader). The spreading-activation mechanism causes an obligatory interaction, that is, one that necessarily occurs when word recognition is slow. For example, Sanford, Garrod, and Boyle (1977) and Seymour (1976) have shown that Morton's (1969) logogen model has this implication. When the rate of feature extraction is slowed, factors that affect the evidence requirements of logogens (e.g., contextual information) necessarily have a greater effect on performance. In an early version of the interactive-compensatory model (Stanovich & West, 1981), it was postulated that a similar obligatory interaction involving the attentional-expectancy mechanism also occurred (this is sometimes termed the time-locked version of the two-process model). Slower word recognition allowed more time for the slow-acting conscious expectancy mechanism to become implicated in performance, thus causing larger context effects. Subsequent results from adult studies led to a relaxation of the time-locked assumption and a reconceptualization of the attentional mechanism more in terms of a strategy under subject control (Stanovich & West, 1983a). Compensatory interactions mediated by this mechanism were thus posited to be optional in that they did not necessarily occur when word recognition was slow.

Although the status of the time-locked assumption in models of adult performance is still debated in the literature (Eisenberg & Becker, 1982; Inhoff, 1984; Stanovich & West, 1983a), Stanovich and West (1983a; Stanovich, 1980) have consistently argued that in most circumstances *both* mechanisms are implicated in the performance of children. This conclusion has been disputed, however. Based on results from a sentence paradigm very similar to that used by West and Stanovich (1978), Briggs, Austin, and Underwood (1984) argued that the automatic spreading-activation mechanism is not implicated in the contextual effects displayed by 10-year-old children, although we believe that their results are severely compromised due to speed-accuracy trade-off problems caused by differential response criteria. In contrast, Simpson and Lorsbach (1983) studied the context effects displayed by second, fourth, and sixth graders and adults in a priming paradigm very different from the sentence context situation examined by West and Stanovich (1978). They concluded that whereas all groups displayed facilitation due to automatic spreading activation, the conscious attentional mechanism was only implicated in the performance of the older groups. The conclusions of these two groups

of researchers are thus inconsistent with each other and contrast with those of the West/Stanovich group (e.g., West et al., 1983), who maintain that in the age range 8–12 (second to sixth grade) both contextual mechanisms are simultaneously operative when the experimental paradigm approximates natural reading and when the stimulus materials contain enough associative relationships to enable the detection of spreading activation. The experiment to be reported provides further evidence relevant to evaluating these three hypotheses about the contextual mechanisms involved in children's word recognition.

In our experiment we created a situation in which the mechanisms of spreading activation and conscious expectancy were opposed to each other. We created a new condition to compare with the standard congruous, neutral, and incongruous sentence types. In the new condition we used a set of stimuli where the target words (e.g., "tractor") were related to words in their associated contexts but were incongruous (e.g., "the farmer planted the tractor"). The use of this word set (termed the related-incongruous or RI set, as opposed to the standard set, which was termed related-congruous or RC) creates a situation in which the effects of spreading activation and expectancy formation are opposed to each other. The response to the target words in the related-incongruous sentences should still be facilitated by automatic activation from the associated words in the context, but to the extent that word recognition is driven by specific expectancies, these words should also experience inhibition (i.e., slowing relative to the neutral condition). A comparison of performance in the related-incongruous condition to that in the neutral condition is diagnostic regarding the operation of the two contextual mechanisms, especially when the performance patterns in the standard conditions involving the RC set are taken into account. For example, if spreading activation is the only contextual mechanism that is operative then the related-incongruous condition should display facilitation relative to the neutral control. If the conscious attentional mechanism is the only one operative, the related-incongruous condition should display inhibition relative to the neutral control. If both mechanisms are operative, any pattern of results may occur, depending on the relative strengths of the two processes. However, equivalent performance in the related-incongruous and neutral conditions is consistent only with the hypothesis that both mechanisms are operating simultaneously, provided inhibition is observed in unrelated-incongruous conditions.

