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Skilled Suppression

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When information from two or more domains conflict, we often experience interference (see Dempster, 1992, for a review). The phenomenon of interference has long held intrigue for experimental psychologists. Many psychological theories revolve around the concept of interference. For example, retroactive and proactive interference have been imputed in many theories of learning and forgetting (Zechmeister & Nyberg, 1982), and disagreement over the locus of interference effects in selective-attention tasks (e.g., an early vs. late "bottleneck") distinguishes several theories of attention (Allport, Tipper, & Chmiel, 1985; Neill & Westberry, 1987; Yee, 1991). Recently, interference has been proposed as a powerful explanation for the cognitive changes associated with childhood development and adult aging (Bjorklund & Harnishfeger, 1990; Dempster, 1992, 1993; Harnishfeger, Chapter 6, this volume; Harnishfeger & Bjorklund, 1993; McDowd, Oseas-Kreger, & Filion, Chapter 11, and Reyna, Chapter 2, this volume).

In this chapter we explore the interference that often arises during comprehension. Consider, for example, the comprehension of a spoken or written sentence. Successful comprehension entails building a coherent mental representation from a string of serially presented words. Thus, at some level, individual words comprise a basis for building a mental representation of a sentence. However, even a brief examination of a dictionary documents that many English words are to some degree ambiguous; they have several, often distinct senses. Early "top-down" models of comprehension (e.g., Schank & Abelson, 1977) stressed the role of prior context; prior context constrained the semantic information that could be activated during word recognition, and thus the interference from different senses of a word was avoided.

Over the past decade, studies of ambiguous words heard or read in a sentence context have, for the most past, suggested the following pattern. Initially, multiple senses of an ambiguous word are activated to greater or lesser degrees; later, the meaning most contextually appropriate is selected (Conrad, 1974; Duffy, Morris, & Rayner, 1988; Merrill, Sperber, & McCauley, 1981; Onifer & Swinney, 1981; Swinney, 1979). Although several studies have challenged the generality of this proposal (Kellas, Paul, Martin, & Simpson, 1991; Tabossi, 1988a, 1988b), we assume that, on average, more information is activated during reading than is appropriate or relevant to comprehension of the text as a whole (Gernsbacher & Faust, 1991b). Thus, the potential for interference from contextually inappropriate information is a basic ingredient of our perspective on comprehension. We are not alone in this respect. Several other researchers have proposed models of comprehension that also include the potential for interference from inappropriate information (Hasher & Zacks, 1988; Just & Carpenter, 1992; Kintsch, 1988).

In this chapter we begin by describing how a mechanism of suppression can reduce the interference from inappropriate information; suppression dampens the activation of contextually inappropriate information. We then describe a series of studies that link the ability to successfully suppress inappropriate information (the facility to attenuate interference) to comprehension skill. We conclude by presenting the results of two experiments that demonstrate that the suppression effects we have examined before are susceptible to the probability of instances when suppression is needed. This finding suggests that our proposed mechanism of suppression is composed of at least some attentionally driven components.

THEORETICAL BACKGROUND

Our conception of suppression derives from the Structure Building Framework, which is a simple framework for understanding the cognitive processes and mechanisms involved in comprehension (Gernsbacher, 1990). According to the Structure Building Framework, the goal of comprehension is to build coherent mental representations or *structures.* The building blocks of these mental structures are what we refer to as memory nodes. Memory nodes represent previously comprehended information, perhaps in a distributed sense.

According to the Structure Building Framework, memory nodes are activated by incoming stimuli. Once activated, memory nodes transmit processing signals, which either enhance (increase) or suppress (dampen or decrease) other nodes' activation. Thus, once memory nodes are activated, two mechanisms control their level of activation: these mechanisms are suppression and enhancement. (For a related perspective on memory strength, see Brainerd's distinction between output interference and episodic activation in Chapter 4, this volume.) Memory nodes are enhanced when the information they represent is necessary for ongoing processing; they are suppressed when the information they represent is not necessary.

The notion that incoming stimuli activate memory representations is familiar. What is novel about the Structure Building Framework's proposal is that activated memory nodes transmit processing signals. This proposal more fully captures the analogy of neural activity—an analogy that inspires many models of cognition. This is because the familiar notion that incoming stimuli activate memory nodes captures only one aspect of the analogy, the electrical transmission of information (along axons); but the novel proposal that activated memory nodes also transmit processing signals completes the analogy. The transmission of processing signals (suppression and enhancement) parallels the chemical transmission of information (across synapses, via neurotransmitters).

The mechanisms of suppression and enhancement are crucial to successful language processing. Consider only the need for suppression: in many situations, irrelevant or inappropriate information is automatically activated, unconsciously retrieved, or naturally perceived. For instance, reading a string of letters activates phonological, semantic, and orthographic information (M. Coltheart, Davelaar, Jonasson, & Besner, 1977; Rosson, 1985). Indeed, laboratory experiments demonstrate that reading the letter string *rows* can activate the phonological sequence */roz/*, which can activate the word *rose* (van Orden, 1987; van Orden, Johnston, & Hale, 1988). But to correctly understand a homophone (e.g., *rows*), the homophone's alternate forms (e.g., *rose)* must be suppressed.

Information from other modalities must also be suppressed. We often read in the presence of background noise, and we conduct conversations in the presence of visual stimuli. In these situations, we often experience interference across modalities. Laboratory experiments demonstrate that it is harder to read a word when it is written within a line-drawing of an object, and it is harder to name a line-drawn object if a word is written within it (Smith & McGee, 1980). But for successful language processing, irrelevant information from other modalities must be suppressed (Tipper & Driver, 1988).

Our previous research has illustrated the role of suppression in various language phenomena. These phenomena include **lexical access** (how we understand the meanings of words); **anaphoric reference** (how we understand to whom or what anaphors, such as pronouns, refer); **cataphoric reference** (how words that are marked by devices, such as spoken stress, gain a privileges status in comprehenders' mental structures); **surface information loss** (why seemingly superficial information, such as syntactic form, is forgotten more rapidly than seemingly more important information, such as thematic content; Gernsbacher, 1985); **syntactic parsing** (how we decode the grammatical form of sentences into meaning); and **general comprehension skill** (which is skill at comprehending linguistic as well as nonlinguistic media).

In addition to demonstrating the ubiquity of suppression, our previous research clarifies the nature of this mechanism. These experiments illustrate three critical principles of suppression:

Principle 1. Suppression is an active dampening of activation.
Principle 2. Suppression signals are transmitted by activated memory nodes.
Principle 3. Suppression is a general cognitive mechanism.

The experiments on lexical access and cataphoric reference (Gernsbacher & Faust, 1991b; Gernsbacher & Jescheniak, 1994) illustrate Principle 1: Suppression is an active dampening of activation. These experiments demonstrate that suppression differs from passive decay and from compensatory inhibition (the notion that some memory nodes must decrease in activation simply because others have increased).

The experiments on anaphoric and cataphoric reference (Gernsbacher, 1989; Gernsbacher & Hargreaves, 1988; Gernsbacher, Hargreaves, & Beeman, 1989; Gernsbacher & Shroyer, 1989) illustrate Principle 2: Suppression signals are transmitted by activated memory nodes. These experiments demonstrate that how strongly suppression signals are transmitted is a function of how marked the anaphoric and cataphoric devices are. The more marked the anaphoric or cataphoric devices are, the stronger the suppression signals will be.

The experiments on general comprehension skill (Gernsbacher & Faust, 1991a; Gernsbacher, Varner, & Faust, 1990) illustrate Principle 3: Suppression is a general cognitive mechanism. These experiments demonstrate that the same mechanism that suppresses inappropriate information during sentence comprehension could suppress inappropriate information during scene comprehension. Moreover, these experiments demonstrate that successful suppression underlies skilled comprehension. In the next part of this chapter we review these experiments. In the last part of this chapter, we present new data that demonstrate that employing the mechanism of suppression that we have identified in our previous work is a strategic skill.

SUCCESSFUL SUPPRESSION UNDERLIES SKILLED COMPREHENSION

According to many models of word understanding, when comprehenders first hear or read a word, information provided by that word activates

various potential meanings. Then, constraints provided by lexical, semantic, syntactic, and other sources of information alter those meanings' levels of activation. Eventually, one meaning becomes most strongly activated. That is the meaning that comprehenders access and incorporate into their developing mental structures (these ideas are culled from the models of Becker, 1976; Kintsch, 1988; Marslen-Wilson & Welsh, 1978; McClelland & Rumelhart, 1981; Norris, 1986).

What the Structure Building Framework adds to these ideas is the proposal that suppression and enhancement modulate the different meanings' levels of activation. The role of the mechanism of suppression can be illustrated by examining how comprehenders access the appropriate meaning of ambiguous words (i.e., words such as *bugs* that have at least two diverse meanings). Immediately after comprehenders hear or read an ambiguous word, multiple meanings of the word are often activated. In fact, multiple meanings are often activated even though one meaning is strongly implied by the context (Conrad, 1974; Kintsch & Mross, 1985; Lucas, 1987; Seidenberg, Tanenhaus, Leiman, & Bienkowski, 1982; Tanenhaus, Leiman, & Seidenberg, 1979; Till, Mross, & Kintsch, 1988). For example, immediately after the word *spade* is heard or read, both the playing card meaning and the garden tool meaning are often momentarily activated. This occurs even when one meaning is strongly implied, for instance, even when the garden tool, not the playing card, meaning of *spade* is implied in the following sentence.

