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The Role of Inhibition in Meaning Selection: Insights From Retrieval-Induced Forgetting

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Over the last decade, several authors have proposed that inhibitory processes play a role in resolving lexical ambiguity (e.g., Faust & Gernsbacher, 1996; Gernsbacher, 1990; Gernsbacher & Faust, 1991a; Simpson & Adamopoulos, chapter 7, this volume; Simpson & Kang, 1994). According to this idea, reading a homograph initially activates all of its meanings. If the comprehender is to construct a coherent interpretation of the sentence, these meanings cannot all remain active. In the selection of the contextually appropriate meaning, inhibition is thought to suppress the inappropriate senses. In support of this view, several studies have found that selecting one meaning either diminishes later priming for the rejected meaning or reverses it (e.g., Faust & Gernsbacher, 1996; Gernsbacher & Faust, 1991a; Simpson & Adamopoulos, chapter 7, this volume; Simpson & Kang, 1994).

The inhibitory effects of meaning selection are often thought to be implemented by a general attentional suppression process. This hypothesis is motivated in part by an analogy between lexical ambiguity resolution and negative priming (e.g., Tipper, 1985; Tipper & Cranston, 1985). Negative priming is an attentional phenomenon in which the time to respond to a visual stimulus increases after it has been actively ignored on a preceding trial. For instance, naming the target letter "D" in a visual display on Trial N is often slower if participants ignored the letter "D" on Trial N-1 while attending to the target "T." Negative priming was initially attributed to attentional suppression of the ignored information on the preceding trial (Tipper, 1985; Tipper & Cranston, 1985). To extend this mechanism to meaning selection, one need only assume that attention can be directed to semantics to overcome internal distraction from competing representations (e.g., M. C. Anderson & Bjork, 1994; M. C. Anderson & Spellman, 1995; Blaxton & Neely, 1983; Carr & Dagenbach, 1990) and that meaning selection is merely a special case of attentional selection (Gernsbacher & Faust, 1991a; Simpson & Kang, 1994).

If a general attentional inhibition process contributes to meaning selection, then inhibitory phenomena in nonlanguage contexts may yield insights into how inhibition operates during meaning selection. In this chapter, we explore this possibility. Our main concern is work on inhibitory processes in memory

retrieval. We adopt this focus for several reasons. First, although the analogy between attentional selection and lexical ambiguity resolution seems apt, there are substantial differences in the cognitive situations posed by the negative priming paradigm (e.g., exogenously focused attention and the need to ignore visual distraction) and by lexical ambiguity resolution (e.g., endogenously focused attention and the need to ignore conceptual distraction). Although a common mechanism may be involved, one might wonder whether the properties of negative priming and meaning selection need map onto one another. To the extent that meaning selection can be seen as a special case of retrieval, work on inhibition in long-term memory may provide a closer analogy. Second, the inhibitory interpretation of negative priming has been questioned (see, e.g., Fox, 1995; Neill & Valdes, 1992; Park & Kanwisher, 1994). In our work on retrieval, however, we have focused considerable effort on excluding noninhibitory alternatives by developing new methodologies for isolating inhibition. Finally, we recently conducted experiments using these methodologies in a paradigm relevant to ambiguity resolution.

In the first section of this chapter, we review our work on inhibitory processes in memory retrieval and the findings that have led us to conclude that inhibition is at work. In the second section, we present studies in which we apply these methods to a paradigm relevant to ambiguity resolution. We close by discussing how our methods can be extended to work on meaning selection to provide more diagnostic tests of inhibition. Of interest are principles of inhibition that transcend any particular variety of retrieval.

Inhibitory Processes and the Forgetting of Events

Retrieval competition is a basic feature of human memory. The more items that are associated to a retrieval cue, the more difficult it is to retrieve any one (Watkins, 1978). The ability to retrieve a target item given a cue is also thought to be more impaired by competitors that are strongly associated to that cue.[1] These principles were advanced early in the history of memory research (McGeoch, 1936, 1942) and motivate relative strength theories of retrieval (e.g., J. R. Anderson, 1983; Raaijmakers & Shiffrin, 1981). The tendency for the meanings of a homograph to compete during word reading is a special case of competition in which the associates of the cue (i.e., the word) are alternative meanings in semantic memory. If this view is correct, theories of lexical access may benefit from research that examines the mechanisms that resolve competition during retrieval.

Our approach to studying retrieval has been to ask people to recall simple events (typically words) and to later measure any side effects of retrieval on the

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[1]As will become clear in later sections, we have questioned the assumption that stronger competitors cause more forgetting. Our work indicates that stronger competitors do not impair recall *probability* of targets, given that (a) the time given for recall is not overly constrained and (b) the contribution of output inhibition from stronger competitors is controlled (M. C. Anderson et al., 1994; Anderson, Bjork, & Bjork, 2000). We agree that stronger competitors increase *retrieval time* for a target, making that competitor more interfering.

ability to recall related memories. Studying the side effects of retrieval allows us to make inferences about the basic mechanisms underlying that process. Like many interested in ambiguity resolution, we have been concerned with the role of domain-general inhibition processes in resolving retrieval competition (M. C. Anderson, Bjork, & Bjork, 1994; M. C. Anderson & Neely, 1996; M. C. Anderson & Spellman, 1995). The main difference in our approach has been an emphasis on episodic retrieval rather than on meaning selection. Nevertheless, several principles of this work appear to transcend our paradigm, suggesting that they may be properties of retrieval more broadly. To illustrate these principles, we first describe our empirical approach. We then describe findings that have led us to favor inhibition.

