Symposium on Reading Research

LESS SKILLED READERS HAVE LESS EFFICIENT SUPPRESSION MECHANISMS

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Abstract—*One approach to understanding the component processes and mechanisms underlying adult reading skill is to compare the performance of more skilled and less skilled readers on laboratory experiments. The results of some recent experiments employing this approach demonstrate that less skilled adult readers suppress less efficiently the inappropriate meanings of ambiguous words (e.g., the playing card vs. garden tool meanings of* spade*), the incorrect forms of homophones (e.g.,* patients *vs.* patience*), the typical-but-absent members of scenes (e.g., a tractor in a farm scene), and words superimposed on pictures. Less skilled readers are not less efficient in activating contextually appropriate information; in fact, they activate contextually appropriate information more strongly than more skilled readers do. Therefore, one conclusion that can be drawn from these experiments is that less skilled adult readers suffer from less efficient suppression mechanisms.*

For most adults, reading feels like an automatic, well-learned habit, but years of cognitive psychological research document that simply reading a five-letter word requires the orchestration of many component mental processes and mechanisms. One approach to identifying these component processes and mechanisms involves comparing adult readers, all of whom read within the "normal" range of adult reading skill, but some of whom are more skilled and some of whom are less skilled. Comparing these more and less skilled adult readers' performance on various laboratory tasks can help identify the mechanisms underlying their difference in skill.

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This is the approach that I have taken in my recent research (Gernsbacher, 1990). The starting point for my laboratory investigations was the finding that (within a normal range of adult reading performance) skill at reading comprehension is highly correlated with skill at listening comprehension (Palmer, MacLeod, Hunt, & Davidson, 1985). Furthermore, I discovered that skill at reading comprehension was highly correlated with skill at comprehending nonverbal picture stories (Gernsbacher, Varner, & Faust, 1990).

Therefore, I suggested that some of the mechanisms underlying adult reading skill could be general cognitive mechanisms—mechanisms that are not specific to the comprehension of language, but are also involved in the comprehension of nonlinguistic media (Gernsbacher, 1990).[1] One mechanism is suppression. I envision suppression as an active dampening of the activation of mental representations. Why is a suppression mechanism needed? Often, irrelevant or inappropriate information is activated automatically, retrieved unconsciously, or perceived naturally. However, for successful comprehension, irrelevant or inappropriate information must not be allowed to affect ongoing processes. If less skilled readers are less efficient at suppressing the automatic activation of irrelevant or inappropriate information, their success at comprehension will be jeopardized. The results of several recent experiments suggest that less skilled readers are less efficient at suppressing the inappropriate meanings of ambiguous words (e.g., the playing card vs. garden tool meanings of *spade*), the incorrect forms of homophones (e.g., *patients* vs. *patience*), the typical-but-absent members of scenes (e.g., a tractor in a farm scene), and words superimposed on pictures. These experiments are summarized next.

1. This commonality might arise because language comprehension evolved from nonlinguistic cognitive skills, as suggested by Lieberman (1984). Or the commonality might arise because the mind is structured by a common architecture, for instance, a connectionist architecture, as suggested by McClelland and Rumelhart (1986), or production systems architecture, as suggested by Anderson (1983).

READING SKILL AND THE ABILITY TO SUPPRESS INAPPROPRIATE WORD MEANINGS

According to most theories of reading, understanding the meaning of a word requires activating a mental representation of that meaning. During the activation of the target word's meaning, candidate meanings of that target word and meanings associated with it are often activated. For instance, reading the word *bread* activates a representation of the meaning of *butter* (Meyer & Schvaneveldt, 1971). If less skilled readers have less efficient suppression mechanisms, then less skilled readers might suppress less efficiently the inappropriate meanings of words they recently read.

Support for this hypothesis is found in a study in which college-aged subjects read short sentences and, after each sentence, judged whether a test word fit the sentence's meaning (Gernsbacher et al., 1990, Experiment 4). Immediately (100 ms) after both more and less skilled adult readers read a sentence such as *He dug with the spade,* they had difficulty rejecting *ace* as unrelated. Readers of all skill levels often activate multiple meanings of ambiguous words—even when only one meaning is implied (as is the garden tool meaning of *spade,* not the playing card meaning).[2] However, when the in-

2. Immediate activation of inappropriate meanings is particularly likely when readers focus their attention on a test word and try to integrate that word into the previous context (Glucksberg, Kreuz, & Rho, 1986; van Petten & Kutas, 1987).

terval between the ambiguous words (*spade*) and the test words (*ace*) was increased to 1 s, an intriguing distinction between more and less skilled readers emerged. More skilled readers had no more difficulty rejecting *ace* after reading *He dug with the spade* than they had rejecting *ace* after reading *He dug with the shovel*. Less skilled readers were less fortunate: For them, contextually inappropriate meanings were as activated a second later as they were immediately. These data, illustrated in Figure 1, suggest that less skilled readers are less able to suppress inappropriate meanings.