(1) He dug with the **spade.**

Successful comprehension must involve suppressing the contextually inappropriate meaning—the playing card meaning. In Gernsbacher et al. (1990), we discovered that skilled comprehenders are more successful in suppressing the inappropriate meanings of ambiguous words.

Skilled Comprehenders Are More Successful in Suppressing Inappropriate Meanings

In Gernsbacher et al. (1990; Experiment 4), we selected two samples of more-skilled and less-skilled comprehenders from the extreme thirds of a distribution of 270 University of Oregon students whom we had tested on the Multi-Media Comprehension Battery (Gernsbacher & Varner, 1988). The Multi-Media Comprehension Battery tests subjects' comprehension of written, auditorily presented, and nonverbal picture stories. When the more- and less-skilled comprehenders returned to the lab, they read short sentences; after each sentence, they saw a test word. Their task was to verify whether the test word fit the meaning of the sentence they just read. On 80 trials, the test word did indeed fit the sentence, but we were more interested in the 80 trials in which the test word did *not* fit the sentence. On half of those trials, the last word of the sentence was an ambiguous word, for example,

(2) He dug with the **spade.**

The test word on these trials was a meaning of the ambiguous word that was inappropriate to the context, for example, *ACE*. We measured how long subjects took to reject a test word like *ACE* after reading a sentence like (2). And we compared the latency with how long subjects took to reject *ACE* after reading the same sentence but with the last word replaced by an unambiguous word, for example.

(3) He dug with the **shovel.**

This comparison showed us how activated the inappropriate meaning of the ambiguous word was; the more time subjects took to reject *ACE* after the *spade* versus the *shovel* sentence, the more activated the inappropriate meaning must have been.

We presented the test words at two intervals: immediately (100 ms) after subjects finished reading each sentence, and after an 850-ms delay. We predicted that at the immediate test point, both the more- and less-skilled comprehenders would take longer to reject test words after ambiguous than after unambiguous words. For example, both groups would take longer to reject *ACE* after reading the *spade* sentence than after reading the *shovel* sentence. This prediction was based on the vast literature demonstrating that immediately after ambiguous words are read, contextually inappropriate meanings are often activated. We particularly expected the inappropriate meanings to be activated because our task required comprehenders to focus their attention on a subsequent word and try to integrate that word into the previous context (Glucksberg, Kreuz, & Rho, 1986; van Petten & Kutas, 1987).

Our novel predictions concerned what would happen after the delay. We predicted that after the delay, the difference between the more-skilled comprehenders' latencies to reject test words following ambiguous versus following unambiguous words would be reduced. This is because more-skilled comprehenders should be more able to successfully suppress the inappropriate meanings.

Figure 1 displays our 64 subjects' data, presented as estimated activation of the inappropriate meanings. We estimated activation of the inappropriate meanings by subtracting subjects' latencies to reject test words like *ACE* after reading ambiguous words like *spade* from their latencies to reject test words like *ACE* after reading unambiguous words like *shovel*.

As Figure 1 illustrates, immediately after comprehenders of both skill levels read the ambiguous words, the inappropriate meanings were highly activated. However, 850 ms after the more-skilled comprehenders read the ambiguous words, the inappropriate meanings were no longer reliably activated. We suggest that by this time the more-skilled comprehenders had successfully suppressed the inappropriate meanings. But for the less-skilled comprehenders, even after the delay, the inappropriate meanings were still highly activat-

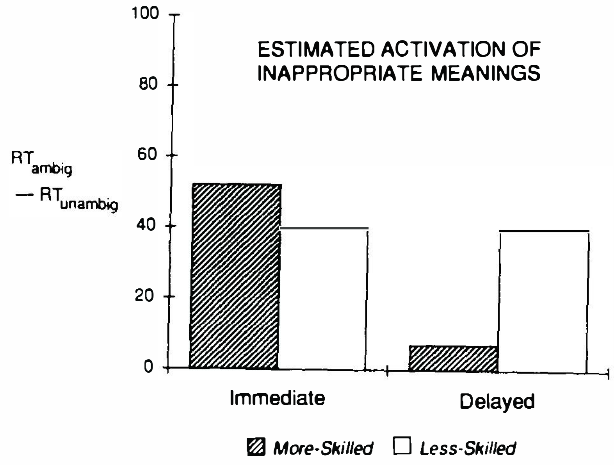

FIGURE 1. Estimated activation is the difference between subjects' latencies to reject test words like *ACE* after reading ambiguous words like *spade* versus unambiguous words like *shovel*. The more-skilled comprehenders are represented by hatching; the less-skilled comprehenders are represented by unfilled bars. Data from M. A. Gernsbacher, K. R. Varner, & M. E. Faust *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1990; Experiment 4).

ed. In fact, they were as highly activated following the delay as they were immediately after reading the ambiguous words. These results support the hypothesis that skilled comprehenders are more successful in suppressing the inappropriate meanings of ambiguous words.

Skilled Comprehenders Are More Successful in Suppressing Incorrect Forms of Homophones

Reading a string of letters activates an array of information. Reading a letter string virtually always activates orthographic information—information about the individual letters in the string and their relative position to one another. Often, reading a letter string activates semantic information, lexical information, and phonological information. In fact, semantic, lexical, and phonological information is often activated even when the string does not compose an English word (M. Coltheart et al., 1977; Rosson, 1985).

Automatic activation of phonological information was the focus of our next experiment. By automatic activation of phonological information we mean the phenomenon in which reading the letter string (and homophone) *rows* activates the phonological sequence /roz/, which can activate *rose* (another form of the homophone). How do we know that a letter string often activates phonological information, which in turn activates other forms of homophones? Consider the following finding: comprehenders have difficulty quickly rejecting the word *rows* as not being an exemplar of the category *FLOWER* (van Orden, 1987; van Orden et al., 1988).

In order to successfully comprehend a written passage, these incorrect forms cannot remain activated. According to the Structure Building Framework, comprehension involves the mechanism of suppression. The same structure-building mechanism that suppresses the inappropriate meanings of ambiguous words could also suppress the incorrect forms of homophones. If this is the same mechanism, and if this general suppression mechanism underlies successful comprehension, then more-skilled comprehenders should be more successful in suppressing the incorrect forms of homophones.

Related evidence already supports this prediction. Consider the sentence:

(4) She **blue** up the balloon.

Six-year-olds are more likely to accept that sentence than are 10-year-olds, even when they clearly know the difference between *blue* and *blew* (Doctor & Coltheart, 1980; see also V. Coltheart, Laxon, Rickard, & Elton, 1988). If we assume that 10-year-olds are more skilled than 6-year-olds at comprehension, this finding suggests that more-skilled comprehenders are more successful in suppressing the incorrect forms of homophones that are often automatically activated.

We tested this hypothesis in Gernsbacher and Faust (1991a; Experiment 1). Our subjects were United States Air Force recruits who were selected from a sample of 455 subjects whom we tested with the Multi-Media Comprehension Battery. We selected 48 subjects from the top third of the distribution (those who scored the highest) and 48 subjects from the bottom third of the distribution (those who scored the lowest). When these more- and less-skilled comprehenders returned to the lab, they performed a laboratory task similar to the task we used in our previous research. They read short sentences, and following each sentence, they saw a test word. The subjects verified whether the test word fit the meaning of the sentence they just read. On 80 trials, the test word did indeed fit the sentence's meaning, but on 80 trials it did not. We were interested in those trials in which the test word did *not* fit the meaning.

On half of those trials, the last word of the sentence was one form of a homophone, for example,

(5) He had lots of **patients**.

On these trials, the test word was related to the homophone's other form, for example, the test word *CALM* is related to *patience.* We compared how long subjects took to reject *CALM* after reading sentence (5) with how long they took to reject *CALM* after reading the same sentence with the last word replaced by a nonhomophone, for example,

(6) He had lots of **students**.

This comparison showed us how activated the incorrect form was; the more time subjects took to reject *CALM* after the *patients* sentence versus after the *students* sentence, the more activated the *patients* form of the homophone must have been.[1]

We presented the test words at two intervals: immediately (100 ms) after subjects finished reading each sentence, and after 1-s delay. We predicted that at the immediate interval, comprehenders of both skill levels would take longer to reject test words following homophones than following nonhomophones. For example, both groups would take longer to reject *CALM* after reading the *patients* sentence than after reading the *students* sentence. This result would corroborate the results of van Orden (1987; van Orden et al., 1988). This result would also demonstrate that comprehenders of both skill levels often activate phonological information during reading. Our novel predictions concerned what would happen after the delay. We predicted that after the 1-s delay, the difference between the more-skilled comprehenders' latencies to reject test words following homophones versus following nonhomophones would be reduced, because more-skilled comprehenders should be more successful in suppressing the incorrect forms.

Figure 2 illustrates our 96 subjects' data, presented as estimated activation of the incorrect forms of the homophones. We estimated activation of the incorrect forms by subtracting subjects' latencies to reject test words like *CALM* after reading nonhomophones like *students* from their latencies to reject test words like *CALM* after reading homophones like *patients.* As Figure 2 illustrates, immediately after comprehenders of both skill levels read the homophones, the inappropriate forms were highly activated; in fact, they were almost equally activated for the more-skilled as for the less-skilled comprehenders. However, one second after the more-skilled comprehenders read the homophones, the incorrect forms were no longer reliably activated. We suggest that the more-skilled comprehenders had successfully suppressed the incorrect forms. But for the less-skilled comprehenders, even after the 1-s delay, the incorrect forms were still highly activated; in fact, they were as highly activated after 1 s as they were immediately after reading the words. These data support the hypothesis that more-skilled comprehenders are more successful in suppressing the incorrect forms of homophones.