Experimental Approach and Basic Findings

All of the experiments reviewed here used variations on the same basic procedure, called the *retrieval-practice paradigm*. This paradigm capitalizes on a simple implication of the attentional inhibition view: If recalling something suppresses competing representations, suppressed items should be more difficult to recall on a later test. The suppressed items should be harder to recall compared with items from a baseline set that was also studied but none of whose members were initially retrieved. To test this, we would ask participants to study a number of categories, typically eight, like *fruits* and *drinks*, with six members in each, and to do "retrieval practice" on some of the items. The goal of the retrieval-practice phase is to have participants repeatedly recall some of the items from some of the categories (e.g., *fruit–orange*), with the aim of examining the impact of that practice on the retention of related items, such as *banana*. To foster selective retrieval of the to-be-practiced items (e.g., *orange*), we give participants cues like *fruit–or——*, which directs them to recall the particular example they studied that corresponds to those cues. Each practiced item is typically practiced three times to ensure that the manipulation is strong.

After a 20-minute delay, participants' memory for all of the items is tested. Each category name is provided in turn, and participants are asked to recall as many members as they can. Naturally, the items that participants practiced (e.g., *orange*) are recalled the best on this test. Of greater interest is the fact that the earlier retrieval-practice manipulation impairs the long-term retention of semantically related items (e.g., *banana*) compared with items in the baseline categories that were studied but not practiced (*drinks*). In other words, repeatedly recalling some items caused long-lasting forgetting of related items— a phenomenon called *retrieval-induced forgetting* (M. C. Anderson et al., 1994).

Retrieval-induced forgetting supports the idea that recalling information from long-term memory involves the suppression of competing items. These findings can also be explained without recourse to inhibition, however (see M. C. Anderson & Bjork, 1994; M. C. Anderson & Neely, 1996, for reviews). For instance, impaired recall of *banana* might simply reflect greater interference on the final recall test from stronger practiced category mates like *orange*. That is, perhaps while trying to recall *banana* on the final test, participants are only able to think of *orange* because it has been made hyperaccessible by its earlier

practice. Because these sorts of blocking mechanisms can explain retrieval-induced forgetting, we need a different form of evidence to provide unique support for active suppression.

M. C. Anderson and Spellman (1995) devised a way of separating noninhbitory and inhibitory factors, called the *independent probe method*. According to Anderson and Spellman, there are situations in which inhibitory theories of retrieval predict forgetting where associative blocking theories predict none. For example, associative blocking theories predict that strengthening category–exemplar associations (e.g., *red–blood*) through retrieval practice should make it more difficult to recall related exemplars (e.g., *red–tomato*) when their shared category (*red*) is given as a test cue. But testing the related exemplar (*tomato*) with an independent cue (e.g., *food*) should circumvent blocking from *red–blood*, and thus no impairment should be found. However, inhibitory theories predict that related items like *tomato* should be made less accessible generally (because they are suppressed), regardless of whether they are tested with the retrieval-practice cue (*red*) or with an independent cue (i.e., an independent probe, e.g., *food*). Thus, retrieval-induced forgetting should be *cue independent*.

Across five experiments, M. C. Anderson and Spellman (1995) confirmed this prediction of the inhibition view. Performing retrieval practice on items such as *red–blood* impaired the recall of *tomato* to the same extent, regardless of whether it was tested with the retrieval-practice cue (*red*) or an independent probe (*food*). This tendency for inhibition to generalize to independent probes has been replicated with different categories (M. C. Anderson, Green, & McCulloch, 2000), with memory for complex factual materials (M. C. Anderson & Bell, 2001) and in a fan-effect design (Radvansky, 2000).

Two lines of research have shown the foregoing memory inhibition effects are linked to the need to resolve interference during retrieval. The first has shown that there is something special about recall that inhibits competitors. For instance, when retrieval practice is replaced with extra study trials on practiced items, related items are no longer impaired (M. C. Anderson, Bjork, & Bjork, in press). This finding has been replicated using visuospatial representations (Ciranni & Shimamura, 1999) instead of taxonomic categories (see also, Blaxton & Neely, 1983, for an analogous dissociation in semantic retrieval). Indeed, extra study trials on to-be-practiced items do not cause cue-independent impairment, even though retrieval practice does (M. C. Anderson & Shivde, 2001b). The second line of work has shown that the amount of retrieval-induced forgetting is related to the degree of interference caused by a competitor. For instance, greater retrieval-induced forgetting is found for high than for low taxonomic frequency exemplars, the latter of which are less likely to interfere during practice (M. C. Anderson et al., 1994; see also Bauml, 1998). These two lines of work suggest that inhibition is triggered by the need to suppress interference caused by competitors, as is predicted by the attentional suppression perspective.

Two additional properties of retrieval-induced forgetting are worth noting. First, inhibition appears to be restricted to those competitors in memory that are not integrated with the retrieval target and that thus impede selective retrieval. That is, if participants encode exemplar-to-exemplar associations be-

tween the to-be-practiced items and their competitors, retrieval practice no longer suppresses other category members (M. C. Anderson & McCulloch, 1999; see also M. C. Anderson & Bell, 2001; Anderson, Green, & McCulloch, 2000). This protective feature of integration has also been found in studies of fan interference (e.g., Myers, O'Brien, Balota, & Toyofuku, 1984; Radvansky & Zacks, 1991).

Second, retrieval-induced forgetting has been generalized to nonverbal stimuli. For example, it has been found with arbitrary geometric stimuli. People have been induced to forget the location, shape, and color of an object by retrieving information about similar objects (Ciranni & Shimamura, 1999). Retrieval-induced forgetting also has been found in an eyewitness memory paradigm, with more complex stimuli than used here (Shaw, Bjork, & Handal, 1995). By "interrogating" participants about a mock crime that they "witnessed" in a slide presentation, participants can be induced to forget other similar information not included in the interrogation (see also Koutstaal, Schacter, Johnson, & Galluccio, 1999). These findings argue that these inhibitory effects are not restricted to memory for previously studied words but generalize to memories varying widely in content and complexity.