READING SKILL AND THE ABILITY TO SUPPRESS INAPPROPRIATE LEXICAL FORMS

What other type of information needs to be suppressed for successful reading? Often, inappropriate phonological information is activated automatically (Coltheart, Davelaar, Jonasson, & Besner, 1977; Rosson, 1985): Reading the homophone *patients* can activate the phonological sequence /payshunz/, which can then activate another form of the homophone, *patience* (Van Orden, 1987; Van Orden, Johnston, & Hale, 1988). But successful reading requires suppressing these incorrect forms. If the same mechanism that suppresses the inappropriate meanings of ambiguous words also suppresses the incorrect forms of homophones, and if this general suppression mechanism is less efficient in less skilled readers, then less skilled readers should also suppress the incorrect forms of homophones less efficiently.

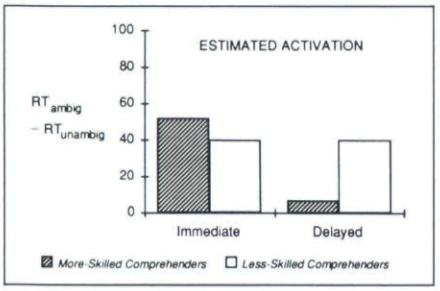

Fig. 1. Data from Gernsbacher, Varner, and Faust (1990, Experiment 4). Estimated activation is the difference between subjects' latencies to reject test words like *ace* after reading ambiguous words like *spade* versus unambiguous words like *shovel*.

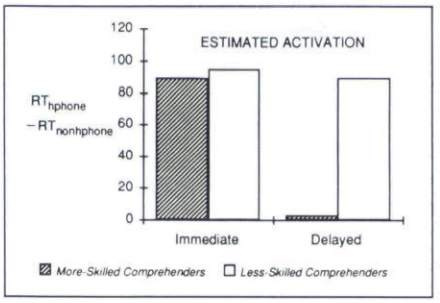

Fig. 2. Data from Gernsbacher and Faust (1991, Experiment 1). Estimated activation is the difference between subjects' latencies to reject test words like *calm* after sentence-final homophones like *patients* versus sentence-final nonhomophones like *students*.

Faust and I (Gernsbacher & Faust, 1991) found support for this hypothesis.[3] In our Experiment 1, subjects read short sentences; after each sentence, they indicated whether a test word fit the sentence's meaning. On 80 trials, the sentence's final word was one form of a homophone (e.g., *He had lots of patients*), but the test word was related to another form of the homophone (e.g., *calm*). Subjects' latencies to reject test words after reading sentence-final homophones versus nonhomophones (e.g., *He had lots of students*) were measured. The greater the difference between subjects' latencies to reject test words after homophones versus nonhomophones, the more activated the incorrect forms of the homophones must have been.

As Figure 2 illustrates, immediately (100 ms) after subjects read the homophones, the incorrect forms were highly activated, regardless of the subjects' comprehension skill. However, after a 1-s delay, the more and less skilled readers differed markedly. For the more skilled readers, the incorrect forms were no longer reliably activated, presumably because they were suppressed successfully. But for the less skilled readers, the incorrect forms were as activated after 1 s as they were immediately. These data support the hypothesis that less skilled readers have less efficient suppression mechanisms.

READING SKILL AND THE ABILITY TO SUPPRESS NONLINGUISTIC INFORMATION

Suppression is also crucial to successful comprehension of nonlinguistic stimuli (Biederman, 1981; Friedman, 1979; Mandler & Johnson, 1976). For instance, observers are more likely to report incorrectly that an object was present in a recently viewed scene if that object typically occurs in that type of scene. For example, observers are more likely to report incorrectly that a tractor was present in a farm scene than a kitchen scene (Biederman, Bickle, Teitelbaum, & Klatsky, 1988; Biederman, Glass, & Stacy, 1973; Biederman, Mezzanotte, & Rabinowitz, 1982; Biederman, Teitelbaum, & Mezzanotte, 1983). But to successfully comprehend a scene, observers must suppress these typical-but-absent objects, just as readers and listeners must suppress the inappropriate meanings of ambiguous words and the incorrect forms of homophones. If the same mechanism that suppresses inappropriate linguistic information also suppresses inappropriate nonlinguistic information, and if this general suppression mechanism is less efficient in less skilled readers, then less skilled readers should suppress typical-but-absent objects less efficiently when viewing scenes.