[1]To ensure that the homophones would be familiar to our subjects, 25 students at the University of Oregon judged, without time pressure, whether the test words fit the meanings of our experimental and filler sentences. We used experimental sentences and test words only if 95% of our students agreed that the test words did *not* fit their sentences' meanings, and we used filler sentences and test words only if 95% of our students agreed that the test words *did* fit their sentences' meanings.

Skilled Comprehenders Are More Successful in Suppressing Typical-but-Absent Objects

According to the Structure Building Framework, many of the cognitive processes and mechanisms involved in comprehending language are involved in comprehending nonlinguistic stimuli, for instance, naturalistic scenes. Other researchers also consider scene perception as "comprehension" (Biederman, 1981; Friedman, 1979; Mandler & Johnson, 1976).

The mechanism of suppression seems critical to successful scene comprehension. Indeed, Biederman writes about the difficulty in "suppressing the interpretations of visual arrays that comprise scenes" (Biederman, Bickle, Teitelbaum, & Klatsky, 1988, p. 456). This difficulty is manifested in the following phenomenon: After briefly viewing a scene, subjects are more likely to incorrectly report that an object was present if that object is typically found in that type of scene. For instance, subjects are more likely to incorrectly report that a tractor was present in a farm scene than in a kitchen scene, and they are more likely to incorrectly report that a kettle was present in a kitchen scene than in a farm scene (Biederman, Glass, & Stacy, 1973; Biederman, Mezzanotte, & Rabinowitz, 1982; Biederman, Teitelbaum, & Mezzanotte, 1983; Palmer, 1975).

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.

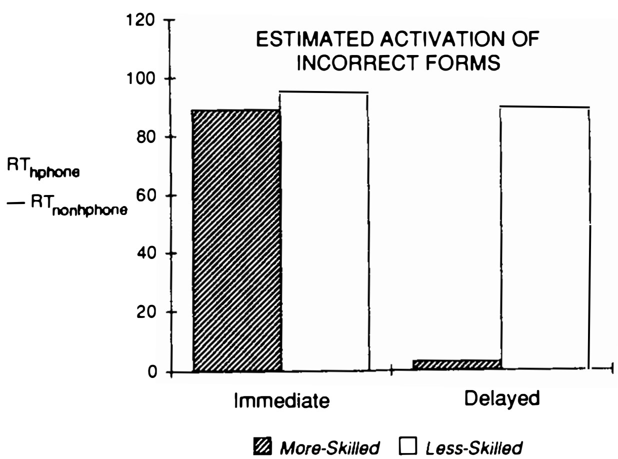

FIGURE 2. Estimated activation is the difference between subjects' latencies to reject test words like *CALM* after sentence final homophones like *patients* versus after sentence final nonhomophones like *students*. Data from M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 1).

The same structure-building mechanism that suppresses the activation of inappropriate linguistic information could suppress the activation of inappropriate nonlinguistic information. If this is the same mechanism, and if this general suppression mechanism underlies skilled comprehension, then more-skilled comprehenders should be more successful in suppressing the activation of typical-but-absent objects when viewing scenes.

We tested this hypothesis (in Gernsbacher & Faust, 1991a; Experiment 2) using Biederman et al.'s (1988) stimuli. Biederman et al. (1988) replicated the phenomenon in which subjects incorrectly report that an object is present in a scene when the object is typical of that scene (for instance, subjects incorrectly report that a tractor was present in a farm scene). Instead of briefly viewing actual scenes, however, the subjects in Biederman et al.'s (1988) experiments viewed clock-face arrangements of objects, as illustrated in Figure 3. For instance, Figure 3A illustrates a clock-face arrangement of six objects normally found in a farm scene; *barn, pig, pitchfork, farmer, rooster,* and *ear of corn*. We refer to these clock-face arrangements as scenic arrays.

We presented all of Biederman et al.'s (1988) scenic arrays that comprised three, four, five, and six objects. However, we slightly modified Biederman et al.'s task so that it would better parallel our linguistic tasks. In our experiment, subjects first viewed a scenic array; then, they saw the name of a

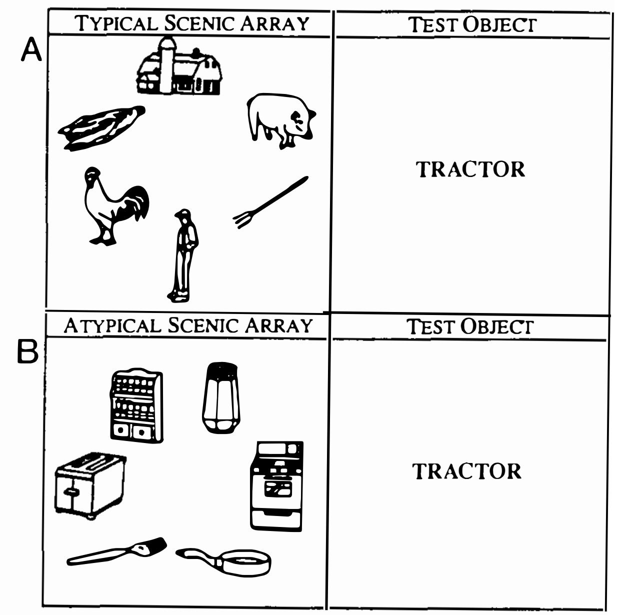

FIGURE 3. Example stimuli. From M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 2).

test object. Their task was to verify whether the named test object had been present in the array they just viewed. On 80 trials, the test object had been present, but in 80 it had not. In this experiment, we were interested in the trials in which the test object had *not* been present.

On half of these trials, the objects in the array were typical of a particular scene, for instance, objects that typically occur in a farm scene, as illustrated in Figure 3A. On these trials, the test object was something that also typically occurs in this type of scene, but it had not been present in the scenic array the subjects viewed. For instance, a *TRACTOR* typically occurs in a farm scene, but no *TRACTOR* occurs in the scenic array illustrated in Figure 3A.

We compared how long subjects took to reject *TRACTOR* after viewing the farm array with how long they took to reject *TRACTOR* after viewing another scenic array, for instance, objects belonging to a kitchen scene, as illustrated in Figure 3B. This comparison showed us how activated the typical-but-absent object was: the longer subjects took to reject *TRACTOR* after viewing the typical (*farm*) array versus the atypical (*kitchen*) array, the more activated the typical-but-absent object must have been.

We presented the names of the test objects at two intervals: immediately (50 ms) after subjects viewed each array, and after a 1-s delay. Figure 4 displays our 40 subjects' data, presented as estimated activation of the typical-but-absent objects. We estimated activation of the typical-but-absent objects by subtracting subjects' latencies to reject names of test objects like *TRACTOR* after viewing atypical (*kitchen*) arrays from their latencies to reject names of test objects like *TRACTOR* after viewing typical (*farm*) arrays. As Figure 4 illustrates, immediately after both the more- and-less skilled comprehenders viewed the scenic arrays, the typical-but-absent objects were highly activated. In fact, the typical-but-absent objects were about equally activated for the more- and the less-skilled comprehenders.

As Figure 4 also illustrates, 1 s after the more-skilled comprehenders viewed the scenic arrays, the typical-but-absent objects were no longer reliably activated. We suggest that the more-skilled comprehenders had successfully suppressed the typical-but-absent objects. But for the less-skilled comprehenders, even after the 1-s delay, the typical-but-absent objects were still highly activated; in fact, they were as activated after the 1-s delay as they were immediately after viewing the arrays. These results support the hypothesis that skilled comprehenders are more successful in suppressing typical-but-absent objects after they view scenic arrays.

Skilled Comprehenders Are More Successful in Suppressing Information across Modalities

To negotiate the environment, we must make sense of stimuli that originate from various modalities. We would be severely handicapped if we were

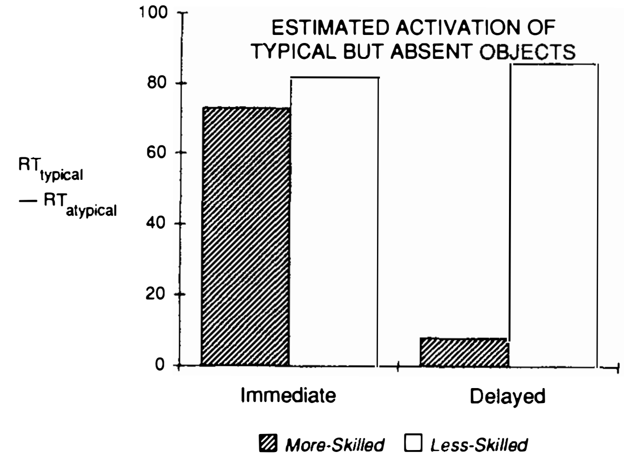

FIGURE 4. Estimated activation is the difference between subjects' latencies to reject the names of test objects like *TRACTOR* after viewing typical arrays (of *farm* objects) versus atypical arrays (of *kitchen* objects). Data from M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 2).

skilled at only reading written words, or only listening to spoken words, or only comprehending graphic displays. Information originates from different modalities, often simultaneously. We read while listening to music, and we drive while carrying on a conversation.

Comprehenders often experience interference across modalities. For instance, it is harder to name a pictured object such as an *ashtray* if a letter string such as *INCH* is written across the picture, as illustrated in Figure 5A. The opposite is also true: it is harder to read a word such as *RIVER* if it is superimposed on a picture, as illustrated in Figure 5B (Smith & McGee, 1980).

Successful comprehension often requires suppressing information across modalities. The same structure-building mechanism that suppresses information within a modality could suppress information across modalities. If this is the same mechanism, and if this general suppression mechanism underlies skilled comprehension, then more-skilled comprehenders should be more successful in suppressing information across modalities.