Trends involving the developmental component of the study can also be predicted. If only the spreading activation component is operative, the standard compensatory interaction between context and age should occur, but the nature of the interaction should be similar for both word sets (RC vs. RI). Thus, there should be no three-way interaction between age, context (related vs. neutral), and word set (RC vs. RI). If, as argued by Simpson and Lorsbach (1983), conscious expectancies are more implicated at higher developmental levels, a three-way interaction should occur, with the older subjects showing more inhibition in the related-incongruous condition but as least as much facilitation in the related-congruous condition. To the extent that conscious expectancies dominate the performance of children relative to adults either in the absence of spreading-activation effects (as assumed by Briggs et al., 1984) or in conjunction with spreading-activation effects (as assumed in the two-process interactive-compensatory model), a three-way interaction between age, context (related vs. neutral), and word set (RC vs. RI) should occur. But it would be different from that predicted by Simpson and Lorsbach (1983): Children should display relatively greater facilitation in the related-congruous condition and should simultaneously display more inhibition in the related-incongruous condition.

Method

Subjects.—The subjects were 24 third-grade children (9 males and 15 females) and 24 fifth-grade children (15 males and 9 females) recruited from a predominantly middle-class elementary school and 24 undergraduate students (10 males and 14 females) recruited through an introductory psychology subject pool. The subjects were tested during March and April. At the time of testing, the mean age of the third graders was 9-6 (range = 9-1 to 9-11) and the mean age of the fifth graders was 11-6 (range = 10-11 to 11-11).

Stimuli and apparatus.—Two target nouns were selected for each of 32 incomplete sentences so that both were semantically related to words in the sentence context but one target was a congruous completion and the other was an incongruous completion (i.e., for the context "the Indian rode the" the word "horse" was a related-congruous completion and the word "arrow" was a related-incongruous completion). The mean number of letters in the RC targets was 4.9 (SD = 1.2) and the mean number of letters in the RI targets was 5.2 (SD = 1.4). According to the Kucera and Francis (1967)

count, the mean frequency of the RC targets was 88.8 and the mean frequency of the RI targets was 36.1. The neutral context condition was the incomplete sentence "they said it was the." Empirical tests of the appropriateness of this neutral condition for the particular sentence context paradigm used in this experiment are reported by Stanovich and West (1983a). Unrelated-incongruous context conditions were created by repairing the RC and RI targets with unrelated sentence contexts. Forty-eight sentence contexts with corresponding congruous target nouns were used as fillers to decrease the proportion of related-incongruous sentences so that subjects would not come to expect trials of this type. These filler sentences were chosen from the appendices of stimuli published by Bloom and Fischler (1980) and Stanovich and West (1981). Finally, 12 sentence contexts and corresponding targets were used to make up practice trials. All the incomplete sentence contexts used in the experiment ended in the word "the."

The stimuli were presented on a BMC CRT monitor with a refresh cycle of 16.7 msec under the control of an Apple II microcomputer. A Mountain Hardware Clock and a Lafayette Instruments voice key were interfaced with the computer to enable the collection of naming times. All letters were uppercase and were presented at a viewing distance of approximately 64 cm. Five-letter words subtended a horizontal visual angle of approximately 1.88° and the space between words was approximately 0.45°. When the target word was presented, it was in the position that it would have occupied had the complete sentence been presented. Target-word onset was controlled by a button pushed by the experimenter, which immediately caused the target to be displayed and simultaneously started the millisecond clock. A voice-activated relay stopped the clock when the subject responded verbally to the target.

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" (the context word that always immediately preceded the target word). The experimenter was instructed to develop a criterion so stringent that occasionally the button was pressed during the articulation of "the," thus aborting the trial. There were only a few experimenter-aborted trials, but those that did occur were distributed approximately equally across experimental conditions, indicating that the criterion was consistently applied (see Stanovich & West, 1983a, for a discussion of this and alternative procedures).

Procedure.—Subjects were individually tested in a session that lasted approximately 25 min. They were told to look at the screen and read aloud the sentence contexts that appeared. In addition, subjects were instructed to read the target word aloud as rapidly as possible when it appeared. The subjects were told that only the response to the target word was timed, so they were free to read the contexts at a comfortable pace.