A Retrieval-Induced Forgetting Study Using Homographs

The foregoing studies support a role of inhibitory processes in retrieval. As predicted, related items are most inhibited when they cause retrieval competition, suggesting that inhibition resolves interference. These processes suppress the competitor itself, causing forgetting that generalizes to novel test cues. This *cue independence* suggests that noninhibitory mechanisms do not cause retrieval-induced forgetting. Indeed, even when associative blocking would be expected, competitors are often unimpaired provided that the practiced items are strengthened in a way that does not require effortful recall. These properties of inhibition appear quite general, having been observed in episodic and semantic recall and with memory for categorical, propositional, visuospatial, and even eyewitness memory materials. Given this generality, it is reasonable to wonder to what extent such effects might provide a viable model of inhibition in meaning selection.

We have recently conducted experiments that suggest that the properties of retrieval-induced forgetting may indeed apply to meaning selection. These studies used our previous methodology except that participants initially encoded homographs and related words as stimuli and responses instead of categories and exemplars. Our goal was to provide converging evidence for the core properties of retrieval-induced forgetting by exploiting the natural characteristics of homographs. In particular, we sought to create varying degrees of retrieval competition by having participants perform retrieval practice on either the dominant or the subordinate meaning of a homograph. We expected that if participants practiced a word related to a homograph's subordinate meaning (e.g., *arm–missile*), words related to its dominant meaning (e.g., *shoulder*) would need to be suppressed. However, when a word related to the dominant meaning is practiced, the subordinate meaning should cause little interference, and so little forgetting should be found.

In these studies, we also sought to learn whether retrieval-induced forgetting would be tied specifically to retrieval practice and not the mere repetition of a word related to one meaning of a homograph. To look at this, we manipulated whether participants received retrieval practices or repeated presentations of a word related to the to-be-practiced meaning (e.g., *arm–missile*). Finally, if inhibition supports retrieval practice, impairment of the suppressed meaning should generalize to independent test cues not related to the homograph or its practiced meaning, as predicted by the *cue-independence* property.
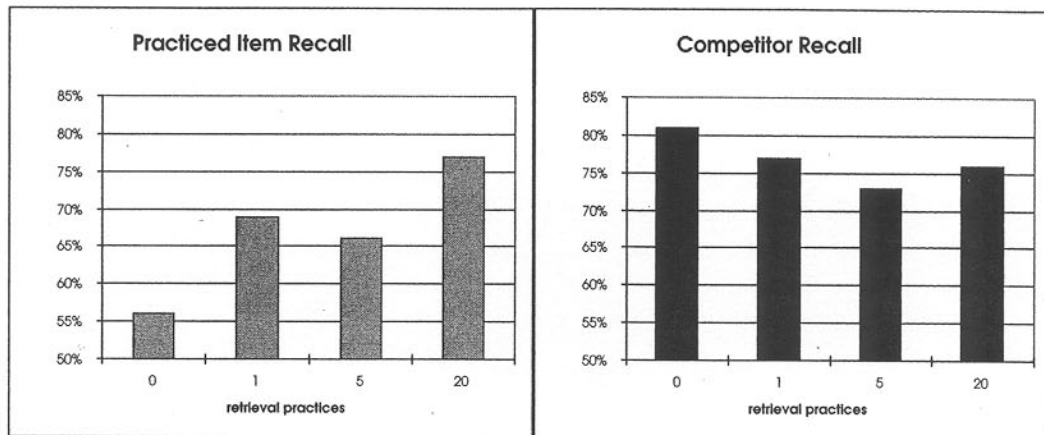
Experiment 1

In our first experiment, participants encoded 56 "triplets" of word pairs, composed of a pair related to the homograph's subordinate meaning (e.g., *arm–missile*), a pair related to its dominant meaning (e.g., *arm–shoulder*), and a pair that provided an independent probe into the dominant meaning (e.g., *satchel–shoulder*); these pairs were presented separately, throughout the list, in random order. Following encoding, participants performed retrieval practice (or received extra presentations, within subjects, but on different items) on the word associated to the subordinate meaning of each homograph (e.g., *arm–missile*) 0, 1, 5, or 20 times during a retrieval-practice phase. Ten minutes after the practice phase, we tested participants' recall of the words associated to the dominant meanings (e.g., *arm–shoulder*) using the homograph and a letter stem as test cues (e.g., *arm–s——*). (We reserved the independent probe pair, *satchel–s——*, for Experiment 2.) In the retrieval-practice condition, we expected retrieval practice on the subordinate meaning (*arm–missile*) to impair the recall of its dominant meaning (*arm–shoulder*), with the degree of impairment increasing with the number of retrieval practices.

The results of this retrieval-practice manipulation are depicted in Figure 11.1a, which plots the percentage of words correctly recalled on the final test. As can be seen in the right half of Figure 11.1a, the final recall of words related to the dominant sense (e.g., *arm–shoulder*) was impaired, with impairment increasing with the number of practices given to the subordinate sense (e.g., *arm–missile*). (Although there is an unexpected increase in recall in the 20-practice condition, this derives from special strategies identified in other studies and will not be discussed here.) The left side depicts a between-subjects control condition in which participants recalled the practiced items on the final test. These data quantify the strengthening of practiced items and how this increases with practice.