We tested this hypothesis (in Gernsbacher & Faust, 1991a; Experiment 3) in the following way. Subjects first viewed a context display, which contained a line-drawn picture of a common object and a familiar word. For example, Figure 5A illustrates a picture of an *ashtray* with the word *INCH* written across it. Figure 5B illustrates the word *RIVER* superimposed on a picture of a *baseball player*. All context displays contained both a picture and a word.

After subjects viewed each context display, they were shown a test display. Each test display contained either another picture or another word. Half

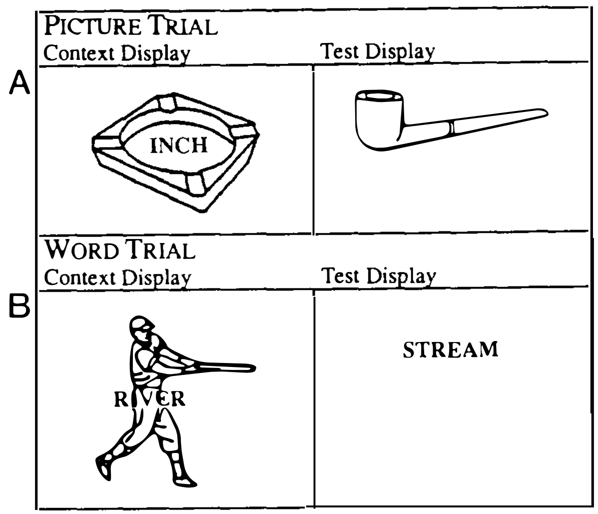

FIGURE 5. Example stimuli for filler trials. From M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 3).

the time, the test display contained another picture, and we referred to those trials as Picture trials; half the time, the test display contained another word, and we referred to those trials as Word trials. Subjects were told before each trial whether that trial would be a Picture trial or a Word trial.

Figure 5A illustrates a Picture trial. On Picture trials, subjects were told to focus on the picture in the context display and ignore the word. For example, for the Picture trial shown in Figure 5A, subjects should have focused on the *ashtray* and ignored the word *INCH*. Following each context display, subjects were shown a test display. On the Picture trials, the test display contained another picture. The subjects' task (on Picture trials) was to verify whether the picture shown in the test display was related to the picture shown in the context display. For the Picture trial shown in Figure 5A, subjects should have responded "yes," because the picture shown in the test display, the *pipe*, was related to the picture shown in the context display, the *ashtray*.

Figure 5B illustrates a Word trial. On Word trials, subjects were supposed to focus on the word in the context display and ignore the picture. For example, for the Word trial shown in Figure 5B, subjects should have focused on the word *RIVER* and ignored the *baseball player*. The test display on Word trials contained another word. The subjects' task was to verify whether the word written in the test display was related to the word written in the context display. For the Word trial shown in Figure 5B, subjects should have

responded "yes," because the word written in the test display, *STREAM*, was related to the word written in the context display, *RIVER*.

On 40 Picture trials and 40 Word trials, the test display was related to what the subjects were to focus on in the context display, just as they are related in Figure 5. However, we were more interested in the 80 trials in which the test display was *unrelated* to what the subjects were supposed to focus on in the context display. On half of those trials, the test display was unrelated to what the subjects were to focus on in the context display, but it was related to what they were supposed to ignore.

For example, Figure 6A illustrates an experimental Picture trial. The context display contains a picture of a *hand* with the superimposed word *RAIN*. Because this is a Picture trial, subjects should have focused on the picture (the *hand*) and ignored the word. The test display is a picture of an *umbrella*. So the test display, the *umbrella*, is unrelated to what the subjects were supposed to focus on in the context display, the *hand*; therefore, the subjects

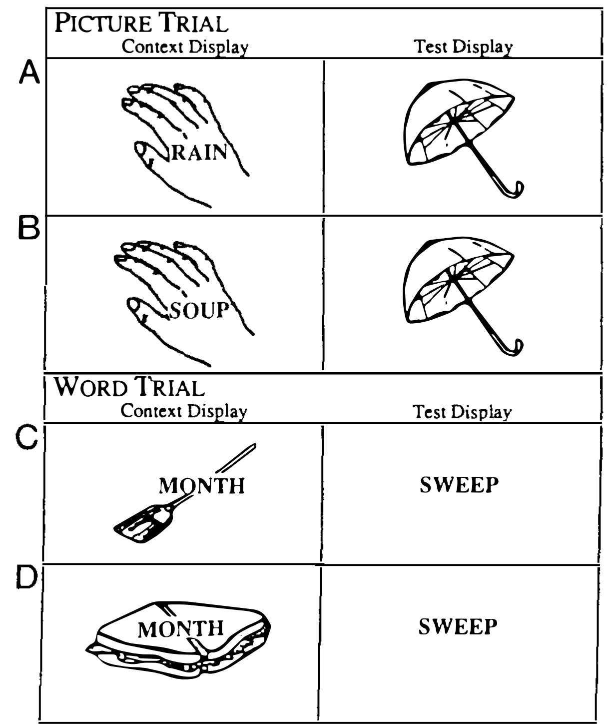

FIGURE 6. Example stimuli for experimental trials. From M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 3).

should have responded "no." But the test display is related to what the subjects were supposed to ignore, the word *RAIN*. We measured how long subjects took to reject the test display, the picture of the *umbrella,* after viewing the context display, the picture of the *hand* with the superimposed word *RAIN*. And we compared that with how long subjects took to reject the same test display, the picture of the *umbrella,* after viewing the same context display, the picture of the *hand,* but with another word superimposed, *SOUP.*

Experimental Word trials worked similarly, as illustrated by Figure 6C. When reading this Word trial context display, subjects should have focused on the word *MONTH* and ignored the surrounding picture of a *broom*. We measured how long subjects took to reject the word *SWEEP* after reading the word *MONTH* surrounded by the *broom*. And we compared that with how long subjects took to reject *SWEEP* after viewing the same context display with the picture of a *broom* replaced by a picture of a *sandwich* (as illustrated by Figure 6C).

As in our other experiments, we presented the test displays at two intervals: immediately (50 ms) after subjects viewed the context-setting display, and after a 1-s delay. Figure 7 displays our 160 subjects' data, presented as estimated activation of the to-be-ignored pictures/words. We estimated activation of the to-be-ignored pictures/words by subtracting subjects' latencies to reject test displays that were unrelated to ignored pictures/words from their latencies to reject test displays that were related to ignored pictures/words.[2] As Figure 7 illustrates, immediately after comprehenders of both skill levels saw the context displays, the ignored pictures/words were highly activated; in fact, they were almost equally activated for the more-skilled and the less-skilled comprehenders. However, 1 s after the more-skilled comprehenders saw the context displays, the ignored pictures/words were no longer reliably activated. We suggest that the more-skilled comprehenders had successfully suppressed them. However, even after the 1-s delay, the ignored pictures/words were still highly activated for the less-skilled comprehenders; in fact, they were as activated after 1 s as they were immediately (after 50 ms). These data support the hypothesis that more-skilled comprehenders are more successful in suppressing information across modalities.

In the experiments we have described, we found that more-skilled comprehenders were more successful in rejecting irrelevant or inappropriate information. We suggest that successful suppression underlies comprehension skill. A counterexplanation is that more-skilled comprehenders are more successful in suppressing inappropriate information because they more fully appreciate what is contextually appropriate. Perhaps they more successfully employ their enhancement mechanisms, not their suppression mechanisms. We tested that hypothesis in two further experiments.

[2]Although comprehenders of both skill levels responded more rapidly on Picture trials than on Word trials, there were no interactions with modality (Picture vs. Word). So, we have collapsed across this variable in our figures.

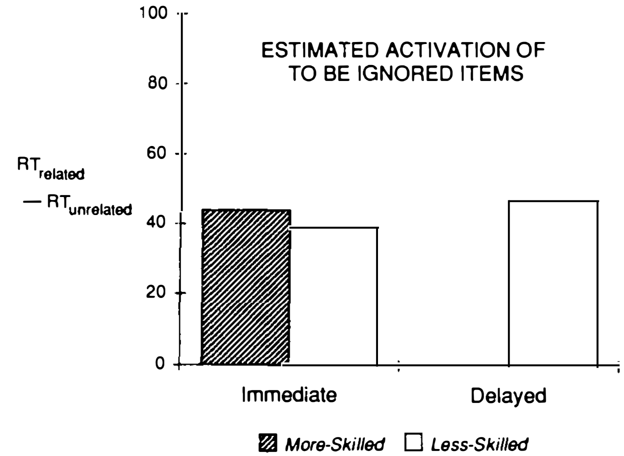

FIGURE 7. Estimated activation is the difference between subjects' latencies to reject test displays that were related versus unrelated to ignored pictures or words. Data from M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 3).

Skilled Comprehenders Do Not More Successfully Enhance Contextually Appropriate Meanings

According to the Structure Building Framework, comprehension requires enhancing the activation of memory nodes when those nodes are relevant to the structure being built. So, perhaps more-skilled comprehenders' enhancement mechanisms, not their suppression mechanisms, underlie their success at comprehension. By this logic, more-skilled comprehenders have less difficulty rejecting *ACE* after reading *He dug with the spade* because they more fully appreciate that the context of **digging** *with a spade* implies a garden tool, not a playing card.

