Lexical Processes in Skilled Reading

A prominent feature of reading is that it involves encounters with words. Accordingly, understanding how these encounters work in skilled reading is a starting point for understanding reading ability. In what follows, the lexical processes of skilled reading are discussed, always in the perspective of how they work in texts.

Lexical Processes and Text Processes

In many cases, reading a single word is a significant accomplishment. An 8-year-old child who, upon seeing *contestant* can unflinchingly produce /kun TEST ənt/ has performed an impressive reading achievement. Why such an achievement has been so scorned by some (cf., Goodman, 1970; Smith, 1973) is a puzzle. In fact, the ability to decode words consistently—not by chance—is the essential reading process.

However, reading single words, no matter how impressive because of the novelty of the words *(rogation; pusilanimous)* or the inexperience of the reader is not what we really think of as reading. In a way, it is nothing more than practice for real reading—something like hitting balls over the fence in batting practice. The skill is there, but will it function in the game? The "game" in reading is comprehending a text. Not merely pronouncing the words, but understanding the text, especially when reading silently. A text is any series of coherently arranged sentences. Some texts tell stories, some explain how to assemble a kite, and others pretend to explain complex phenomena such as reading.

Thus our discussion focuses on a person who is reading a text of some sort. We want to know what processes bring comprehension of the text in a reader skilled at this task.

In accounting for the ability to read a text, there are two general classes of processes to consider. *Lexical processes* identify a word, including its constituent letters, and activate its semantic properties. The semantic encoding that results is the link to the other class, *comprehension processes*, which themselves include a number of different processes, some of them not so different from lexical processes. The two systems, the lexical and the comprehension, work together. Indeed they are linked by *semantic encoding*, the "comprehension" of contextually appropriate word meanings.

LEXICAL PROCESSES IN SKILLED READING OF TEXT

There is a general impression that we read words in bunches, skipping over many words. We read selectively, by this account. This impression does not reflect reality. The fact is that when we read the eyes come to rest on *(fixate)* most of the words of the text. Not many words are skipped.

There have been many studies of eye fixations and they reveal some important facts, some counterintuitive, about what the eyes are doing. The two most important may be these: (1) In normal reading, most words are fixated. (2) During a fixation, only limited information can be obtained from the visual periphery. Beyond five or six character spaces to the right of the fixation, letters are not perceived. There is a third fact worth noting: (3) Little information concerning words or letters is obtained during the eye's movement from one fixation to another (a *saccade*). Fact number 1 seems to be to be determined by facts 2 and 3. If information is obtained only during fixations, and then only within a few character spaces right of the fixation, then successful reading depends on fixating many words, not just a few.

To illustrate some facts about eye fixations, Figure 2-1 shows the eye fixations of a college reader studied by Carpenter and Just (1981; also Just & Carpenter, 1980). These are not actually individual fixations, but rather "gaze durations" that sum over individual fixations within a word. The fixations are numbered in order in parentheses. The numbers above each word are the durations (in milliseconds) for each fixation. It should be noted that the procedure used by Carpenter and Just to measure fixations is not universally used in eye movement research and that the measurement issue is important for theories of reading based on eye fixations (Kliegl, Olson, & Davidson, 1982). However, the conclusion that most words are fixated does not seem to depend on this measurement issue.[1]

There is more of interest than the frequency of fixation. Carpenter and Just (1981) estimated that about 80% of the text's content words (nouns, adjectives, verbs, adverbs) were fixated. However, the duration of a fixation is variable. Long words are fixated for a longer time than short words,

(4) (11)
286 466

(1) (2) (3) (5) (6) (7) (8) (9)
166 200 167 299 217 268 317 399

Radioiostopes have long been valuable tools in scientific and medical

(5)
183

(10) (1) (2) (3) (4) (6) (8) (7) (9)
463 317 250 367 416 333 183 450 650

research. Now, however, four non-radioactive isotopes are being produced.

(4) (8)
366 183

(1) (2) (3) (5) (6) (7) (9) (10) (11)
250 200 367 400 216 233 317 283 100

They are called "icons"—four isotopes of carbon, oxygen, nitrogen and

(12) (13)
683 150

sulfur.