Again, Faust and I (Gernsbacher & Faust, 1991) found support for this hypothesis. In our Experiment 2, subjects viewed arrays of objects that were typical of a particular scene, such as objects from a farm scene or kitchen scene, as

3. The subjects in these experiments were U.S. Air Force recruits whom we tested during their 6th day of basic training. We eliminated subjects if their accuracy on our laboratory tasks suggested they were not giving the tasks enough effort. Air Force recruits are high school graduates, and typically 20% have completed some college courses. Their ages ranged from 17 to 23, and approximately 18% were female. All subjects were tested with the Multi-Media Comprehension Battery (Gernsbacher & Varner, 1988). More skilled readers scored in the upper third and less skilled readers scored in the lower third of a distribution of 450 subjects who were tested with the comprehension battery. The more and less skilled readers also differed significantly on the Air Force Reading Abilities Test (a modified version of the Nelson-Denny reading skills test).

illustrated in Figure 3.[4] After viewing each array, the subjects indicated whether a named test object had been present. On some trials, the test object was typical of the scene suggested by the array but had not been present in the array, as illustrated by the top panel of Figure 3. For these trials, the array is referred to as typical. On other trials, the test object was not typical of the scene suggested by the array, as illustrated in the bottom panel of Figure 3. Such arrays are referred to as atypical. Subjects' latencies to reject test objects after viewing typical versus atypical arrays were measured. The greater the difference between subjects' latencies to reject test objects after viewing typical versus atypical arrays, the more activated the typical-but-absent objects must have been.

Figure 4 shows the results. Immediately (50 ms) after subjects viewed the arrays, the typical-but-absent objects were highly activated, for both more skilled and less skilled readers. However, after a 1-s delay, the two groups differed markedly. For the more skilled readers, the typical-but-absent objects were no longer reliably activated, presumably because they were successfully suppressed. But for the less skilled readers, the typical-but-absent objects were just as activated as they were immediately. These data support the hypothesis that less skilled readers have less efficient suppression mechanisms.

READING SKILL AND THE ABILITY TO SUPPRESS INFORMATION ACROSS MODALITIES

Information originates from different modalities, often simultaneously. We read while listening to music; we drive while carrying on a conversation. Readers often experience interference across modalities. For instance, reading a word is harder when it is superimposed on a picture, and identifying a pictured object is harder when a word is written across it (Smith & McGee, 1980). If the same mechanism that suppresses information within a modality also suppresses information across modalities, and if this general suppression mechanism is less efficient in less skilled readers, then less skilled readers should also suppress information across modalities less efficiently.

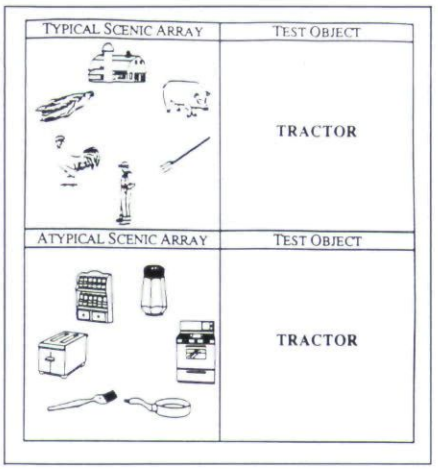

Fig. 3. Example stimuli from Gernsbacher and Faust (1991, Experiment 2).

Faust and I (Gernsbacher & Faust, 1991) investigated this hypothesis in our Experiment 3. Subjects first viewed context displays; each contained a picture and a word, as illustrated in Figure 5. After each context display, subjects were shown a test display that contained either another picture (on picture trials) or another word (on word trials). Subjects were informed whether each trial would be a picture or word trial. For picture trials (see the top of Fig. 5), subjects were told to focus on the picture in the context display and ignore the word; then, they were to indicate whether the picture in the test display was related to the picture in the context display. On word trials (see the bottom of Fig. 5), subjects were told to focus on the word in the context display and ignore the picture; then, they were to indicate whether the word in the test display was related to the word in the context display.