This explanation seems unlikely given the repeated finding that more-skilled comprehenders are not more appreciative of predictable sentence contexts; in fact, laboratory research suggests just the opposite: less-skilled comprehenders often benefit *more* from predictable contexts more than do more-skilled comprehenders. For example, the word *dump* is predictable in the following context:

(7) The garbage men had loaded as much as they could onto the truck. They would have to drop off a load at the garbage **dump.**

In contrast, *dump* is less predictable in the following context:

(8) Albert didn't have the money he needed to buy the part to fix his car. Luckily, he found the part he wanted at the **dump.**

All comprehenders pronounce the word *dump* more rapidly when it occurs in the predictable context than when it occurs in the less predictable context; in other words, all comprehenders benefit from the predictable contexts. But less-skilled comprehenders benefit more than do more-skilled comprehenders (Perfetti & Roth, 1981).

We also evaluated this counterexplanation (in Gernsbacher & Faust, 1991a; Experiment 4) with adult comprehenders and a task similar to those we had used in our previous experiments. Subjects read short sentences, and following each sentence they saw a test word. As in our other experiments, the subjects' task was to verify whether the test word fit the meaning of the sentence they just read. However, in this experiment we were interested in the 80 trials in which the test word *did* indeed match the meaning of the sentence (and, therefore, the subjects should have responded "yes").

On half of those trials, the last word of the sentence was an ambiguous word, for example, *spade,* and the verb in the sentence was biased toward one meaning of the ambiguous word, for example,

(9) He **dug with** the spade.

The test word was related to the meaning of the ambiguous word that was biased by the verb, for example, *GARDEN.* In a comparison condition we presented the same sentence, but the biasing verb was replaced with a neutral verb, for example,

(10) He **picked up** the spade.

The *spade* in sentence (10) could be either a garden tool or a playing card.

We measured how rapidly subjects accepted test words after reading sentences with biasing verbs versus neutral verbs.[3] This comparison showed us how fully comprehenders could appreciate the biasing contexts: the faster subjects accepted *GARDEN* after reading the sentence with the biasing verb phrase *dug with* versus the neutral verb phrase *picked up,* the more fully they appreciated the biasing context.

We presented the test words at two intervals: immediately (100 ms) after subjects finished reading each sentence, and after a 1-s delay. We predicted that comprehenders of both skill levels would benefit from the biasing contexts; that is, both groups of comprehenders would accept test words more rapidly when the sentences contained biasing as opposed to neutral verbs. However, we were particularly interested in whether the more-skilled comprehenders would benefit more than the less-skilled comprehenders.

[3]To ensure that the biased verbs were biased and the neutral verbs were neutral, 25 students at University of Oregon read all of the experimental and comparison sentences and made unspeeded judgments about the meanings of the ambiguous words. We used biased verbs only if 95% of our students selected the meaning of the ambiguous word that we intended, and we used neutral verbs only if our students were roughly split over which meaning we intended (e.g., when given the sentence *He picked up the spade,* approximately 50% chose *GARDEN TOOL* and approximately 50% chose *PLAYING CARD*).

If more-skilled comprehenders are more successful in rejecting contextually inappropriate information (as we found in our previous experiments) simply because they are more appreciative of context, then the more-skilled comprehenders should have benefited more from the biasing contexts. In contrast, if more-skilled comprehenders are more successful in rejecting inappropriate information because they are more skilled in employing suppression, then the more-skilled comprehenders should not have benefited any more from the biasing contexts than the less-skilled comprehenders did. Based on previous literature, we predicted that the less-skilled comprehenders would benefit even more from the biasing contexts than the more-skilled comprehenders did.

Figure 8 displays our 120 subjects' data, presented as estimated activation of the biased meanings. We estimated activation of the biased meanings by subtracting subjects' latencies to accept test words like *GARDEN* after reading sentences with biasing verbs like **dug with** from their latencies to accept *GARDEN* after reading sentences with unbiased verbs like **picked up.** As Figure 8 illustrates, at both the immediate and delayed test intervals, the biased verbs led to greater activation, and this occurred for both more- and less-skilled comprehenders. Indeed, as Figure 8 also illustrates, at both test inter-

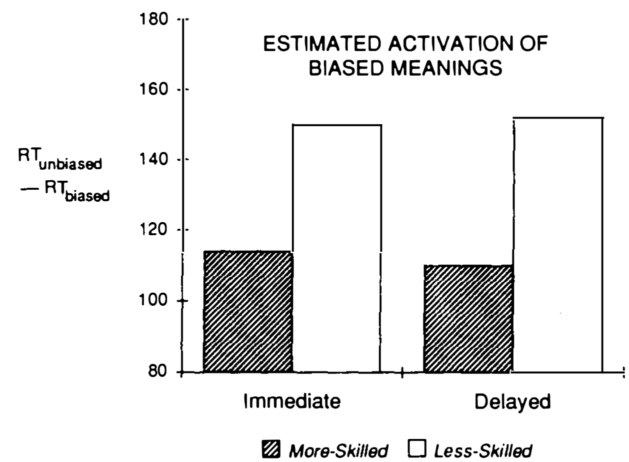

FIGURE 8. Estimated activation is the difference between subjects' latencies to accept test words like *GARDEN* after reading sentences with biasing verbs (*digging with*) versus neutral verbs (*picked up*). Data from M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 4).

vals, the less-skilled comprehenders benefited more from the biasing verbs than the more-skilled comprehenders benefited. These data do not support the hypothesis that more-skilled comprehenders are more skillful in suppressing inappropriate information because they more fully appreciate what is contextually appropriate.

Skilled Comprehenders Are Not Necessarily More Successful in Enhancing Typical Objects in Scenes

Just as sentence comprehension often requires enhancing appropriate or relevant information, scene comprehension might also require enhancing relevant information (i.e., information present in the visual array). In Gernsbacher and Faust (1991a; Experiment 2) we found that more-skilled comprehenders were more successful in suppressing the typical-but-absent objects presented in scenic arrays. Perhaps more-skilled comprehenders' enhancement mechanisms, not their suppression mechanisms, underlie their success in suppressing the typical-but-absent objects presented in scenic arrays. By this logic, more-skilled comprehenders have less difficulty rejecting *TRACTOR* after viewing an array of farm objects in which a tractor is *not* present because more-skilled comprehenders more fully comprehend the objects that are present in the scenic array.

We tested this hypothesis (in Gernsbacher & Faust, 1991a; Experiment 5) in the following way. Subjects first viewed a scenic array of objects, and then they read the name of a test object. For instance, subjects first viewed the scenic array illustrated in Figure 9A, and then they saw the test object, *TRACTOR*. The subjects' task was to verify whether the test object had been present in the array they just viewed. On 80 trials, the test object had not been present, but on 80 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 those trials, the other objects in the array were typical of the scene in which the test object typically occurs. For example, the other objects in the array shown in Figure 9A typically occur in a farm scene, just as a *tractor* does. In a comparison condition, the other objects were atypical of the scene in which the test object typically occurs. For example, the other objects in the array shown in Figure 9B do not typically occur in a farm scene.

We compared how rapidly subjects accepted *TRACTOR* after viewing it in an array of typical objects with how rapidly they accepted *TRACTOR* after viewing it in an array of atypical objects. This comparison showed us how fully comprehenders could appreciate the typical 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 context.

We presented the names of the test objects at two intervals: immediately (50 ms) after subjects finished viewing each scenic array, and after a 1-s delay.

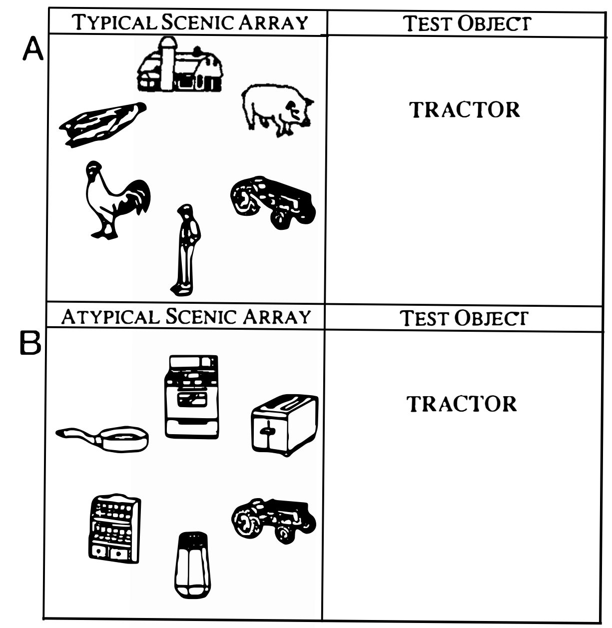

FIGURE 9. Example stimuli for experimental trials. From M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 5).

We expected that comprehenders of both skill levels would benefit from the typical contexts. That is, both groups of comprehenders would accept test objects more rapidly when the arrays contained typical objects as opposed to atypical objects. This result would corroborate Biederman et al. (1988).

However, we were interested in whether the more-skilled comprehenders would benefit more from the typical contexts. If more-skilled comprehenders are more successful in rejecting contextually inappropriate information (as we found in our previous experiments) simply because they are more appreciative of context, then they should have benefited more from the typical contexts. In contrast, if more-skilled comprehenders are more successful in rejecting inappropriate information because they are more skilled in employing suppression, then the more-skilled comprehenders should not have benefited any more from the typical contexts than the less-skilled comprehenders did.