Figure 2-1. Eye-fixation pattern of a college student reading a technical passage. The numbers 1,2,3 . . . indicate the sequence of fixations. Thus, number 4 is a regressive fixation, i.e., the result of the reader's gaze going back to the first word. The numbers below each fixation number represent the duration of the fixation. For example, fixation number 7 was on *tools* for 268 msec. The subject read with the expectation of a true-false text. Adapted from Carpenter and Just (1981).

and infrequent words are fixated longer than frequent words. Also, the last word of a sentence receives a longer fixation than other words. In Figure 2-1, *research* and *produced*, each the final word of its sentence was fixated about half a second, much longer than the average fixation. Carpenter and Just (1981) refer to this as "sentence wrap up" time. The wrap-up time appears to capture extra processing in which the reader is assembling sentence parts or adding interpretations to parts of the sentence that were incompletely or incorrectly interpreted. In fact, the Carpenter and Just model assumes that each word is semantically encoded as much as possible when it is initially encountered. There is no "buffering" for later interpretation.

Visual and lexical access factors

The fact that linguistic variables such as word length and word frequency have an effect on fixation times is important for a theory of reading. It implicates specific properties of words that are part of the reader's memory representation for words. It also encourages the assumption that linguistically based lexical factors are critical in reading ability. On the other hand, it is important to realize that these lexical processes are also visual processes. For example, the fact that the eye spends more time (makes more discrete fixations) on a long word than a short word is partly due to the requirements of visual sampling. The longer a word is in letters, the more sampling may be required. Kliegl et al. (1982) found that the number of fixations (hence the "gaze duration") was at least as related to the number of letters in a word as to the number of syllables. They point out that the number of fixations a word receives is partly a function of whether an initial fixation was "inconveniently" placed near the beginning or end of the word. After an "inconveniently" placed fixation an additional fixation is more likely to occur. The study of eye fixations during reading is providing a bit of information about the cognitive, linguistic, and perceptual demands of the reading task. All things considered, it seems clear that the number of discrete fixations on a word, and hence the total duration of fixations, reflects linguistic and cognitive demands of lexical access. That is, some of the actual fixation time is going to cognitive processing (Rayner & McConkie, 1976; Rayner, 1977). On the other hand, the essentially visual demands of the reading task and their effect on directing the eye to its next fixation should not be underestimated.

Lexical Processes in Rapid Reading

The purpose of the reader has an effect on these eye fixations. The fixations of Figure 2-1 are for a reader who expected a true-false test following reading. When readers are "skimming" the text without such an expectation, they show fewer and shorter fixations (Just, Carpenter, & Masson, 1982). However, they show a similar sensitivity to word-level variables such as length and frequency.

In fact, eye movement studies of speeded reading show little support for the widespread belief that the skilled reader can process texts at very high rates while maintaining acceptable levels of comprehension. Just et al. (1982) report eye movement studies of readers who have been trained in a speed-reading course. They had had about 50 hours of practice at rapid reading. These trained speed readers were compared both with normal readers and with readers instructed to read rapidly using their own techniques (skimmers). Both the skimmers and the speed readers read at 600–700 words per minute, compared with the normal readers' 250 words per minute. Note that the speed-reading and skimming rates are rather modest when compared with anecdotal and even scientific reports of very high rates of 5,000 words per minute and more. It appears that to achieve such very high rates, readers are in fact skipping enormous chunks of text as they follow odd patterns down and up the page. The fastest reader reported in the literature appears to be one described by Thomas (1962) who read at a rate of 10,000 words per minute. According to Thomas' report (described in Just et al., 1982) this reader made an average of only six fixations per page, going down the left side and up the right side and skipping the bottom one-third of the page altogether! Studies by McLaughlin (1969) and Taylor (1962) on somewhat slower speed readers tell a similar story. For example, McLaughlin's (1969) 3,500-word-per-minute reader averaged fourteen fixations per page.

Compared with such rates, the speed readers of the Just et al. (1982) studies were plodders. Still, they read at two to three times the normal rate. How did they read? There were two important departures from normal. The speed readers fixated fewer words, only about half the words fixated by normal readers, and their average fixation duration was about two-thirds as long as that of normal readers, about 230–240 milliseconds per fixation compared with about 330 milliseconds per fixation for normal readers.

There were some important similarities as well. Speed readers, like normal readers, fixated content words more frequently than function words—about 50% of the content words and about 25% of the function words. Normal readers had corresponding figures of 77% and 42%, respectively. (All the data are based on averages of two very different passages, one a *Reader's Digest* story and the other a *Scientific American* article. The differences in fixation data between the two passages were very small.)

Thus the speed readers made fewer and shorter fixations but distributed them similarly with respect to content and function words. Are their lexical and comprehension processes the same as those of normal readers, except faster? Apparently so, with some qualification. We can summarize the answer suggested by Just et al.'s data by referring to *lexical difficulty*, *selectivity*, *adaptability*, and *comprehension*.

Lexical Difficulty. As with normal readers, the fixation durations of speed readers were affected by the length and frequency of a word. But speed readers were less affected by these factors. They may in fact, as Just et al. suggest, have had a "processing deadline" for words so that the lexical factors of length and frequency would exert an effect, but a limited one.