Each subject completed 96 experimental trials that were preceded by 12 practice trials. The practice trials consisted of a random ordering of eight related congruous and four unrelated-incongruous trials. The 96 experimental trials consisted of a random ordering of 24 trials employing the RC targets (eight related-congruous, eight neutral, and eight unrelated-incongruous), 24 trials employing the RI targets (eight related-incongruous, eight neutral, and eight unrelated-incongruous), and 48 filler trials (all congruous). The full design of the experiment was thus a 3 (age) × 2 (word set: RC, RI) × 3 (context: related, neutral, unrelated-incongruous) factorial. Note that when an RC word appeared with a related context, the related-congruous condition is created, and when an RI word appears with a related context the related-incongruous condition is created. The design of the study is indicated with sample sentences in Table 1. The assignment of targets from the RC and RI populations was counterbalanced across subjects so that each target was presented equally often under each of the three corresponding context conditions. No subject saw the same target word or sentence context more than once in the course of the experiment. All subjects received the same filler trials.

In order to insure that the subject groups were processing the contexts to a similar depth, a short recognition memory test was administered immediately after the last naming trial. The subjects were told to answer yes if the sentence that the experimenter read to them was exactly like one that they had just seen or no if they had not just seen the sentence. Six of the filler sentences used in the experiment and six foils were randomly intermixed and served as stimuli for all subjects. The mean number of correct identifications was 10.6, 11.3, and 10.5 for the third-grade children, fifth-grade children, and adults, respectively, with performance not differing significantly across subject group, $F(2,69) = 2.86$.

Results

Trials on which the subject incorrectly named the target word, trials on which the

TABLE 1

EXAMPLES OF THE STIMULI

CONTEXT CONDITION	WORD SET	
	RC	RI
Related	The farmer planted the corn.	The farmer planted the tractor.
Neutral	They said it was the corn.	They said it was the tractor.
Unrelated-incongruous ...	The musician played the corn.	The musician played the tractor.

response time was greater than 2,000 msec, and trials on which the response time was more than 2.5 SDs above the subject's mean for that condition were scored as errors and dropped from the reaction-time analysis. The mean reaction time in each condition for each subject was used in the analysis of variance. The mean reaction time in each condition is displayed in Table 2, along with the magnitude of the facilitation effects (neutral reaction time minus related-congruous reaction time and neutral reaction time minus related-incongruous reaction time) and the inhibition effects (unrelated-incongruous reaction time minus neutral reaction time). In Table 2, the first three conditions (labeled related-congruous, neutral, and unrelated-incongruous) refer to the data from the RC word set. The last three conditions (labeled related-incongruous, neutral, and unrelated-incongruous) refer to the data from the RI word set.

An overall analysis of variance on the reaction times indicated that in addition to the expected main effects of age, $F(2,69) = 45.7$, $p < .001$, and context, $F(2,138) = 31.5$, $p < .001$, the main effect of word set was also significant, $F(1,69) = 83.3$, $p < .001$. Subjects named the RC words more rapidly, perhaps due to the fact that the targets in the RC set had higher word frequencies according to the Kucera and Francis count (88.8 vs. 36.1) and that the mean number of letters in the RI set was slightly higher (0.3). There was an interaction between word set and age, $F(2,69) = 6.49$, $p < .01$, the response time difference between the two word sets being larger for the younger children.

Both critical two-way interactions were significant. The word set × context interaction was significant, $F(2,138) = 8.85$, $p < .001$, indicating that the context conditions had differential effects on the two word sets. The related-congruous condition displayed facilitation but the related-incongruous condition did not. As in many previous experiments, there was a significant interaction between age and context, $F(4,138) = 3.14$, $p < .025$, larger context effects being displayed by the younger children. This is most clearly seen in the data from the RC word set, where both facilitation and inhibition decrease with age and where the overall context effect (the difference between the times in the related-congruous and unrelated-incongruous conditions) decreases from 122 msec in the third grade to 74 msec in the fifth grade to 40 msec for the adult subjects.

There was no three-way interaction between age, context, and word set, $F(4,138) = 0.48$. However, since the critical part of the interaction concerned only the related and neutral context conditions (both the RC and RI words were expected to display inhibition when unrelated and incongruous, and age was not expected to modify this portion of the two-way interaction), a 3 (age) × 2 (word set) × 2 (context: related, neutral) analysis of variance was run eliminating the unrelated-incongruous conditions. The three-way interaction was still not significant in this analysis, $F(2,69) = 0.66$.