The results of our retrieval-practice condition extend the impairment found in previous studies of retrieval-induced forgetting to homographs and show further that the degree of impairment increases with the number of practices given to a target. The extra-presentations condition yielded a surprise, however. Unlike in prior work, repeatedly presenting to-be-practiced items impaired the recall of words related to the dominant meaning. As shown in Figure 11.1b, the recall of the dominant meaning was highly impaired, with forgetting increasing with the number of extra presentations given to the subordinate sense. The practiced words themselves were strengthened, as can be seen in the left panel

Retrieval Practice Condition (a)

Practiced Item Recall

Competitor Recall

retrieval practices

retrieval practices

Extra Exposures Condition (b)

Practiced Item Recall

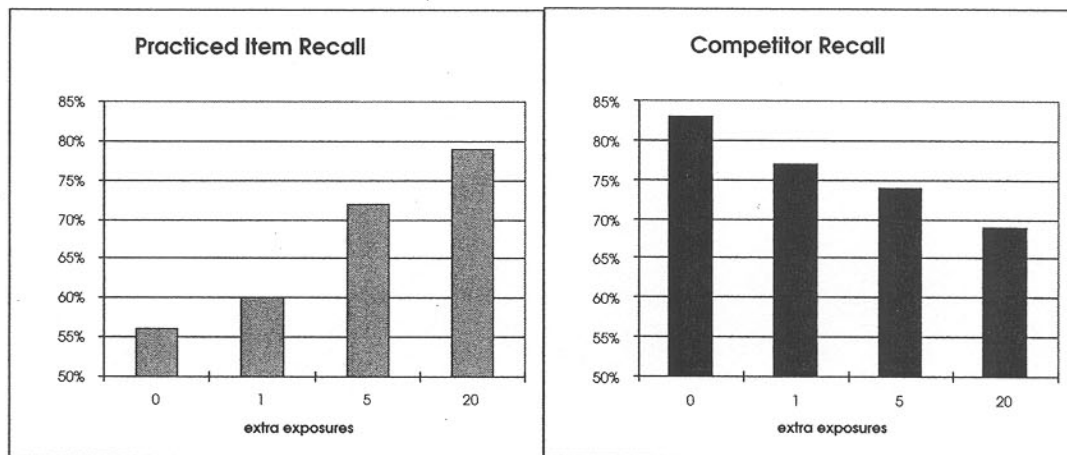**Competitor Recall**

extra exposures

extra exposures

Figure 11.1. (a) Final recall for the word pairs that received retrieval practice (1st panel, left) and the competing dominant meaning (2nd panel) as tested by the homograph and a letter stem in Experiment 1. (b) Final recall for the word pairs that received extra exposures (3rd panel) and the competing dominant meaning (4th panel) as tested by the homograph and a letter stem in Experiment 1. For both conditions, performance on the practiced items increases with increasing amounts of extra exposure, whereas performance on the unpracticed competitor declines.

of Figure 11.1b. Comparing Figures 11.1a and 1b, it is clear that neither strengthening nor impairment varied across the retrieval-practice and extra-presentations conditions.

Because we expected inhibition to be specific to retrieval practice, we must consider why retrieval practice and extra presentations yielded similar results. There are at least three ways to explain this similarity. First, the impairment may be caused by associative blocking. That is, participants may have been unable to recall *arm–shoulder* because the practiced meaning (*arm–missile*)

was strengthened so much by extra presentations that it intruded perseveratively during the test phase, blocking access to the dominant meaning. This account is consistent with the significant and comparable strengthening of practiced items in the retrieval-practice and extra-presentations conditions but is incompatible with work showing that strengthening practiced items does little to impair recall (M. C. Anderson, Bjork, & Bjork, 1994; M. C. Anderson et al., 2000; Blaxton & Neely, 1983; Ciranni & Shimamura, 1999; see also, Bauml, 1998). Second, inhibition may have caused impairment in both the retrieval-practice and extra-presentations conditions. This explains similar impairment in the two conditions, but it requires the assumption that inhibitory mechanisms work differently in meaning selection, because inhibition has been found to be recall specific in other contexts.

A final possibility—and the one that we favor—is that the impairment found in Experiment 1 is caused by a recall-specific suppression process, as we had hypothesized. Why then might retrieval practice and extra presentations have impaired the recall of the dominant sense similarly? Perhaps these manipulations had their effects at different stages in the procedure. Suppose the dominant meaning was inhibited by retrieval practice and not by extra presentations as we hypothesized. Although this should have led to differential impairment on the final test, perhaps this difference was compensated for by a new source of impairment in the extra-presentations condition during the test itself. For instance, the strengthening of the practiced meanings by extra presentation may have led the practiced words to be recalled first (covertly) on the final test, even though the dominant meaning was desired. This covert recall may have functioned like a retrieval-practice trial, causing test-time suppression of the dominant meaning. Thus, even though there was no retrieval practice, the impairment may nevertheless reflect recall-specific inhibition. This test-time impairment would grow as more extra presentations are given, because the additional strengthening would have made practiced items more likely to be covertly recalled. We evaluated these hypotheses and the property of cue independence in Experiment 2.

Experiment 2: Cue Independence and Recall Specificity

Experiment 2 was identical to Experiment 1, except for the final test. In Experiment 2, we tested participants' memory for the associate of the dominant meaning using a unique cue and a letter stem (e.g., *satchel–s——* for *shoulder*) instead of using the homograph and a letter stem (e.g., *arm–s——*). Using a unique cue allowed us to test the dominant meaning in a way that precludes associative blocking. When participants try to recall *shoulder* given *satchel–s——*, it is unlikely that *missile*, the practiced word, will come to mind and block *shoulder*. Thus, if blocking caused the impairment in Experiment 1, *shoulder* should be unimpaired by retrieval practice or extra presentations with this new test. If suppression causes the impairment, however, then the associate of the inhibited meaning should be less accessible even when it is tested from a unique cue (i.e., an independent probe). In other words, impairment should be cue independent.