Selectivity. Also like normal readers, speed readers were not selective about fixating "important" words in the text. This, too, counters common conceptions. The eye is not directed to words that will turn out to be more important in the text. It has to discover what is important, at least at the word level.

Adaptability. There was an increase in the fixation rate in sections of higher text difficulty for both normal and speed readers. However, speed readers did not change much in a difficult section. They increased their sampling rate on a difficult "page" (a screen, actually) but they did not modify durations nor abandon their strategy of uniform sampling. (This contrasts with the skimmers, who sometimes reverted to more normal patterns.)

Comprehension. Speed readers did well enough at answering questions on high-level information (they were better than skimmers at getting gist). However, they did less well at responding to questions requiring detail. Generally, they could not answer a question unless they had fixated within three character spaces of the answer during reading. Since they fixated less material in the text, their comprehension had to be less.

Summary. These eye movement studies should take much of the mystery out of speed reading. Comprehension that depends upon explicit text information cannot be maintained without fixating on many text words. Since reduction of fixation frequency is a major contributor to the faster rates, it follows that comprehension must undergo some reduction. On the other hand, it is equally clear that speed readers can learn to control fixation durations and frequency in such a way to sample enough information to obtain the gist of a text.

The Perceptual Span

As we have seen, a normal reader fixates up to 80% of the content words in a text. Furthermore, a reader who samples less of the text also comprehends less of it, as the studies of speed reading demonstrate. Why is so much text sampling necessary?

Part of the reason is that the span is relatively narrow. The perceptual span is the spatial extent from the central fixation where some information is obtained. The narrowness of the perceptual span comes as another of those surprises to our intuitions, in this case our feeling that we can read words at the far side of the page (the visual periphery) when we are focusing on the center of the page. In fact, this span appears to be only a few letters, perhaps as few as three (Rayner, 1975). This conclusion comes from studies using visual displays that could be changed in response to a subject's fixation on any given location. Thus the perceptual span can be inferred by altering the text, e.g., changing a letter four

character spaces away from the reader's fixation. If the alteration affects the reader by lengthening the duration of his present fixation, or if his next fixation indicates an effect of the change in some way, then his perceptual span is at least four character spaces long. Rayner (1975) found that a letter alteration that changed one word into another had little effect when it was beyond three spaces to the right. However, Rayner (1975) concluded that some information concerning word shape and specific letters was obtained out to twelve spaces from the fixation. Word-length information is also noticed at the distance (McConkie & Rayner, 1973).

As more evidence on perceptual spans has been obtained, only very minor variations in the span estimations appear. It seems certain that specific letter and word information is obtained from only a relatively narrow range beyond the fixation point. Furthermore, comparison of children with adults shows that this span does not change much with increasing reading skill (McConkie, 1982). However, this does not mean that useful information is completely restricted to the word being fixated. There is evidence that some information in the next word beyond the fixation can be used. Rayner, McConkie, and Zola (1980), using the text alteration procedure described above, found that the first three letters of a word presented parafoveally facilitated recognition of the word on the next fixation. While the word in the parafoveal region could not be identified, the reader was obtaining partial information from its initial letters that could be used to identify it when it was actually fixated. Furthermore, if the parafoveally presented word merely had letters visually similar to the word presented when the eyes moved to its location, there was also facilitation.

Thus, at the edge of the narrow foveal span where words can be identified, the reader is able to use partial information from the next word. In a sense, the reader may be processing more than one word on a fixation, although only the fixated word is "accessed." We can think of this as a preactivation of the letters contained in a word that reduces the amount of processing needed to identify it (Rayner, Well, Pollatsek, & Bertera, 1982). At the same time, it seems correct to say that reading, as lexical access, is confined to the word being fixated.

Summary

This section has demonstrated the importance of *lexical processes* in reading. The eye movement research is perhaps uniquely able to inform us about the significance of individual words for reading texts. (See Rayner [1978] for a thorough review of eye movement research.) Normally, most words are read and words beyond the one being read are not processed sufficiently for their meanings to be encoded. Thus lexical access, the process by which a word is recognized, is the central recurring part of reading.

LEXICAL ACCESS

In this section, we consider the processes used to access a word in permanent memory. The starting point for lexical access in the case of reading is a visually available input. Languages, of course, differ in how they graphically represent the units of language. Some are logographic, representing a word-concept with a single sign, and others are syllabic, assigning a meaningless spoken unit to each written symbol. However, most modern systems are, like English, alphabetic systems. In an alphabetic system, the graphic signs correspond, however variably, to single, abstract speech sound units, or phonemes. In discussing lexical access in this section, we are referring to access in an alphabetic orthography. However, because the level of description will not be highly detailed, much of it will apply to lexical access in other systems.