Planned comparisons on the separate facilitation and inhibition effects indicated that in the related-congruous condition the facilitation effect was significant for the third-grade ($p < .001$) and fifth-grade children ($p < .025$), and was marginally so for the adults ($.05 < p < .10$). In the unrelated-incongruous condition of the RC words, the only inhibition effect to attain significance was the 38-msec effect displayed by the third-grade subjects ($p < .05$). For all three age groups, naming times in the related-incongruous condition did not differ from the naming times in the neutral condition. Both the third-grade and the fifth-grade children displayed significant inhibition effects when the RI words were unrelated and incongruous ($p < .01$ in both cases), but the adults did not.

The pattern of effects for the RC words was similar to that observed in previous experiments (see Stanovich, West, & Feeman, 1981). Although the magnitude of the overall

TABLE 2

MEAN REACTION TIMES (msec)

	CONTEXT CONDITION									
	RC Targets					RI Targets				
SUBJECT GROUP	Related Congruous	Neutral	Unrelated Incongruous	Facilitation	Inhibition	Related Incongruous	Neutral	Unrelated Incongrous	Facilitation	Inhibition
Third graders .	556 (2.1)	640 (6.3)	678 (5.7)	84	38	690 (7.8)	694 (10.9)	754 (11.5)	4	60
Fifth graders .	480 (.5)	528 (3.7)	554 (1.0)	48	26	570 (3.7)	564 (4.2)	616 (9.9)	−6	52
Adults	442 (.0)	474 (1.6)	482 (2.1)	32	8	493 (1.0)	486 (4.7)	509 (2.1)	−7	23

NOTE.—Mean percentage of errors in parentheses. RC = related-congruous word set; RI = related-incongruous word set.

context effect decreases with age, the pattern also changes, tending toward facilitation without inhibition in the fluent adult reader. The RI word set also displayed the tendency for inhibition in the unrelated-incongruous condition to disappear with age. The critical comparison between the neutral and the related-incongruous condition indicated that for all age groups the naming times in these two conditions were very similar. Finally, it should be noted that, with one possible exception (see below), none of the major patterns in the data is obscured by speed-accuracy trade-offs, nor are the conclusions changed if the context effects are expressed as percentages of the times in the neutral condition, rather than as absolute time differences.

Discussion

One striking finding in the data is that for both groups of children the naming times in the related-incongruous condition were very similar to those in the neutral condition (the two did not differ significantly). Taken in conjunction with the inhibition these groups displayed in the unrelated-incongruous conditions, the equality of the times appears to indicate that, consistent with the two-process interactive-compensatory model, both expectancy processes were operative in the performance of the children. If, as argued by Briggs et al. (1984), only the attentional mechanism had been operative, the related-incongruous condition should have displayed inhibition relative to the neutral condition. Alternatively, if only spreading activation had operated for the younger children (the conjecture of Simpson & Lorsbach, 1983), facilitation would have obtained for the related-incongruous condition.

Although the results are consistent with the two-process interactive-compensatory model on the general point that both expectancy mechanisms are operative in the performance of children, other aspects of the results are problematic for the model. However, the two alternative conceptualizations considered in the introduction fare no better. For example, the failure to observe a significant three-way interaction is inconsistent with all three conceptualizations. It fails to confirm the predictions derived from the conjectures of Briggs et al. (1984) that conscious expectancies dominate the performance of children relative to adults and that no spreading activation mechanism is operative. The nonsignificant three-way interaction is, by itself, consistent with the assumption that only the spreading-activation mechanism is operative, but the significant two-way interaction between context and word set is inconsistent with this idea. The significant two-way interaction is consistent with the two-process interactive-compensatory model, but the lack of a significant three-way interaction is not.

The reason for the lack of fit between the results and the predictions of the interactive-compensatory model appears to lie in the adult data. It might have been expected that adults would show some facilitation in the related-incongruous condition because previous results have indicated that they are little disrupted by incongruity (e.g., Stanovich & West, 1983a; West & Stanovich, 1978). The failure to observe facilitation in the related-incongruous condition of the adult data inhibits the detection of the three-way interaction that would have supported the two-process interactive-compensatory model. It is important to note that the observation of this pattern may have been obscured by a difference in error rates between conditions. Specifically, adult performance in the related-incongruous condition did display a 3.7% facilitation effect in the error rates. Such an error rate difference could mask a substantial facilitation effect in the reaction times (Pachella, 1974). This (perhaps disguised) facilitation in the times would bring the adult results themselves more in line with the model and would simultaneously increase the three-way interaction contrast.