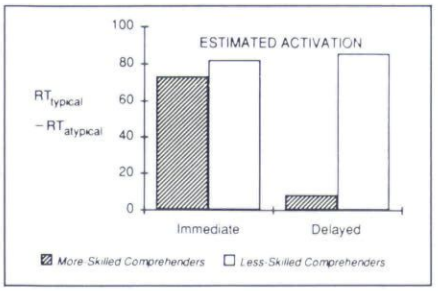

Fig. 4. Data from Gernsbacher and Faust (1991, Experiment 2). Estimated activation is the difference between subjects' latencies to reject the names of test objects like *tractor* after viewing typical arrays (of farm objects) versus atypical arrays (of kitchen objects).

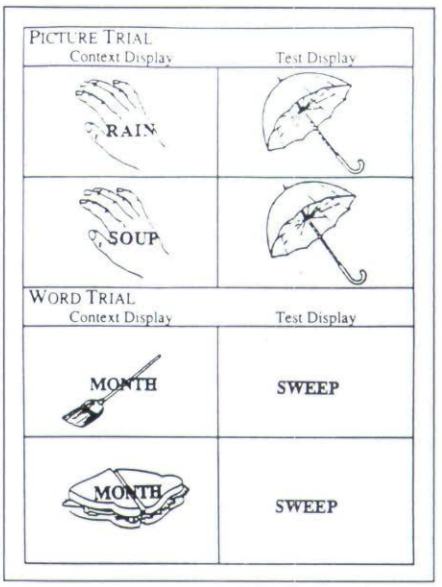

Fig. 5. Example stimuli from Gernsbacher and Faust (1991, Experiment 3).

On 80 trials, the test display was unrelated to what the subjects focused on in the context display, but was related to what they ignored, as illustrated in Figure 5. Subjects' latencies to reject test displays that were related versus unrelated to the pictures and words they ignored were measured. The greater the difference between subjects' latencies to reject test displays that were related versus unrelated, the more activated the ignored pictures and words must have been.

Figure 6 illustrates the results, which support the hypothesis. Immediately (50 ms) after subjects viewed the context displays, the ignored pictures or words were highly activated, for both more skilled and less skilled readers. However, for the more skilled readers, the ignored pictures or words were no longer reliably activated after a 1-s delay, presumably because they were successfully suppressed. In contrast, for the less skilled readers, the ignored pictures or words were just as activated after the 1-s delay as they were immediately. Again, the data suggest that suppression mechanisms of less skilled readers are less ef-

4. I thank I. Biederman for providing his stimuli.

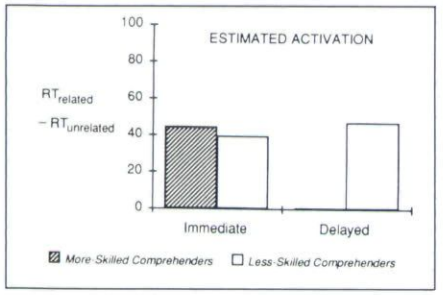

Fig. 6. Data from Gernsbacher and Faust (1991, Experiment 3). Estimated activation is the difference between subjects' latencies to reject test displays that were related versus unrelated to ignored pictures or words.

ficient than suppression mechanisms of more skilled readers.

READING SKILL AND THE ABILITY TO ENHANCE LINGUISTIC AND NONLINGUISTIC INFORMATION

Together, these four experiments demonstrate that less skilled readers are less efficient at rejecting inappropriate meanings of ambiguous words, incorrect forms of homophones, typical-but-absent members of scenes, and ignored pictures and words. I propose that this inability arises because less skilled readers are plagued by less efficient suppression mechanisms. A counterhypothesis is that less skilled readers have difficulty rejecting inappropriate information because they less fully appreciate what is contextually appropriate. By this logic, less skilled readers have difficulty rejecting *ace* after reading *He dug with the spade* simply because they less fully appreciate that the context of *digging with a spade* implies a garden tool, not a playing card.

However, Faust and I (Gernsbacher & Faust, 1991) did not find support for this counterhypothesis in our Experiment 4. Subjects read short sentences; after each sentence, they indicated whether a test word fit the sentence's meaning. On 80 trials, the sentence-final word was ambiguous (e.g., *spade*), and the test word was related to one meaning of the ambiguous word (e.g., *garden*). We compared subjects' latencies to accept test words when the sentences' verbs were biased toward that meaning (e.g., *He dug with the spade*) with latencies when the sentences' verbs were neutral (e.g., *He picked up the spade*). The greater the difference between subjects' latencies to accept test words after biasing versus neutral verbs, the more fully they must have appreciated the biasing contexts.