First, a definition of *lexical access.* Lexical access and word identification will be used interchangeably. Or rather "lexical access" will be taken to include word identification. These two processes ordinarily are distinguished, but this distinction is largely a matter of the experimental paradigms which give meaning to the terms. Thus word identification has meant the recognition of a letter string as a particular word, while lexical access has usually meant the recognition that some letter string is a real word rather than not a word. It seems clear that it is word *identification* that is relevant for reading. The reader has to identify, somehow, the words he encounters, not merely register their occurrence. The reason for using the phrase "lexical access" rather than "word identification" is that it is more theoretically neutral, once it is acknowledged that *mere* access (dictionary registration) is not enough for reading. So here is the working definition: *lexical access* is the process of finding a written word in long-term memory. It initiates the critical processes of *semantic encoding,* i.e., attaching a contextually relevant meaning for the word to the ongoing text processing. It initiates also the process of phonetic activation that may also play a critical role in reading.

The processes of lexical access and word identification have been very widely investigated and a number of contested issues have developed. These include especially the role of speech recoding prior to access and whether there are whole-word processes independent of individual letter recognition. For the most part, the discussion of lexical access will ignore these issues, developing instead a perspective that makes them less critical for the theory of reading ability. (For a review of some of the issues of word recognition, see Baron, 1978). The perspective needed is to consider lexical access the result of interactive processes.

Interactive Processes in Lexical Access

Interactive processing occurs when information at different levels is combined to jointly determine some outcome. In the present case, the outcome is access to a word's location in permanent memory. An interactive model of lexical access can be of the *strong* type (strongly interactive) or the *weak* type (weakly interactive). *Strong* and *weak,* of course, are not properties of the model's power but rather of its processing assumptions. A *strongly interactive* model assumes that processes are mutually influenced at all levels. Lower level processes affect and are affected by higher level processes. A weakly interactive model assumes only that multiple sources of information affect a final outcome. These sources either do not actually affect each other or, if they do, they do so only in one direction, from lower level to higher level. These two types of weakly interactive models are represented, respectively, by the logogen model of Morton (1969) and the cascade model of McClelland (1979). It is also the kind of model described by Perfetti and Roth (1981) specifically to account for individual differences in reading ability.

The weakly interactive models will in fact do a rather good job of accounting for the facts of word recognition. So too might some stage models, such as that of Massaro (1978), since despite their names, stage models often seem to contain weakly interactive assumptions. The point here is not to assess which models account for most basic facts of lexical access nor even to compare the models. However, it seems likely that the facts of recognition and access are best handled by some model that assumes that processes interact. The model described by Rumelhart and McClelland (1981; 1982; McClelland & Rumelhart, 1981) serves this requirement very well. It is a model of the strongly interactive type and perhaps a more powerful model than is actually needed to account just for lexical access.

Figure 2-2 shows the essential features of an interactive model, based on the proposals of Rumelhart and McClelland. Its key assumptions are (1) that each level of information—grapheme, phoneme, word—is separately represented in memory and (2) that information passes from one level to the other in *both* directions. (This is what makes it *strongly* interactive.)

An interactive model of this type contrasts with a strictly "bottom-up" model. In bottom-up processing, information goes only from the lower levels to the higher levels and not the reverse. Thus, detection of lines and angles leads to identification of letters, which in turn leads to iden-

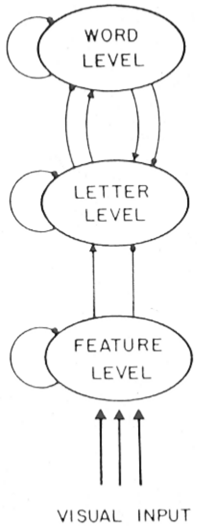


Figure 2-2. Levels of information of the interactive word-perception model of Rumelhart and McClelland (1981). Activation travels up to the word level from the letter level and down to the letter level from the word level. (Inhibition also occurs within a level—e.g., activation of *H* inhibits other letters—and between letters—e.g., activation of the word *rest* inhibits g and all other letters not linked to the word.) A phoneme level, omitted here for simplification, may be necessary for some lexical processes (See Chapter 4).

tification of words. Such processes are, of course, essential to reading because they allow the reader to identify what is actually on the page—to read instead of hallucinate.