Figure 11.2a displays the results from the retrieval-practice condition of Experiment 2, with final recall performance for the unpracticed dominant sense plotted in the right half of the figure. As expected, final recall of the dominant sense varied reliably with the number of retrieval practices given to the subordinate sense. However, the relation between the number of practices and inhibition was more complex than expected. As shown in Figure 11.2a, accessibility of the dominant sense increased (relative to the zero baseline condition) after the first practice of the subordinate sense. This initial boost is likely to arise from the very low recall rate for the first practice trial (34%) compared with the practice success rate on all later trials (83%). According to participants' postexperimental questionnaire responses, the early practice trials on a given word were difficult because the dominant sense of the homograph intruded, hindering recall of the subordinate meaning. Thus, the word related to the dominant sense may have been strengthened by its intrusion, leading to facilitation in the final recall of items in the single retrieval-practice condition. However, because we provided corrective feedback after the first practice trial, participants' later practices of the subordinate meaning (in the 5 and 20 conditions) were successful, and the initial facilitation was ultimately suppressed. This pattern—an initial rise followed by gradual suppression—is informative and would not have been detected had we not varied the number of practices. We return to this point in the last section of this chapter.

The impairment in the retrieval-practice condition of Experiment 2 rules out the blocking account of the results of Experiment 1. Inhibition is likely to have been involved. Two alternatives remain, however: nonselective inhibition and recall-specific inhibition. These alternatives are addressed by the extra-presentations condition. According to nonselective inhibition, final recall in the extra-presentations and retrieval-practice conditions should look similar because both manipulations cause inhibition. However, if impairment in the extra-presentations condition of Experiment 1 was caused by the covert intrusion of extra-presented items during the final test (and the retrieval-based suppression this would have caused), no impairment should occur in the extra-presentations condition of Experiment 2. No impairment should occur because using a unique cue on the final test (e.g., *satchel–s———*) should eliminate opportunities for the practiced item (e.g., *arm–missile*) to intrude and suppress the dominant sense.

Figure 11.2b presents the results of the extra-presentations condition. As can be seen, extra presentations did not impair the recall of the dominant meaning: Final recall did not vary with the number of extra presentations. Because we found no evidence for inhibition, we can exclude nonspecific inhibition in favor of recall-specific inhibition. Thus, even though Experiment 1 suggests that extra presentations and retrieval practice have the same inhibitory effects on the alternative meanings of the homographs, this behavioral similarity is deceiving. The pattern was generated in two different ways: by practice-induced suppression in the retrieval-practice condition and by tested-induced suppression in the case of extra presentations. Although suppression may have contributed to both patterns, the independent probe method reveals its usefulness here in isolating the conditions that are crucial to the induction of this effect: Retrieval but not mere exposure triggers suppression.
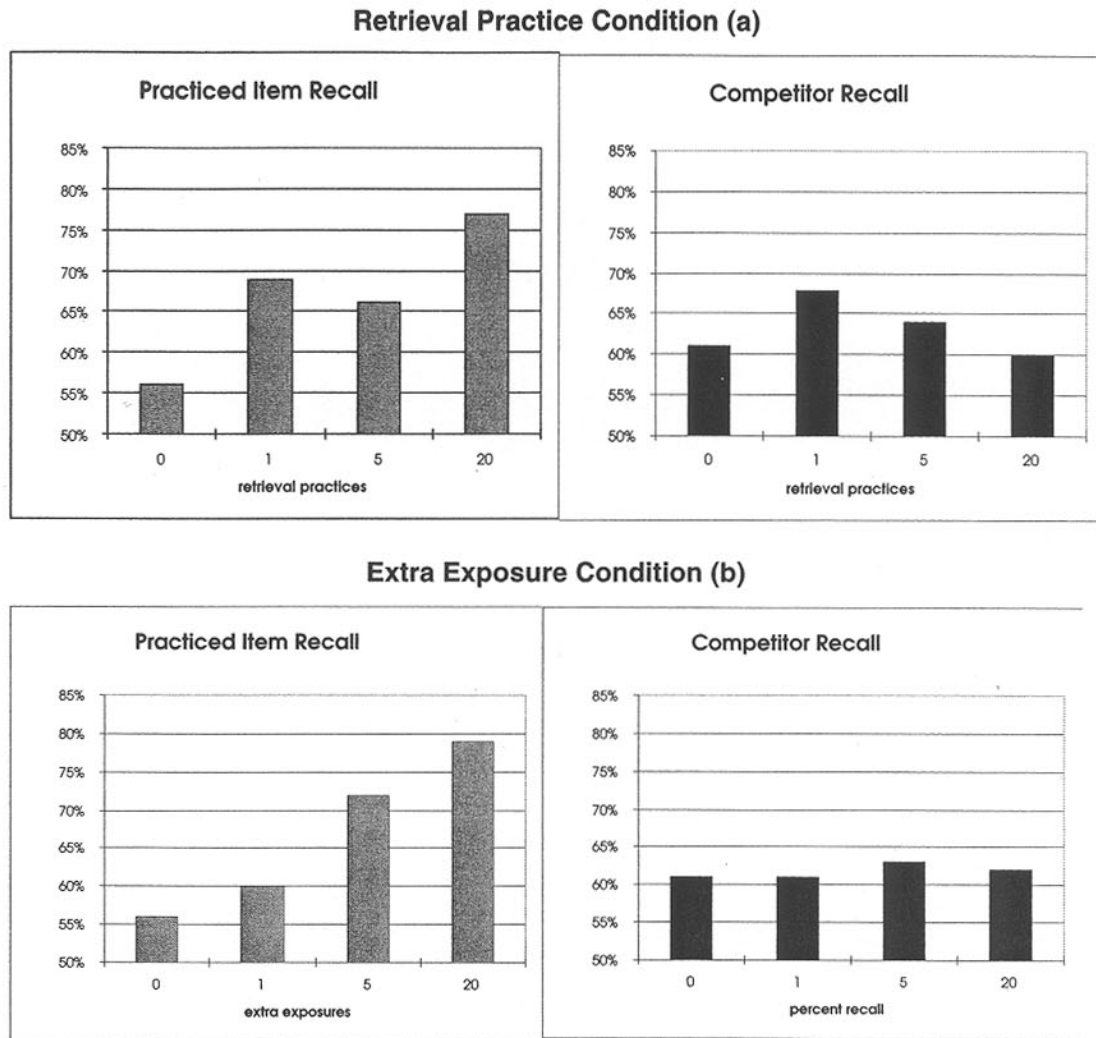
Retrieval Practice Condition (a)