As Figure 7 illustrates, both immediately and after a 1-s delay, readers of both skill levels appreciated the biasing contexts. In fact, the less skilled readers appreciated the biasing contexts even more than the more skilled readers, replicating the finding that among school-age readers identifying written words, the less skilled often benefit more from a biasing sentence context than the more skilled do (Perfetti & Roth, 1981).

An experiment using nonlinguistic stimuli (Gernsbacher & Faust, 1991, Experiment 5) also did not support the counterhypothesis that less skilled readers have difficulty rejecting inappropriate information because they less fully appreciate what is contextually appropriate. Subjects first viewed a scenic array of objects, and then they read the name of a test object. The subjects' task was to verify whether the test object had been present in the array they just viewed. On half the trials, the test object had not been present, but in half it had. In this experiment, we were interested in the trials in which the test object had been present (and, therefore, the subjects should have responded "yes"). On half of the trials in which the object was present, the other objects in the array were typical of a scene in which the test object typically occurs. For example, a tractor was presented in an array of objects that typically occur in a farm scene. In a comparison condition, the other objects in the array were atypical of the scene in which the test object typically occurs. For example, a tractor was presented in an array of objects that typically occur in a kitchen scene. We compared how rapidly subjects accepted *tractor* after viewing it in an array of typical (farm) objects with how rapidly they accepted *tractor* after viewing it in an array of atypical (kitchen) objects. This comparison showed us how fully the subjects could appreciate the scenic contexts: The faster subjects were to accept *tractor* after viewing the array of typical versus atypical objects, the more fully the subjects must have appreciated the contexts. As shown in Figure 8, both immediately and after a 1-s delay, readers of both skill levels appreciated the scenic contexts. Indeed, the less skilled readers appreciated the scenic contexts even more than the more skilled readers. Therefore, these data fail to support the counterhypothesis.

I conclude that less skilled readers can initially activate information as efficiently as more skilled readers; indeed, they activate contextually appropriate information more strongly than more skilled readers do. What plagues less skilled readers is their inefficiency in dampening the activation of irrelevant or inappropriate information. This dilemma is similar to—although less grave than—a legendary difficulty faced by schizophrenics (Chapman & Chapman, 1973) and more similar to a difficulty faced by educated healthy elderly adults

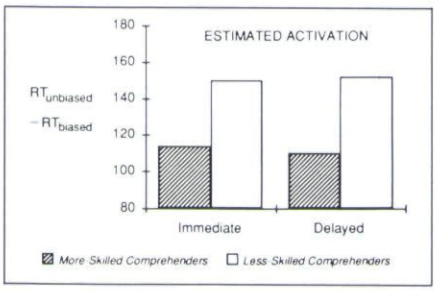

Fig. 7. Data from Gernsbacher and Faust (1991, Experiment 4). Estimated activation is the difference between subjects' latencies to accept test words like *garden* after reading sentences with biasing verbs (*digging with*) versus neutral verbs (*picked up*).

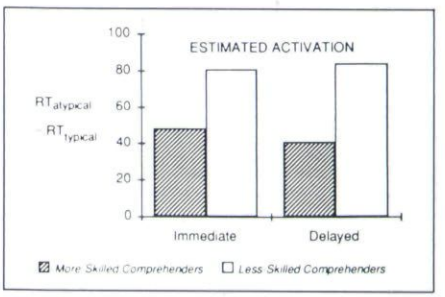

Fig. 8. Data from Gernsbacher and Faust (1991, Experiment 5). Estimated activation is the difference between subjects' latencies to accept test objects like *tractor* after viewing those test objects in typical (farm) versus atypical (kitchen) arrays.

(Hasher, Stoltzfus, Rympa, & Zacks, 1991). Schizophrenics and healthy elderly adults often activate contextually appropriate information very strongly but are less efficient in their dampening of the activation of irrelevant or inappropriate information.

Other general cognitive mechanisms might be inefficient in less skilled readers. Furthermore, some mechanisms contribute exclusively to the comprehension of one modality. For instance, some neurological insults affect only the ability to decode letters in text, to identify phonemes in speech, or to recognize objects in visual arrays. But the experiments described here have identified a general cognitive mechanism that characterizes less skilled readers regardless of whether they are comprehending linguistic or nonlinguistic media: They have less efficient suppression mechanisms.