The interactive model, of course, includes bottom-up processes. It differs, as can be seen in Figure 2-2, in allowing *activation* to travel from words to letters, as well as from letters to words. The links between levels are both excitatory and inhibitory. Thus as the lines and angles (visual features) are detected, activation travels up to letters that are consistent with these features. For example, very early in processing, the letters *H, E, F* would all be activated if the feature level passed on the information that there was a vertical line bisected by a rightward extending horizontal line (⊢). Activation of other letters would be low. As the feature level detected a second vertical line in a certain location, the activation of *H* would greatly increase and the *net* level for *E* and *F* would decrease.

The same activation principle results in the activation of candidate words, i.e., words consistent with all information available at any precise point in the process. In the example given, all words having *H, F,* or *E* would receive some activation that pushes them beyond their resting level. One can assume, as Rumelhart and McClelland do, that a word's resting activation level will be a function of its familiarity, or frequency of encounter. It will take more activation to access *martyr* than *martha* because its resting activation is lower for most readers. It is possible that what is responsible for the resting activation level is the *recency* of an encounter rather than its *frequency*. Of course, as more feature information gets detected, the activation of letter candidates and word candidates changes. One word finally wins out. The operative principle seems to be that many are activated, few are accessed.

This much is bottom-up processing. What makes the processing interactive is that activation travels down from words as well as up to words. Suppose, to follow the earlier example, *H, F,* and *E* are all highly activated, and at the word level, THE, OFF, and DEN are among those with some activation because of having a highly activated letter in the second position. Of course the letter level contains *T, H, E, O, F, P, N,* the letters found in the activated words. These letters are increased in activation even though none of them, except those consistent with ⊢, have been "seen." Because of this "top-down" (word to letter) activation, less feature information is now needed to "see" a *T* or *P* or any of these letters. And since this indirect activation of these letters is added to that being initiated at the feature level, the final perception of the word has been speeded up. It is faster than if each letter had to be completely identified before the words could be identified.

Context Effects

This interaction of letter level and word level is the part of an interactive system that has been worked out in detail (Rumelhart & McClelland, 1981; 1982; McClelland & Rumelhart, 1981). However, there is another level to consider that is at least as important for skilled reading. Suppose the word level can also receive activation from context. For this, we can imagine a text memory buffer, perhaps working memory, that, as it processes the text, activates the words in permanent memory as they are encountered. Activation spreads to semantically related words. This means that a given word's activation might well be above resting level prior to any information whatsoever from the word itself. In fact, at least one other word-recognition model makes this sort of assumption (Morton, 1969) and a mechanism of spreading semantic activation is a central processing assumption for which there is much evidence (Collins & Loftus, 1975). This kind of semantic influence was also a part of an earlier interactive model of Rumelhart (1977), and its application to the Rumelhart and McClelland model is consistent with the assumptions of the theory.

A semantic influence of this sort means that identification of words will be facilitated in context. Such context effects are well documented (e.g., Morton, 1964; Perfetti, Goldman, & Hogaboam, 1979; Schuberth & Eimas, 1977; Tulving & Gold, 1963; West & Stanovich, 1978). The application of context can be only weakly interactive. It simply lowers the threshold for perceiving a word. In the strongly interactive model it would operate to affect activation levels of letters that are part of activated word candidates as well as the words themselves.

In short, whether by weakly or strongly interactive assumptions, this top-down semantic effect makes a difference for lexical access in reading. For example, the word window, which appears here as a blur to represent a stage of feature processing that is incomplete, is hard to recognize. But if it occurs in sentence (1) it is a bit easier to recognize:

(1) *There were several repair jobs to be done.*
The first was to fix the window.

However, even this context is less helpful than (2):

(2) *The room was warm and stuffy, so they opened the*

As the text increasingly constrains the choice of words—(2) is more constraining than (1)—the top-down activation is spread less thin. In (1) semantic activation is spread among many words—*window, chair, bicycle, hot water heater*, etc.—that refer to repairable objects. In (2) semantic activation is more concentrated, and *window* receives most of the activation; *door* perhaps receives some also.

Thus, by this account, the access of a word in memory is the result of semantic processes as well as processes that identify letters strictly on the basis of feature information. Semantic information may in fact compensate for impoverished feature information, as the *window* example above demonstrates. For example, Perfetti and Roth (1981) report experiments based on just this principle, in which children read words that were visually degraded by randomly deleting features. (Since these were computer-printed words, the features were essentially dots.) The degree of stimulus degradation could be varied by the percentage of dots that were deleted. Figure 2-3 shows an example of three levels of degrading. At the highest level of degrading, words were very slowly identified and often not identified correctly at all. When the word appeared in context, it became more identifiable, both in accuracy and speed of identification. The contexts were arranged to vary the constraint applied to the final word, which was always the word to be identified. Figure 2-4 shows the result that speed of identification rose with increases in the degree of constraint imposed by the context.