There are perhaps other reasons why the adults did not show more facilitation in this condition, although undoubtedly the most important factor is the error rate difference. Recent results have emphasized the fact that traditional word recognition tasks are subject to postlexical effects that may be incorrectly interpreted as arising from processes involved in lexical access (Seidenberg et al., 1984; West & Stanovich, 1982). Although this is more of a problem when a lexical-decision task rather than a naming task is employed (West & Stanovich, 1982), the latter may also be subject to postlexical effects, which would cause inhibition in an incongruous condition. The results, however, provide inconsistent evidence regarding this hypothesis. The adults displayed a small (although nonsignificant) amount of inhibition in the unrelated-incongruous condition of the RI words but no hint of inhibition in the unrelated-incongruous RC condition.

Interestingly, the equality of times in the neutral and related-incongruous conditions also obtained in the naming times of both groups of children. In short, even the

youngest children named a word that both violated their expectancies and made the sentence incongruous no slower than they named a word in a neutral context. It might have been expected that the children would display slower naming times in the related-incongruous condition because of the relatively larger inhibitory effects that they display due to expectancy violation and incongruity (that such inhibitory effects were operating for the children is indicated by the significant slowing of the naming times in the unrelated-incongruous conditions). If the inhibition effects in the unrelated-incongruous conditions indicate more use of conscious expectancies by the younger children, why are there not age differences in the relationship between the related-incongruous and neutral conditions? The answer would appear to be that whereas the greater use of conscious expectancies by the younger children does indeed make their performance in the related-incongruous condition more prone to inhibition, this is probably balanced off by the fact that these subjects experience greater facilitation due to automatic spreading-activation effects. The results are consistent with the existence of a spreading-activation mechanism that can produce facilitation to balance the inhibitory effects of expectancy violation and incongruity. The inclusion of 48 congruous filler trials insured that only eight of the total of 108 trials (96 experimental and 12 practice) were related-incongruous, so it is likely that the facilitation resulting from semantic relationships was due to automatic spreading activation and not to any type of conscious expectancy for a related-incongruous word.

On theoretical grounds it is to be expected that facilitation due to spreading activation will be greater when word recognition speed is slower (see Perfetti & Roth, 1981; Stanovich & West, 1983a). Theoretical arguments aside, the results of studies by Simpson and Lorsbach (1983) have indicated that younger subjects experience greater facilitation due to automatic spreading activation. In short, relative to adult performance, children's naming in the related-incongruous condition should be more inhibited by the operation of the conscious expectancy mechanism and more facilitated by the spreading-activation mechanism. The particular paradigm and stimuli employed in this experiment led to a pattern of results indicating that the relative contribution of the two mechanisms did not change with age. We of course are not arguing that the exact equality of times in the related-incongruous and neutral conditions is anything more than a fortuitous outcome of our choice of materials. It is not the absolute difference between these conditions that is the critical finding, but the additivity with age. The conclusions drawn do not necessitate a defense of the claim that the semantic relationships between the RI words and their related contexts are representative of natural text.

It is perhaps most parsimonious to explain the current results by invoking the time-locked version of the two-process model (Neely, 1977; Stanovich & West, 1981). As word recognition is slowed (either by experimental manipulations or developmental immaturity) both the spreading-activation and the expectancy-based contextual mechanisms become more implicated in performance; the former for the reasons discussed by Seymour (1976), and the latter because as a slow-acting mechanism it will have a higher probability of affecting response time if recognition is slow. Based on a series of studies employing only adult subjects, Stanovich and West (1983a) abandoned the time-locked version of the two-process model and argued for a variant of the model where the conscious expectancy process operated more like an optional subject strategy than as a process strictly tied to recognition time. It is interesting to note, however, that the older time-locked version of the model not only is a parsimonious explanation of the present results but actually provides a better explanation of the developmental results reported by Stanovich, West, and Feeman (1981). Thus it appears that currently the time-locked version gives a slightly better account of the developmental results in the literature, whereas the strategy version seems to give a somewhat better account of the adult data reported by Stanovich and West (1983a).