Extra Exposure Condition (b)

Figure 11.2. (a) Final recall for the word pairs that received retrieval practice (1st panel) and the competing dominant meanings (2nd panel) in Experiment 2. The dominant meaning was tested with an independent probe and a letter stem (e.g., *satchel*–*s*——), whereas the practiced meaning was tested with the homograph and a letter stem. Recall of the practiced items increases with retrieval practice, whereas recall of the unpracticed competitor initially increases and then declines. (b) Final recall for the word pairs that received extra exposures (3rd panel) and the competing dominant meaning (4th panel). Note that whereas extra exposures facilitated the practiced meaning (3rd panel), they did little to impair the competing meaning when it is tested from an independent probe (4th panel).

Experiment 3: Interference Dependence of the Inhibition

In Experiment 3 we sought to determine whether the amount of inhibition depends on the degree of interference caused by the competing meaning during retrieval practice. If so, more inhibition should be found when a competitor word is related to the dominant than to the subordinate meaning. To test this, we changed which word pairs received retrieval practice. Whereas in Experi-

ments 1 and 2 participants practiced the word related to the subordinate meaning, participants in Experiment 3 practiced the word related to the dominant meaning. If inhibition functions to overcome interference, little impairment should occur in this experiment, because the subordinate sense should not be particularly interfering. Little impairment should occur even when the practiced items themselves are strengthened by retrieval practice and regardless of the type of recall test given for the subordinate sense (i.e., a shared cue, such as *arm–m——* or a unique cue such as *fire–m——*).

Figure 11.3 presents the results of Experiment 3, with the shared-cue (homograph cued) data in panels A and B and the unique cue data in panels C and D. We also included our manipulation of practice type, with the retrieval-practice condition in panels A and C and the extra-presentations condition in panels B and D. These results can be summarized simply. Under no circumstances was inhibition found. As expected, the subordinate sense did not need to be inhibited because it was not especially interfering. Consistent with this latter presumption, retrieval-practice success rates were very high (95%), even on the first practice trial (70%, compared with 34% in Experiment 1).

In addition to establishing the dependence of inhibition on the degree of interference, Experiment 3 provides evidence against the blocking hypothesis. Even though the practiced items in Experiment 3 were greatly strengthened (see left sides within each panel), the final recall of the subordinate sense was unimpaired, even after 20 practice trials. Together with the results of Experiments 1 and 2, these findings strongly support a role for inhibition in resolving interference during retrieval. They further suggest that these inhibitory processes, which have now been observed in a variety of retrieval contexts, may also extend to the resolution of competition during meaning selection.

General Discussion

The present studies suggest that the inhibitory processes that underlie retrieval-induced forgetting may contribute to meaning selection. When participants recalled a word associated with one meaning of a homograph, words associated with the competing meaning were inhibited. The extent of the inhibition depended on whether the alternative meaning was interfering, with words related to dominant meanings being more inhibited than those related to subordinate meanings. Importantly, these inhibitory effects generalized to novel cues that did not present the homograph, demonstrating cue independence (M. C. Anderson & Spellman, 1995). Finally, recall but not the mere repetition of the practiced meanings led to inhibition, consistent with the view that inhibition resolves retrieval interference.