The interaction of contextual constraint and degrading suggests that high semantic activation can compensate for insufficient feature and letter ac-

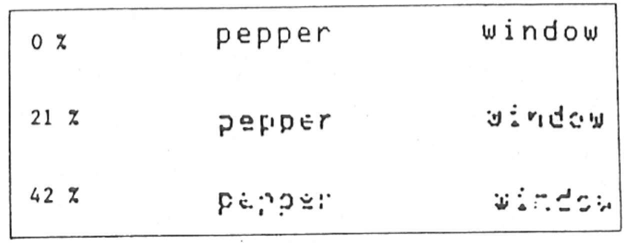
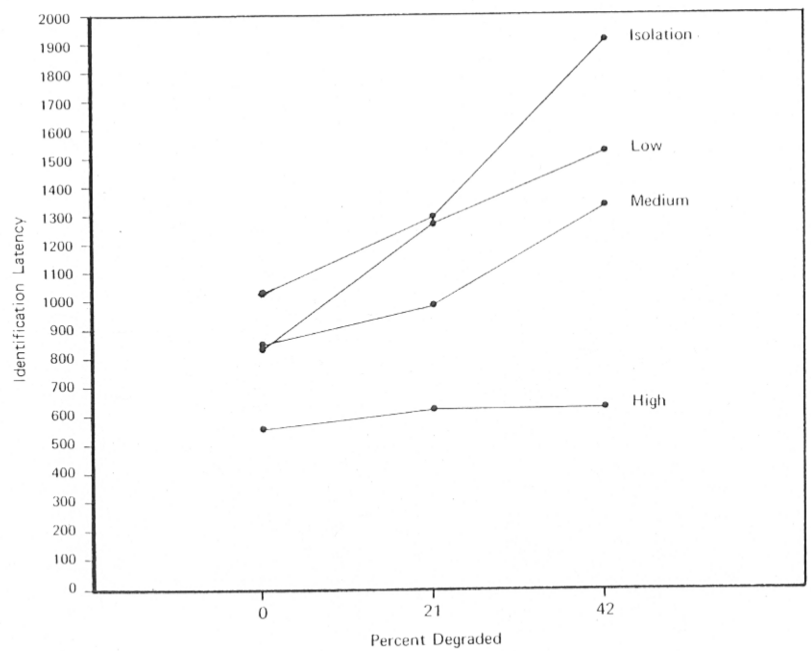


Figure 2-3. Three levels of stimulus degrading used in word-identification experiments of Perfetti and Roth (1981). Identification times increased with degrading.

tivation. It makes another important suggestion as well. The fact that there was a statistical interaction of constraint and degrading can be taken to demonstrate that the contribution of semantic activation *increases* as lower level feature and letter activation *decreases*.[2] Theoretically, this is important because it is consistent with an assumption that the interactive system is asymmetrical. The asymmetry is that the lower level processes in skilled reading are *autonomous*. That is, they can make a contribution to word identification that is independent of context. To put it another way, the asymmetry in the interactive system means that low level in-

Figure 2-4. Identification of words related to degree of contextual constraint—high, medium, low, and words in isolation—and to degree of degradation.



formation is *sufficient* for identification whereas semantic information is not sufficient. Free associating is not the same as reading.

To summarize, an interactive model of lexical access will account for semantic activation effects as well as the basic facts of isolated word recognition. The model of Rumelhart and McClelland has been worked out in detail only for isolated word recognition. Semantic activation, in which ongoing text processes affect lexical access, can be incorporated into such a model, although its processing features have not been worked out.

Context Mechanisms for Semantic Activation

If semantic activation actually assists lexical access, there are several questions to ask. The central question is how does semantic activation work? One possibility is that the reader actively anticipates possible word candidates during reading (a pernicious version of the psycholinguistic guessing game). This is possible in principle, but we are talking here about *skilled* reading. Skilled reading is, by definition, a very fluent process. If a reader fixates three or four words per second, around the normal rate, where is there time to guess? Moreover, if he is skilled at reading, why bother? Reading is much easier than guessing. The case may be different in, for example, reading in a foreign language that is incompletely mastered. There is plenty of time to guess in such cases and perhaps enough payoff for doing so. But for a skilled reader and a familiar language, there must be a mechanism other than conscious anticipation.

The alternative, of course, is automatic (unconscious) activation. The feature-detection and letter-activation processes that bring about lexical access from the bottom are of this sort. Automatic semantic activation could rise very rapidly in time to assist word identification. There are a number of models that describe such automatic activation during reading (Becker, 1976; Fischler & Bloom, 1979; Stanovich, 1981). These models are different in how they handle facilitative and inhibitory effects of context. Inhibitory effects refer to increases in processing time associated with a misleading context.