Recent developmental studies of sentence context effects and work on the two-process interactive-compensatory model of individual differences in reading can be usefully integrated with current developments in cognitive science, if placed within the framework outlined by Foder (1983) in his influential book, *Modularity of Mind*. According to him (see also Forster, 1979), it is important for cognitive theorists to distinguish modular from nonmodular systems. He conceptualizes modular input systems as those that are fast, automatic (obligatory and not capacity demanding), and informationally encapsulated. The latter is the most important aspect of modularity and means that a module operates autonomously: specifically, it is not

under the direction of higher-level cognitive structures and is not supplemented by real-world knowledge. Using this framework, one way to phrase the emerging consensus in the adult literature on context effects is that word recognition is modular, in roughly Fodor's sense (see Forster, 1979; Henderson, 1982; Seidenberg et al., 1984; Stanovich & West, 1983a).

This conclusion does not imply that context does not affect the word recognition of fluent adults. Such effects are observed but appear to be due to the operation of a spreading-activation mechanism. That is, contextual facilitation of word recognition in the fluent adult is due to interconnections within the lexicon itself rather than to hypotheses that are developed from background knowledge by higher-level cognitive structures. According to Fodor (1983), processes of spreading activation in the lexicon are internal to the language recognition module and thus do not violate the assumption of encapsulation as would the use of context and background knowledge to generate expectancies that guide lexical access.

Corresponding to the conclusion drawn from the adult studies, one way to summarize the outcomes of several recent developmental studies of context effects (e.g., Perfetti & Roth, 1981; Stanovich, West, & Feeman, 1981) is to say that the word recognition module becomes more encapsulated as reading fluency develops. This conclusion, however, does not necessarily imply that word recognition in young children is completely nonmodular. Indeed, the results of our experiment indicated that word recognition in third- and fifth-grade children does show some indications of modularity. The results indicate that the word recognition module in our younger subjects displays enough encapsulation and that their interlexical connections (which will facilitate performance via spreading activation when in a supportive environment of semantic relationships) are developed enough to overcome a considerable degree of potentially disrupting information from higher levels (e.g., expectancies based on world knowledge and message-level incongruities).

Convergent data have been produced by experiments utilizing a completely different paradigm that relates to the modularity issue. According to Fodor (1983, pp. 52–55), another important property of modular input systems is that their operation is obligatory—that the subject has very limited ability to suppress the operation of a module. Of course, the standard paradigm used to study this aspect of word recognition is the Stroop test—Stroop interference resulting from an inability to suppress the conflicting response elicited by words. Developmental studies employing variants of the Stroop task (e.g., Ehri & Wilce, 1979; Guttentag & Haith, 1978, 1979, 1980; Schadler & Thissen, 1981; Stanovich, Cunningham, & West, 1981) have consistently found that Stroop interference increases markedly during the first and second grades, but only marginally after the third grade. Thus, another aspect of modularity (obligatory processing) appears to have developed to a considerable extent by the third grade.

It is important to note that we are not making the paradoxical argument that the word recognition processes of children are simultaneously more modular and more nonmodular than those of adults. We have hypothesized that children's performance is more affected both by expectancies that make use of background knowledge and by spreading activation in the lexicon. The effects caused by the former are an indication of nonmodularity. However, the degree of facilitation due to spreading activation should not be interpreted as an *index* of modularity. Rather, lexical priming is an intramodular facilitative effect that is made possible by the encapsulation of the module; however, the magnitude of the priming is determined by factors other than the degree of encapsulation (see Fodor, 1983, pp. 78–82). Thus, the hypothesis of greater lexical priming in children does not contradict the conjecture that their word recognition input system is less modular.

The fact that word recognition is modular in adults and displays some modular properties even in children as young as third graders has implications for global theories of the reading process. A series of recent findings (e.g., Gough, 1983; Mitchell, 1982; Perfetti & Roth, 1981; Stanovich, 1980, 1982, 1984) has suggested that skilled and/or older readers are more sensitive to contextual variables when the task that is employed taps comprehension processes but are actually *less* likely to use context to facilitate word recognition. This finding is more easily accommodated by modular models of reading than by hypothesis-testing models that do not as strongly demarcate the word level of processing (e.g., Smith, 1971). Further indications of modularity in the subprocesses of reading may thus help to clarify developmental reading theory.

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