Figure 10 displays our 40 subjects' data, presented as estimated activation of the typical-and-present objects. We estimated activation of the typical-and-present objects by subtracting subjects' latencies to accept test objects like *TRACTOR* after viewing a *tractor* in a typical (*farm*) array from their latencies to accept *TRACTOR* after viewing a *tractor* in an atypical (*kitchen*)

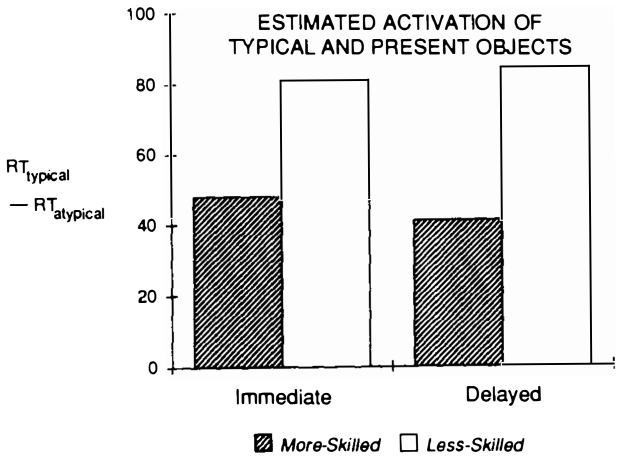

FIGURE 10. Estimated activation is the difference between subjects' latencies to accept test objects like *TRACTOR* after viewing those test objects in typical (*farm*) versus atypical (*kitchen*) arrays. Data from M. A. Gernsbacher & M. E. Faust. *Journal of Experimental Psychology: Learning, Memory, and Cognition* (1991; Experiment 5).

array. As Figure 10 illustrates, at both the immediate and delayed test intervals, the typical contexts led to greater activation, and this occurred for comprehenders of both skill levels. Indeed, as Figure 10 also illustrates, the less-skilled comprehenders benefited more from the typical contexts than did the more-skilled comprehenders. These data do not support the hypothesis that more-skilled comprehenders are more skillful in suppressing inappropriate information because they more fully appreciate what is contextually appropriate.

This dissociation between enhancement and suppression is suggested by data collected from other populations who might have comprehension difficulty. For instance, 1 s after reading a sentence such as, *The man moved the piano,* less-skilled fifth-grade readers show activation of a semantically associated but contextually less-relevant word, such as *music,* as well as activation of contextually relevant words, such as *heavy*; in contrast, 1 s after reading the same sentence, more-skilled fifth-grade readers show activation of only contextually relevant words (Merrill et al., 1981). This result suggests that less-skilled fifth-grade readers are not deficient in activating contextually appropriate information (e.g., the sense of a piano being heavy), yet they are deficient in suppressing contextually irrelevant semantic associates (e.g., the conception of a piano as a musical instrument).

Some older adults might also be characterized by less-efficient suppression mechanisms but relatively healthy enhancement mechanisms. Elderly adults show little deficit in traditional semantic priming tasks, yet they show

difficulty in "negative-priming" tasks. After younger adults focus on one object and ignore another, they are less able to identify the object they ignored (hence the term, "negative priming"). For example, after younger adults focus on a green *A* superimposed on a red *B,* they are less able to identify a red *B* if it appears on the next display. Presumably, the younger adults have efficiently suppressed the object they were supposed to ignore (e.g., the red *B*). However, older adults do not experience this negative-priming effect, suggesting that they less efficiently suppressed the to-be-ignored item (Hasher, Stoltzfus, Zacks, & Rypma, 1991; McDowd, Oseas-Kreger, & Filicon, Chapter 11, this volume; Neill, Valdes, & Terry, Chapter 7, this volume).

Finally, consider a population whose members experience grave difficulties in many everyday cognitive tasks: schizophrenics. Among other difficulties, schizophrenics are notoriously inefficient at maintaining the same topic while speaking, suggesting that they suffer from less-efficient suppression mechanisms; however, they are notoriously hyperactive in their semantic associations, suggesting that they do not suffer from less-efficient enhancement mechanisms (Chapman & Chapman, 1973). (For a more complete discussion of susceptibility to interference among schizophrenics, see Lewandowsky and Li, Chapter 10, this volume.)

SUPPRESSION IS SUSCEPTIBLE TO PROBABILITY

According to the Structure Building Framework, memory nodes are automatically activated by incoming stimuli. Once activated, memory nodes transmit processing signals: they send signals to suppress other memory nodes when the information represented by those other nodes is less relevant to the structure being developed. And they send signals to enhance other memory nodes when the information represented by those other nodes is more relevant.

This simple conception implies that suppression operates relatively automatically. According to this conception, suppression signals are obligatorily sent, based on some criterion, for instance, a similarity criterion. The literature on cognitive processes differentiates between this type of automatic mental activity from processes that are more attentional (Keele & Neill, 1978; Posner & Snyder, 1975a, 1975b). Is suppression an automatic mental activity or is the deployment of suppression signals a function of attention?

Automatic versus attentional mechanisms have been claimed to be distinguishable in the laboratory by manipulating the probability of a particular type of trial occurring within an experiment. The logic of a probability manipulation is this: if a certain type of experimental trial occurs only rarely, subjects might not even notice that type of trial. But if a certain type of trial occurs frequently, subjects might attend to that type of trial at some level of conscious or even unconscious awareness.

Consider the following experimental task: subjects see pairs of letter strings, appearing side by side (e.g., *DORTZ BLAUGH*). The subjects' task is to decide whether each member of the pair is a word. On some trials, both members are words, and on some of the trials in which both members are words, the two words are semantically related, for example, *BREAD BUTTER* . A classic finding is that the second letter string is recognized more rapidly when it appears in a pair of related words; for example, *BUTTER* is recognized more rapidly when it appears in the related-word pair *BREAD BUTTER* than when it appears in the unrelated-word pair *NURSE BUTTER* (Meyer & Schvaneveldt, 1971).

Now consider the following manipulation: in one condition, only 1/8 of the word pairs are related (*BREAD BUTTER*), and the majority (7/8) are unrelated (*NURSE BUTTER*); in another condition 1/2 are related, and 1/2 are unrelated; and in a third condition, the majority (7/8) of the word pairs are related, and only 1/8 are unrelated. With this manipulation, subjects recognize the second word of the pair more rapidly if the pair is related (just as other experiments have shown), and the advantage of the relatedness between the two words in a pair is a function of the probability of a related-word pair appearing in the experiment. When only 1/8 of the word pairs in the experiment are related, the advantage is smallest; when 7/8 of the word pairs are related, the advantage is largest. The high probability of related pairs affects subjects' processing and responses (Tweedy, Lapinski, & Schvaneveldt, 1977).

In other experiments, subjects also respond differently when there is a high versus low probability of a certain type of experimental trial. For instance, in experiments in which subjects perform a letter-matching task, subjects are shown pairs of letters, and they decide rapidly whether the members of the pair match (either physically, e.g., *A* and *A*, or in name, e.g., *a* and *A*). In Posner and Snyder's (1975b) experiment, the letter pairs were preceded by three types of cues: an informative cue, which was one of the letters of the pair (e.g., the cue was *A*, and the pair was *AA*), a neutral cue (a plus sign), or an uninformative cue, which was a letter that did not match either member of the pair (e.g., the cue was *B*, and the pair was *AA*). Posner and Snyder (1975b) varied the probability of the cue being informative. It was informative on 20%, 50%, or 80% of the trials. Subjects were fastest when the cue was informative, and when the informative cue occurred 80% of the time.

However, subjects do not always respond differently when there is a high versus a low probability of a particular type of trial. For instance, in an experiment in which subjects have to decide whether each member of a pair of letter strings is a word, subjects typically respond more rapidly to the related-word pairs (e.g., *BREAD BUTTER*) when there is a high probability of related-word pairs. However, subjects are affected by the proportion manipulation only if they have enough time to process the first word of the pair; without adequate time for processing the first word, a 1/8 versus 1/2 versus 7/8 ratio of related- to unrelated-word pairs is ineffective (den Heyer, Briand, & Dannenbring, 1983).

Consider another experimental situation in which subjects were unaffected by a proportion manipulation. In Simpson and Burgess (1985), subjects first read an ambiguous prime word, such as *BANK*. After 750 ms, each prime word disappeared, and the subjects saw a test word, such as *MONEY*. The subjects made a lexical decision to each test word. On some trials, the test words were related to the most-frequent meaning of the ambiguous prime words. For example, *MONEY* is related to the most-frequent meaning of *BANK*. On other trials, the test words were related to a less-frequent meaning of the ambiguous prime words. For example, *RIVER* is related to a less-frequent meaning of the ambiguous prime word *BANK*. These relations are illustrated in Table 1.

Simpson and Burgess (1985) measured how rapidly subjects responded to the test words (*MONEY* or *RIVER*) when the prime words were ambiguous (*BANK*) versus when they were unambiguous (e.g., *RIDDLE*), as illustrated in Table 1. Simpson and Burgess (1985) also manipulated the probability that the test words were related to the less- versus more-frequent meanings of the ambiguous prime words. In one condition, test words were related to the less-frequent meaning on the majority, 80%, of the trials, and on only 20% of the trials were the test words related to the more-frequent meanings. In a second condition, the test words were related to the less- versus more-frequent meanings on an equal number of the trials (50%). In a third condition, the test words were related to the less-frequent meanings on only 20% of the trials, and they were related to the more-frequent meanings on 80% of the trials.