An example of an activation model that can account for context effects is the model of Posner and Snyder (1975), as applied to reading by Stanovich (1981). This model assumes two separate processing mechanisms that govern expectancy, one that is automatic, or attention-free, and one that is conscious, or attention-controlling. The two processes are assumed to have different time courses. The conscious attention process works more slowly because it has to direct a limited-capacity process to a new input. Or, in other words, it shifts the location of attention from one point to another within semantic memory (in the case of reading).

By contrast, the attention-free mechanism operates quickly and at no cost to the limited-capacity processor. The two-process theory accounts for inhibition effects by the conscious attention process and for facilitation effects by the automatic attention process. The implication that facilitative effects are more rapid than inhibitory effects gets some support from experiments by Stanovich (1981). Other research has been interpreted to support alternative models (Becker, 1980; Fischler & Bloom, 1979). Under what conditions inhibitory effects occur seems to be the dividing issue. However, it seems clear, at minimum, that there is some rapidly occurring activation function that can facilitate lexical access under the right conditions.

As an alternative to these concerns over inhibition, there is an assumption perhaps more suitable for reading, namely, that inhibition processes do not occur. (That is why the earlier discussion of context ignored inhibition.) Inhibition is a process that results from a really unexpected occurrence. If a woman is reading a book as she begins to cross the street, and a bus suddenly interrupts her reading, that is inhibition. A new signal must be processed, and attention is clearly shifted to a new location. But within the reading process itself, inhibition should be a rare event. Perhaps encountering a four-letter epithet in the middle of a *New York Times* column would be such a case. But for run-of-the-mill reading, this kind of attention-shifting inhibition should be rare.

By this alternative, conscious attention mechanisms are of very reduced significance.[3] What is significant is unconscious spreading semantic activation. Activation would spread among concepts in memory as the text meanings are encoded. The activation can be thought of as spreading along the nodes of a semantic memory network (Collins & Loftus, 1975). On such a system, we would want activation to occur for words other than simple associations. For example consider sentence (3):

(3) It was really *hot*, so we *opened* the *window*.

It would be nice if *window* received some prior semantic activation (or "priming") from the sentence. *Opened* could initiate activation to things that are marked in a semantic network as [can be opened]. Perhaps *door*, *window*, *shutter*, *bottle*, *package*, and a number of other words get some activation from *open*. But if *window* is to get more than its share of activation, and the evidence suggests that is does, it must get an additional jolt from somewhere else. A likely source is *hot*. However, *hot* would not be directly linked to *window* in a semantic network. The spread of activation occurs along all links as the nodes are encountered, and *window* will receive some activation from intermediate links between its node and *hot*. Another source of activation lies in the previous sentence. The problem with assuming such distant context effects based on spreading activation is that the time course is probably wrong. Activation rises and falls rapidly. Whether there would be much effect after several words have intervened is doubtful.

There are two more contextual mechanisms that will help out. One is based on syntax. It is possible that at least some activation results from the initial encoding of a syntactic pattern. Parts of the pattern not yet encountered are activated. For example *the* would trigger a noun-phrase pattern. Any noun in the system gets a piece of the activation and so would any prenominal adjective. When an adjective is also encountered, e.g., *the old*, there continues to be activation for all nouns, supplemented by semantic activation from *old*. Words that cannot be nouns would receive inhibition (in the interactive model sense of inhibitory links, not an active inhibition). There is in fact some evidence for an automatic syntactic priming mechanism for definite articles (Irwin, Bock, & Stanovich, 1982). There are also strong effects of syntactic expectation on how a sentence is interpreted (Frazier & Rayner, 1982).

The third contextual mechanism is based on the assumption that the reader builds a mental model of the text during reading. That is, he attempts to comprehend the text by constructing a representation of the underlying text meaning. This mental model can be thought of as an abstract conceptual schema but with specific verbal information. For example, halfway through reading Little Red Riding Hood (for the first time) the reader's model includes information about a visit to a sick grandmother interrupted by an encounter with a wolf. This central thread has connections to many lower level information structures—for example, the mother-daughter episode at the beginning of the story—that recede as the text model gets updated. The context mechanism is that activation is available to elements in the text model. Activation rises and falls for particular elements as the story progresses. Thus the part of the model to which the most recent piece of information is attached is more active than other parts of the model. However, all elements of the model are active relative to the base level. Thus even though grandmother has not been mentioned for a few sentences, grandmother-related concepts are at least weakly activated. Lexical access for words linked to their concepts may be slightly facilitated. Alternatively, and more likely, access may be relatively unaffected but the semantic processes that assign contextually appropriate meanings to words may be significantly affected.