Although these experiments move closer to applying the methodology of retrieval-induced forgetting to meaning selection, the present paradigm still relies on episodic memory retrieval. To establish the relevance of retrieval-induced forgetting as a model for inhibition in meaning selection, our approach must be extended to a paradigm more closely related to meaning selection in language comprehension. In this section, we highlight some of the challenges that must be addressed to isolate inhibition in meaning selection.
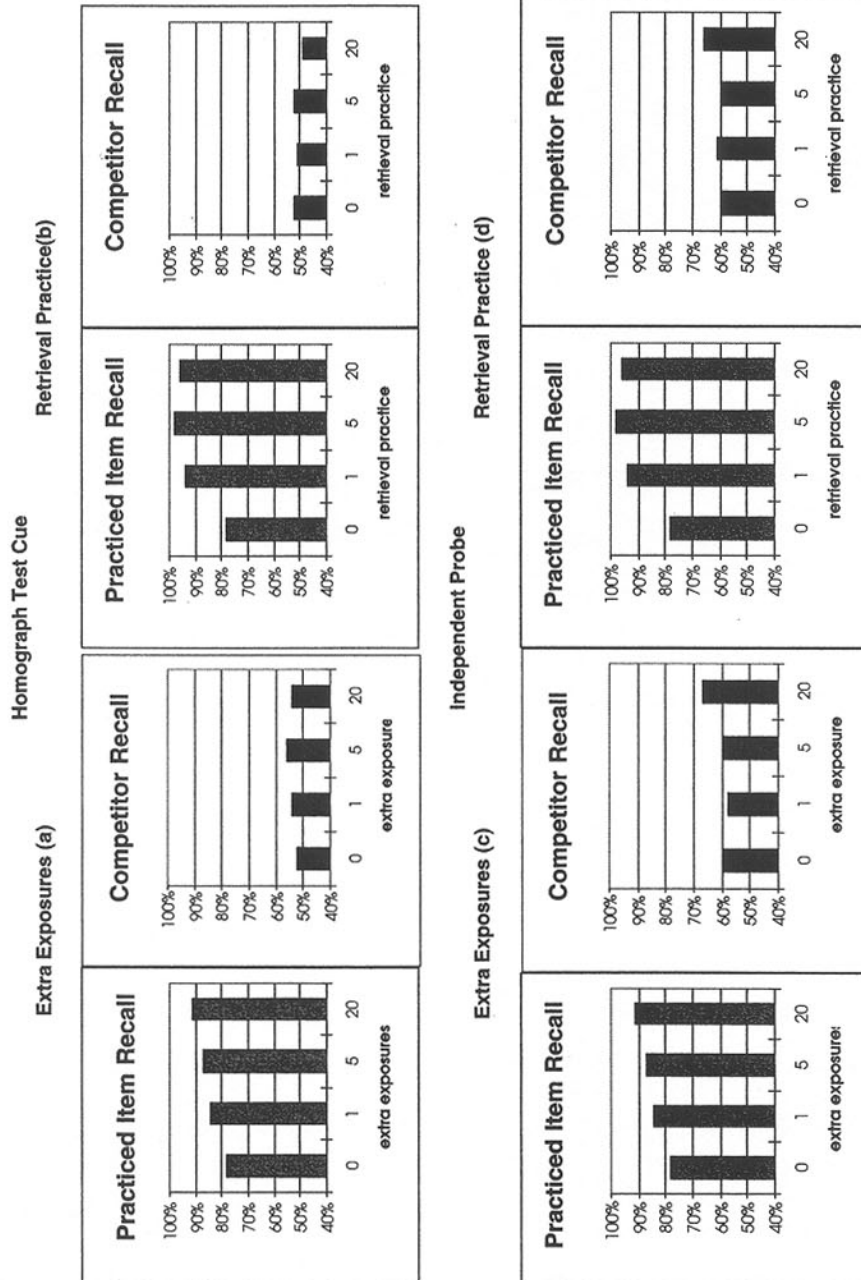
Figure 11.3. Final recall in four groups of participants. In the left panels, participants received retrieval practice on the dominant meanings, and in the right panels, extra exposures. In the top panels, participants were tested with the homograph; in the bottom panels, they were tested with an independent probe. Within each panel, the left collection of bars displays recall for the practiced items, which were always tested with the homograph and a letter stem. The right half of each panel depicts recall of the unpracticed subordinate competitor. Although practiced items were always facilitated, the subordinate sense remained unimpaired, even after 20 practices or extra exposures.

Distinguishing Inhibitory and Noninhibitory Mechanisms of Impairment

One theme of this chapter has been the importance of distinguishing inhibition from other sources of impairment that masquerade as inhibition. For instance, blocking, resource diffusion, and associative unlearning mechanisms can each explain the basic phenomenon of retrieval-induced forgetting (see M. C. Anderson & Bjork, 1994, for a review of these and other mechanisms). Although our evidence for cue independence shows these mechanisms to be inadequate as accounts of this effect, they may operate in other contexts. It is thus important to develop methods for separating inhibitory and noninhibitory sources of impairment, as we have done here. Such methods are important not only for establishing inhibition but also for refining theories about the conditions of this process. For instance, if we had no way to isolate inhibition, we might have concluded from Experiment 1 that recall was not essential in inducing inhibition. This conclusion would have been inaccurate, as the independent probe data from Experiment 2 show.

Noninhibitory alternatives complicate the interpretation of lexical ambiguity studies. Consider the increase in time to judge the plausibility of the sentence *He poured some punch* after reading *He got a bruise from the punch*. The slowed response time may reflect suppression of the "drink" sense of punch that occurred during comprehension of the first sentence. However, participants may simply remember having just read *punch* while reading the "drink" sentence, becoming momentarily distracted by this reminding. Reaction times might be further slowed if the recent presentation of *punch* biases its interpretation during the second sentence, increasing the time needed to activate the appropriate sense. Neither of these accounts requires inhibition, and both are consistent with the episodic reminding view of negative priming (e.g., Neill & Valdes, 1992). The episodic reminding view, in this case, is equivalent to a blocking theory in which blocking increases response time rather than error rate during the second reading of the homograph.

One might argue that the noninhibitory view cannot explain the entire pattern of "inhibitory" findings in research on lexical ambiguity resolution. Recently, however, Gorfein (2001) noted that most of the evidence favoring inhibition has been found in paradigms that measure inhibition by re-presenting the homograph in a new context favoring the ostensibly inhibited meaning (e.g., presenting *arm–shoulder* after initially presenting *arm–missile*). If the alternative meaning (e.g., body part) was truly inhibited, however, one should be able to omit the second presentation of the homograph and still find evidence that the meaning was impaired. For instance, presenting a word related to the suppressed meaning without re-presenting the homograph (*shoulder*) should still yield slower response times if that meaning was truly inhibited. Interestingly, Gorfein tested this and found little evidence for inhibition. This finding may be an example of how not everything that looks like inhibition necessarily is.

Gorfein's (2001) strategy of testing by omitting the homograph during the critical measurement of inhibition is one approach to using the independent probe method described in this chapter and elsewhere (M. C. Anderson & Spellman, 1995). His study illustrates the usefulness of developing methods

that distinguish inhibitory from noninhibitory theories of impairment. It should be noted, however, that just because inhibition was not found in Gorfein's study does not mean that inhibition is not involved in meaning selection. There are several ways in which this result can emerge even if inhibition was deployed to resolve ambiguity in his procedure. We discuss some of those complexities next.