REFERENCES

Anderson, J.R. (1983). *The architecture of cognition*. Cambridge, MA: Harvard University Press.

Biederman, I. (1981). On the semantics of a glance at a scene. In M. Kubovy & J.R. Pomerantz (Eds.), *Perceptual organization* (pp. 213–252). Hillsdale, NJ: Erlbaum.

Biederman, I., Bickle, T.W., Teitelbaum, R.C., & Klatsky, G.J. (1988). Object search in nonscene displays. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 456–467.

Biederman, I., Glass, A.L., & Stacy, E.W., Jr. (1973). Searching for objects in real world scenes. *Journal of Experimental Psychology, 97*, 22–27.

Biederman, I., Mezzanotte, R.J., & Rabinowitz, J.C. (1982). Scene perception: Detecting and judging objects undergoing relational violations. *Cognitive Psychology, 14*, 143–177.

Biederman, I., Teitelbaum, R.C., & Mezzanotte, R.J. (1983). Scene perception: A failure to find a benefit of prior expectancy or familiarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 9*, 411–429.

Chapman, L., & Chapman, J. (1973). *Disordered thought in schizophrenia*. New York: Appleton-Century-Crofts.

Coltheart, M., Davelaar, E., Jonasson, J.T., & Besner, D. (1977). Access to the internal lexicon. In S. Dornic (Ed.), *Attention and performance VI* (pp. 535–555). Hillsdale, NJ: Erlbaum.

Friedman, A. (1979). Framing pictures: The role of knowledge in automatized encoding and memory for gist. *Journal of Experimental Psychology: General, 108*, 316–355.

Gernsbacher, M.A. (1990). *Language comprehension as structure building*. Hillsdale, NJ: Erlbaum.

Gernsbacher, M.A., & Faust, M.E. (1991). The mechanism of suppression: A component of general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 245–262.

Gernsbacher, M.A., & Varner, K.R. (1988). *The Multi-Media Comprehension Battery* (Technical Report No. 88-03). Eugene: University of Oregon, Institute of Cognitive and Decision Sciences.

Gernsbacher, M.A., Varner, K.R., & Faust, M. (1990). Investigating differences in general comprehension skill. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 430–445.

Glucksberg, S., Kreuz, R.J., & Rho, S.H. (1986). Context can constrain lexical access: Implications for models of language comprehension. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*, 323–335.

Hasher, L., Stoltzfus, E.R., Rympa, B., & Zacks, R. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17*, 163–169.

Lieberman, P. (1984). *The biology and evolution of language*. Cambridge, MA: Harvard University Press.

Mandler, J.M., & Johnson, N. (1976). Some of the thousand words a picture is worth. *Journal of Experimental Psychology: Human Learning and Memory, 2*, 529–540.

McClelland, J.L., & Rumelhart, D.E. (1986). A distributed model of human learning and memory. In J.L. McClelland & D.E. Rumelhart (Eds.), *Parallel distributed processing: Explorations in the microstructure of cognition. Vol. 2. Psychological and biological models* (pp. 170–215). Cambridge, MA: MIT Press.

Meyer, D.E., & Schvaneveldt, R.W. (1971). Facilitation in recognizing pairs of words: Evidence of a dependence between retrieval operations. *Journal of Experimental Psychology, 90*, 227–234.

Palmer, J., MacLeod, C.M., Hunt, E., & Davidson, J.E. (1985). Information processing correlates of reading. *Journal of Memory and Language, 24*, 59–88.

Perfetti, C.A., & Roth, S. (1981). Some of the interactive processes in reading and their role in reading skill. In A.M. Lesgold & C.A. Perfetti (Eds.), *Interactive processes in reading* (pp. 269–297). Hillsdale, NJ: Erlbaum.

Rosson, M.B. (1985). The interaction of pronunciation rules and lexical representations in reading aloud. *Memory & Cognition, 13*, 90–99.

Smith, M.C., & McGee, L.E. (1980). Tracing the time course of picture-word processing. *Journal of Experimental Psychology: General, 109*, 373–392.

Van Orden, G.C. (1987). A ROWS is a ROSE: Spelling, sound, and reading. *Memory & Cognition, 15*, 181–198.

Van Orden, G.C., Johnston, J.C., & Hale, B.L. (1988). Word identification in reading proceeds from spelling to sound to meaning. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 371–386.

van Petten, C., & Kutas, M. (1987). Ambiguous words in context: An event-related potential analysis of the time course of meaning activation. *Journal of Memory and Language, 26*, 188–208.