Simpson and Burgess (1985) found that the probability manipulation was ineffective. Regardless of the probability that the test words would be related to the less- versus more-frequent meanings, subjects recognized (made lexical decisions to) the more-frequent meanings (*MONEY*) more rapidly than they recognized the less-frequent meanings (*RIVER*). Thus, even when

TABLE 1. Example Stimuli[a]

Context word	Test words: River	Test words: Money
Bank	Related to LESS-frequent meaning	Related to MORE-frequent meaning
Riddle	Unrelated to either meaning	Unrelated to either meaning

[a]From Simpson & Burgess, 1985.

the test words were related to the less-frequent meanings on 80% of the trials, subjects still recognized the more-frequent meanings more rapidly than they recognized the less-frequent meanings (just as they did when the test words had an equal probability of being related to the less- versus more-frequent meanings). In fact, in a fourth condition, subjects were informed that many of the prime words would be ambiguous and that 80% of the test words would be related to those prime words' less-frequent meanings. But even with this informative warning, subjects still did not recognize the less-frequent meanings more rapidly than they recognized the more-frequent meanings. These data suggest that subjects could not improve their recognition of the less-frequent meanings of ambiguous words.

In the last set of experiments that we discuss here, we used a probability manipulation to investigate further the cognitive mechanism of suppression. In Gernsbacher et al. (1990), we demonstrated that correctly understanding a sentence that contains an ambiguous word requires a suppression of the meanings of that ambiguous word that are not implied by the sentence's context. For example, correctly understanding the sentence. *He dug with the spade,* requires suppression of the meaning of *spade* that is associated with playing cards. Is this suppression of contextually inappropriate meanings of ambiguous words susceptible to the proportion of trials on which suppression is needed?

Successful Suppression of Contextually Inappropriate Meanings Is Affected by Probability

In this experiment, subjects read short sentences, and after each sentence they saw a test word. Their task was to verify whether the test word fit the meaning of the sentence they just read. On 60 trials, the test word did indeed fit the sentence, but we were more interested in the 60 trials in which the test word did *not* fit the sentence. In these 60 trials, the sentence final word was either an ambiguous word (e.g., *spade*) or an unambiguous word (e.g., *shovel).* We manipulated the proportion of trials in which the sentence final word was ambiguous or unambiguous. In the High-Proportion condition, the sentence final word was ambiguous on the majority, 67%, of the trials and unambiguous on only 33% of the trials. In the Low-Proportion condition, the sentence final word was ambiguous on only 33% of the trials and unambiguous on the majority, 67%, of the trials. The design of this experiment is illustrated in Table 2.

The test word on both types of trials was related to a meaning of the ambiguous word that was inappropriate to the context, for example, *ACE.* All the test words were presented 1000 ms after the offset of the sentence final words, and the proportion variable was manipulated between subjects. Rejecting a test word like *ACE* following an ambiguous sentence final word like *spade* requires suppressing the inappropriate meaning. Rejecting *ACE* following an unambiguous sentence final word like *shovel* does not require this suppression. If subjects' suppression of inappropriate meanings is susceptible to the probability of trials on which suppression is needed, then subjects should be more likely to suppress the contextually inappropriate meanings in the High-Proportion condition than in the Low-Proportion condition.

TABLE 2. Experimental Design

	Context sentence	Test word	# of trials	Proportion	Trial type
Gernsbacher, Varner, and Faust (1990)	He dug with the spade.	ACE	40	50%	Suppression
	He dug with the shovel.	ACE	40	50%	No suppression
Low-Proportion condition	He dug with the spade.	ACE	20	33%	Suppression
	He dug with the shovel.	ACE	40	67%	No suppression
High-Propostion condition	He dug with the spade.	ACE	40	67%	Suppression
	He dug with the shovel	ACE	20	33%	No suppression

Figure 11 displays our 202 subjects' data, presented as estimated activation of the inappropriate meanings. We estimated activation of the inappropriate meanings by subtracting subjects' latencies to reject test words like *ACE* after reading ambiguous words like *spade* from their latencies to reject test words like *ACE* after reading unambiguous words like *shovel.* In Figure

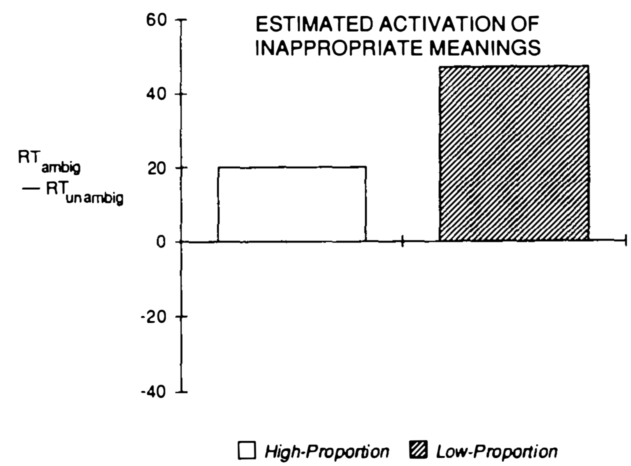

FIGURE 11. Data from the ambiguous word proportionality manipulation experiment. Estimated activation is the difference between subjects' latencies to reject test words like *ACE* after reading ambiguous words like *spade* versus unambiguous words like *shovel.*

11, the data provided by the subjects tested in the High-Proportion condition are represented by the unfilled bars, and the data provided by subjects tested in the Low-Proportion condition are represented by the hatched bars.

As Figure 11 illustrates, the inappropriate meanings remained more activated in the Low-Proportion condition than they did in the High-Proportion condition. This finding suggests that subjects were more inclined to suppress the contextually inappropriate meanings in the High-Proportion condition.

Successful Suppression of Incorrect Forms of Homophones Is Affected by Probability

In Gernsbacher and Faust (1991a), we demonstrated that correctly understanding a sentence that contains a homophone requires suppressing the other forms of that homophone that are not implied by the sentence's context. For example, correctly understanding the sentence, *He had lots of patients,* requires suppressing the homophone *patience.* In a recent experiment, subjects read short sentences, and after each sentence they saw a test word. Their task was to verify whether the test word fit the meaning of the sentence they just read. On 60 trials, the test word did indeed fit the meaning of the sentence, but we were more interested in the 60 trials in which the test word did *not* fit the meaning of the sentence. These were our experimental sentences.

We manipulated how many of these 60 experimental sentences had sentence final words that were homophones versus nonhomophones, for example, *He had lots of* ***patients*** versus *He had lots of* ***students.*** In the High-Proportion condition, 67% of the 60 experimental sentences contained homophonic sentence final words, and only 33% of the experimental sentences had nonhomophonic sentence final words. In the Low-Proportion condition, only 33% of the 60 experimental sentences contained homophonic sentence final words, and 67% had nonhomophonic sentence final words. The design of this experiment is summarized in Table 3.

The test words for all the experimental sentences were related to a meaning of the homophone's other form, for example, *CALM.* All the test

TABLE 3. Experimental Design

	Context sentence	Test word	# of trials	Proportion	Trial type
Gernsbacher and Faust (1991b)	He had lots of **patients.**	CALM	40	50%	Suppression
	He had lots of **students.**	CALM	40	50%	No suppression
Low-Proportion condition	He had lots of **patients.**	CALM	20	33%	Suppression
	He had lots of **students.**	CALM	40	67%	No suppression
High-Proportion condition	He had lots of **patients.**	CALM	40	67%	Suppression
	He had lots of **students.**	CALM	20	33%	No suppression

words were presented 1000 ms after the offset of the sentence final words, and the proportion variable was manipulated between subjects. Rejecting a test word like *CALM* following a homophonic sentence final word like *patience* requires suppressing the incorrect form. Rejecting *CALM* following a nonhomophonic sentence final word like *students* does not require this suppression. If subjects' suppression of the incorrect forms of homophones is susceptible to the probability of trials on which suppression is needed, then our subjects should have been more likely to suppress the incorrect forms in the High-Proportion condition than in the Low-Proportion condition.

Figure 12 displays our 200 subjects' data, presented as estimated activation of the homophones' incorrect forms. We estimated activation of the homophones' incorrect forms by subtracting subjects' latencies to reject test words like *CALM* after reading nonhomophones like *students* from their latencies to reject test words like *CALM* after reading homophones like *patients.* In Figure 12, the data provided by the subjects tested in the High-Proportion condition are represented by the unfilled bars, and the data provided by the subjects tested in the Low-Proportion condition are represented by the hatched bars.

As Figure 12 illustrates, the incorrect forms remained more activated in the Low-Proportion condition than they did in the High-Proportion condition. This finding suggests that subjects were more inclined to suppress the homophones' incorrect forms in the High-Proportion condition than they were in the Low-Proportion condition.

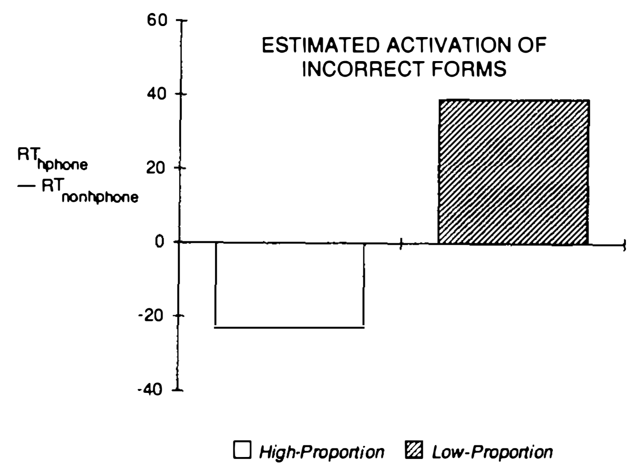

FIGURE 12. Data from the homophone proportionality manipulation experiment. Estimated activation is the difference between subjects' latencies to reject test words like *CALM* after sentence final homophones like *patients* versus sentence final nonhomophones like *students.*

CONCLUSIONS

We began this chapter by briefly sketching our conception of suppression. We envision suppression as an active dampening of activation. We propose that suppression differs from passive decay. We also propose that successful suppression underlies skilled comprehension. We then presented several experiments that demonstrated that skilled comprehenders are more successful in suppressing inappropriate, incorrect, absent, or to-be-ignored information. And we presented some further experiments that demonstrated that skilled comprehenders are not better at rejecting inappropriate or related-but-absent information simply because they more keenly recognize what is appropriate or related.