The force of this proposal is that context effects may occur both because of what has just been read and because of what is in the mind of the reader. The latter, in the right circumstances, will include a representation of the text.

What do context mechanisms affect?

Do context mechanisms work on lexical access or do they work on some process following lexical access? In conventional descriptions of the reading process, this seems to be an important question. Mitchell and Green (1978), for example, interpret the kind of evidence discussed in this section as reflecting postaccess processes (involved in saying the word, for example). They suggest that in normal reading, context plays little role in lexical access itself. To assess this issue, we can return to what the eye tells us about reading. Zola (1979; reported in McConkie & Zola, 1981) studied the eye movements of subjects reading paragraphs with highly predictable words. Some of the words were 85% predictable. What would the eye do, for example, on the word *popcorn* when it was preceded by *buttered* compared with when it was preceded by *adequate*? What it did *not* do is skip the word. The target word, e.g., *popcorn*, was fixated 96% regardless of how predictable it was. Contextual constraint did have some effect, however. When the word was highly predictable, the fixation was about 14 msec shorter. These context effects, however, do increase when the target word is short enough so that nonfixations are possible. Ehrlich and Rayner (1981) reported that target words are fixated less often when they are highly predictable. They also found a larger effect of predictability on fixation durations (over 30 msec). Of course it is possible that the savings of 14–30 milliseconds occur during some postaccess process. In particular, the contextually appropriate semantic encoding of the predictable word is made easier. But if this encoding is what is meant by a "postaccess" process, then it is certainly an important early occurring part of reading. If we accept a basic distinction between preaccess and postaccess then it may turn out that most semantic context effects are postaccess in ordinary reading.

As a matter of fact, the preaccess vs. postaccess distinction becomes less meaningful in a fully interactive model. Since activation is passing between multiple information sources *there is no clearly defined stage of lexical access*. There is simply some time after which activation is high enough to say that a word has been "identified." Meanwhile semantic activation, which has been going on during this time, may continue. So, roughly speaking, the semantic encoding of a word is part of its lexical access.

SUMMARY

This chapter has described some of the lexical processing in skilled reading. Skilled reading, defined as a combination of speed and comprehension, was examined by considering some basic studies of eye movements. Research indicates that most words are fixated during skilled reading, with content words fixated more than function words. Speed readers read faster by making fewer and shorter fixations. However, their comprehension of details suffers because only words that are fixated provide information about meaning. The perceptual span for specific word identification is only a few characters, although some shape-length information has a large span. These studies demonstrate the central importance of lexical access in reading.

Lexical access, defined as access to a word's location in memory, was described as an interactive process. Although weakly interactive models of access would serve well, the strongly interactive model of Rumelhart and McClelland was taken as a powerful and plausible description of lexical access during reading. Lower level and higher level information travel through a network along activation links in both bottom-up and top-down directions. Activation also is initiated by semantic processes. Thus access to a word in context, the usual case in reading, is facilitated compared with access in isolation. Experiments using trade-offs between context and word-level information demonstrate this important effect. Three possible activation processes are proposed: semantic activation from words in the sentence being read, activation from incomplete syntactic frames based on grammatical categories represented in the memory network, and a model of the text's meaning constructed by the reader. Evidence for these mechanisms is needed. The question of whether the context effects occur during "preaccess" or "postaccess" processes is less important in an interactive model.

NOTES

1. The issue is what counts as a fixation. Carpenter and Just (1981; Just & Carpenter, 1980) have used an aggregate measure (gaze duration) that sums all fixations beyond some minimum. It is more typical in eye movement research not to summate over fixations. According to Kliegl, Olson, and Davidson (1982), the procedure of Just and Carpenter (1980) produces misreadings of fixation time that cause problems for theoretical modeling. However, this controversy should not affect the conclusion that most words are fixated.
2. Interactions between contextual constraint and word-level factors are also found for word factors other than degrading. For example, Perfetti, Goldman, and Hogaboam (1979) found a word length × context interaction. Longer words were facilitated more by context than were shorter words. Stanovich (1981) found a similar result with the same measure, time to identify a word (word naming). Stanovich and West (1981) also report an interaction of context with degrading. However, this interaction involves an *inhibitory* effect (incongruent context) more than a facilitative effect. A reliable interaction for facilitation may be more detectable with multiple levels of degrading and context, as were used in the Perfetti and Roth (1981) experiments but not the West and Stanovich (1978) and Stanovich (1981) experiments.
3. It also follows that the best way to assess context effects in ways that apply to normal reading is to compare different degrees of facilitative context with weak or no context. Experiments which have inhibitory instances mixed in with facilitative ones may not assess facilitation appropriately for reading.

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