In the last part of our chapter we discussed whether the mechanism of suppression that we have identified to underlie skilled comprehension is susceptible to probability. We presented two new experiments that demonstrated that successful suppression of the contextually inappropriate meanings of ambiguous words and successful suppression of the incorrect forms of homophones are susceptible to the probability of trials on which suppression is needed. These new data suggest that our conception of suppression is mediated somewhat by the demands of the experimental context. It remains for our further investigation to discern where skilled suppression during comprehension falls on the continuum of automatic versus more attentionally demanding cognitive processes.

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REFERENCES

Allport, D. A., Tipper, S. P., & Chmiel, N. R. (1985). Perceptual integration and postcategorical filtering. In M. I. Posner & O. S. M. Marin (Eds.), *Attention and performance XI* (pp. 107–132). Hillsdale, NJ: Erlbaum.

Becker, C. A. (1976). Semantic context and word frequency effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 2*, 556–566.

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 non-scene 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.

Bjorklund, D. F., & Harnishfeger, K. K. (1990). The resources construct in cognitive development: Diverse sources of evidence and a theory of inefficient inhibition. *Developmental Review, 10*. 48–71.

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). New York: Academic Press.

Coltheart, V., Laxon, V., Rickard, M., & Elton, C. (1988). Phonological recoding in reading for meaning by adults and children. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 387–397.

Conrad, C. (1974). Context effects in sentence comprehension: A study of the subjective lexicon. *Memory & Cognition, 2*, 130–138.

Dempster, F. N. (1992). The rise and fall of the inhibitory mechanism: Toward a unified theory of cognitive development and aging. *Developmental Review, 12*, 45–75.

Dempster, F. N. (1993). Resistance to interference: Developmental changes in a basic processing mechanism. In M. L. Howe & R. Pasnak (Eds.), *Emerging themes in cognitive development* (pp.1–27). New York: Springer-Verlag.

den Heyer, K., Briand, K., & Dannenbring, G. L. (1983). Strategic factors in a lexical-decision task: Evidence for automatic and attention-driven processes. *Memory & Cognition, 11*, 374–381.

Doctor, E. A., & Coltheart, M. (1980). Children's use of phonological encoding when reading for meaning. *Memory & Cognition, 8*, 195–209.

Duffy, S. A., Morris, R. K., & Rayner, K. (1988). Lexical Ambiguity and fixation times in reading. *Journal of Memory and Language, 27*, 429–446.

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. (1985). Surface information loss in comprehension. *Cognitive Psychology, 17*, 324–363.

Gernsbacher, M. A. (1989). Mechanisms that improve referential access. *Cognition, 32*, 99–156.

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

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

Gernsbacher, M. A., & Faust, M. (1991b). The role of suppression in sentence comprehension. In G. B. Simpson (Ed.), *Understanding word and sentence* (pp. 97–128). Amsterdam: North-Holland.

Gernsbacher, M. A., & Hargreaves, D. (1988). Accessing sentence participants: The advantage of first mention. *Journal of Memory and Language, 27*, 699–717.

Gernsbacher, M. A., Hargreaves, D., & Beeman, M. (1989). Building and accessing clausal representations: The advantage of first mention versus the advantage of clause recency. *Journal of Memory and Language, 28*, 735–755.

Gernsbacher, M. A., & Jescheniak, J. D. (1994). *Cataphoric devices in spoken discourse.* Manuscript submitted for publication.

Gernsbacher, M. A., & Shroyer, S. (1989). The cataphoric use of the indefinite *this* in spoken narratives. *Memory & Cognition, 17*, 536–540.

Gernsbacher, M. A., & Varner, K. R. (1988). *The multi-media comprehension battery* (Tech. Rep. 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.
Harnishfeger, K. K., & Bjorklund, D. F. (1993). The ontogeny of inhibition mechanisms: A renewed approach to cognitive development. In M. L. Howe & R. Pasnak (Eds.), *Emerging themes in cognitive development* (pp. 28–49). New York: Springer-Verlag.
Hasher, L., Stoltzfus, E. R., Zacks, R., & Rypma, B. (1991). Age and inhibition. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 163–169.
Hasher, L., & Zacks, R. T. (1988). Working memory, comprehension, and aging: A review and a new view. In G. H. Bower (Ed.), *The psychology of learning and motivation* (Vol. 22, pp. 193–225). San Diego: Academic Press.
Just, M. A., & Carpenter, P. A. (1992). A capacity theory of comprehension: Individual differences in working memory. *Psychological Review, 99,* 122–149.
Keele, S. W., & Neill, W. T. (1978). Mechanisms of attention. In E. C. Carterette & M. P. Friedman (Eds.), *Handbook of perception* (pp. 3–47). New York: Academic Press.
Kellas, G., Paul, S. T., Martin, M., & Simpson, G. B. (1991). Contextual feature activation and meaning access. In G. B. Simpson (Ed.), *Understanding word and sentence* (pp. 47–71). New York: Elsevier.
Kintsch, W. (1988). The role of knowledge in discourse comprehension: A construction-integration model. *Psychological Review, 95,* 163–182.
Kintsch, W., & Mross, E. F. (1985). Context effects in word identification. *Journal of Memory and Language, 24,* 336–349.
Lucas, M. (1987). Frequency effects on the processing of ambiguous words in sentence context. *Language and Speech, 30,* 25–46.
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.
Marslen-Wilson, W., & Welsh, A. (1978). Processing interactions and lexical access during word recognition in continuous speech. *Cognition, 10,* 29–63.
McClelland, J. L., & Rumelhart, D. E. (1981). An interactive activation model of context effects in letter perception: Part 1. An account of basic findings. *Psychological Review, 88,* 375–407.
Merrill, E. C., Sperber, R. D., & McCauley, C. (1981). Differences in semantic encoding as a function of reading comprehension skill. *Memory & Cognition, 9,* 618–624.
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.
Neill, W. T., & Westberry, R. L. (1987). Selective attention and the suppression of cognitive noise. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 327–334.
Norris, D. (1986). Word recognition: Context effects without priming. *Cognition, 22,* 93–136.
Onifer, W., & Swinney, D. A. (1981). Accessing lexical ambiguities during sentence comprehension: Effects of frequency of meaning and contextual bias. *Memory & Cognition, 9,* 225–236.
Palmer, S. E. (1975). The effects of contextual scenes on the perception of objects. *Memory & Cognition, 3,* 519–526.
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.

Posner, M. I., & Snyder, C. R. R. (1975a). Attention and cognitive control. In R. L. Solso (Ed.), *Information processing and cognition: The Loyola symposium* (pp. 55–85). Hillsdale, NJ: Erlbaum.
Posner, M. I., & Snyder, C. R. R. (1975b). Facilitation and inhibition in the processing of signals. In P. M. A. Rabbitt & S. Dornic (Eds.), *Attention and performance V* (pp. 669–682). New York: Academic Press.
Rosson, M. B. (1985). The interaction of pronunciation rules and lexical representations in reading aloud. *Memory & Cognition, 13,* 90–99.
Schank, R. C., & Abelson, R. P. (1977). *Scripts, plans, goals and understanding.* Hillsdale, NJ: Erlbaum.
Seidenberg, M. S., Tanenhaus, M. K., Leiman, J. M., & Bienkowski, M. (1982). Automatic access of the meanings of ambiguous words in context: Some limitations of knowledge-based processing. *Cognitive Psychology, 14,* 489–537.
Simpson, G. B., & Burgess, C. (1985). Activation and selection processes in the recognition of ambiguous words. *Journal of Experimental Psychology: Human Perception and Performance, 11,* 28–39.
Smith, M. C., & McGee, L. E. (1980). Tracing the time course of picture-word processing. *Journal of Experimental Psychology: General, 109,* 373–392.
Swinney, D. A. (1979). Lexical access during sentence comprehension: (Re)consideration of context effects. *Journal of Verbal Learning and Verbal Behavior, 18,* 645–659.
Tabossi, P. (1988a). Accessing lexical ambiguity in different types of sentential contexts. *Journal of Memory and Language, 27,* 324–340.
Tabossi, P. (1988b). Effects of context on the immediate interpretation of unambiguous nouns. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 153–162.
Tanenhaus, M. K., Leiman, J. M., & Seidenberg, M. S. (1979). Evidence for multiple stages in the processing of ambiguous words in syntactic contexts. *Journal of Verbal Learning and Verbal Behavior, 18,* 427–440.
Till, R. E., Mross, E. F., & Kintsch, W. (1988). Time course of priming for associate and inference words in a discourse context. *Memory & Cognition, 16,* 283–299.
Tipper, S. P., & Driver, J. (1988). Negative priming between pictures and words in a selective attention task: Evidence for semantic processing of ignored stimuli. *Memory & Cognition, 16,* 64–70.
Tweedy, J. R., Lapinsky, R. H., & Schvaneveldt, R. W. (1977). Semantic-context effects on word recognition: Influence of varying the proposition of items presented in an appropriate context. *Memory & Cognition, 5,* 84–89.
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.
Yee, P. L. (1991). Semantic inhibition of ignored words during a figure classification task. *Quarterly Journal of Experimental Psychology, 43A,* 127–153.
Zechmeister, E. B., & Nyberg, S. E. (1982). *Human memory: An introduction to research and theory.* Monterey CA: Brooks/Cole.