The Activation–Inhibition Balance

One of the lessons of the present studies is that inhibition can be at work even when an experiment suggests it is not. Consider Experiment 2, which assessed final recall with an independent probe. A key feature of the data was the nonmonotonic function relating recall of the dominant sense of the homograph and the number of earlier retrieval practices on the subordinate meaning. Specifically, recall initially improved with one practice (over the zero-practices baseline) but was gradually suppressed as retrieval practices were added. This nonmonotonic pattern arose because on the first practice trial, participants often failed to suppress the competing associate, leading to its facilitation. Once corrective feedback was given after the first trial, participants ultimately suppressed the competing item.

Although these data clearly favor inhibition, consider how the findings would have been interpreted had we only had two levels of retrieval practice—for instance, baseline (0 practices) and 1, 5, or 20 practices. As can be seen in Figure 11.2a, comparing the baseline with any other point on the parametric function yields either facilitation (when compared with either 1 or 5 retrieval practices) or negligible impairment (when compared with 20 practices). With such a limited design, we would have falsely concluded that inhibition was not involved in this task. Because of our parametric design, we were able to detect that recall initially went up and was then gradually suppressed. This illustrates how inhibition may be involved, even if the design of a study does not permit its observation.

The nonmonotonic pattern in Experiment 2 makes an important point about measuring inhibition that cuts across all domains concerned with its operation. In most theories, inhibition is thought to reduce excess activation on some competing representation so that a target response can be made. Unless this process is assumed to be perfectly effective, which it almost never is, then the amount of inhibition applied to reduce interference will not always exceed the activation a competitor has accrued. Indeed, activation may often exceed inhibition when a competitor is as interfering as our dominant associates were in Experiments 1 and 2. In these cases, inhibition may be at work but will fail to suppress a competitor below its baseline level of activation. Thus, if an experiment only has two measurement points—a baseline and a single inhibition condition—then whether one finds impairment, no effect, or facilitation depends not only on whether inhibition is at work at all but also on the *activation–inhibition balance*. If inhibition happens not to exceed a competitor's activation, one will erroneously conclude that no inhibition has occurred at all.

The issue of how activation and inhibition balance is particularly important because so many investigators of attention, memory, and language use

only two measurement points to study inhibition (i.e., a baseline and a condition thought to cause some degree of inhibition)—a problem we refer to as the *two-point problem*. The two-point problem limits the ability to interpret any result other than impairment below baseline for the reasons described above. These theoretical ambiguities apply even if the independent probe method is used to isolate inhibition, and even if the manipulation of inhibition is strong (e.g., many retrieval practices are given, or there are multiple negative priming trials for a given item). The key is the use of a *parametric* design with several measurement points that enable one to see a gradual shift from excitation to inhibition. Studies not using this design risk not seeing a change in accessibility with a task thought to induce inhibition. This two-point problem may underlie Gorfein's failure to find inhibition in meaning selection—a possibility made plausible by a nonsignificant difference favoring inhibition in his independent probe method.

Interference Reduction as a Prerequisite for Inhibitory Effects

Inhibition may not be found even when the independent probe method is used with a parametric design. Whether inhibition occurs depends on whether inhibition is made necessary by the task being used. Inhibition should only be necessary when a competing representation causes interference. If the alternative meaning of a homograph generates little interference during the processing of a target meaning, no inhibition should be found, regardless of the whether one uses a parametric design.

The present studies suggest at least two circumstances in which this interference-dependence property may lead to null inhibition effects. First, when the competing meaning of a homograph is low in frequency and recency, it should not cause as much interference and should require less inhibition during the retrieval of the homograph's dominant meaning. Our studies show that (in an episodic recall paradigm) subordinate meanings are completely unimpaired by retrieval practice on the dominant meaning, even after 20 retrieval practices. Thus, if a lexical ambiguity study fails to find inhibition, the null finding may arise because the materials do not generate much interference.[2]

Second, null inhibition findings should also emerge when meaning selection is made particularly easy by contextual factors. For instance, if words related to the target meaning are presented immediately prior to the homograph in a passage, or if recent processing history strongly favors the to-be-selected meaning, then meaning selection may proceed with little interference from competing meanings. Under these conditions, the target meaning may be so primed that even otherwise dominant competitors may not prevent the target's selection. If little interference occurs, no inhibition should be necessary. This possi-

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[2]Some studies using a prime–target paradigm have found comparable inhibition for high- and low-dominance meanings. Such findings suggest that the interference an item causes does not predict how inhibited it will be, in contrast to what the attentional view asserts. However, most studies that fail to find this difference have not separated slowing arising from competition (due to episodic reminding of the prime word) from that arising from inhibition. If the independent probe method were used, a difference might be found.

bility is supported by the lack of inhibition in our extra-presentations condition, in which selection of the target meaning during the extra-presentations phase was made easy by the intact presentation of a to-be-practiced word. Because the paired word allowed the complete disambiguation of the homograph with little effort, the dominant competitor did not need to be and was not suppressed, even after as many as 20 extra presentations.

The specificity of inhibition to the act of recall in the present experiments may provide a useful guide for thinking about the conditions under which meaning selection is most likely to suppress alternative meanings. Whenever the isolation of the appropriate meaning requires active recollection of the contextual information (e.g., words or meanings from prior portions of a sentence or discourse) that might constrain the interpretation of the homograph, lexical ambiguity resolution becomes similar to retrieval practice. If the demand to disambiguate the homograph poses little retrieval difficulty, less inhibition should be found. This dimension—degree of active recall—may help to sort those experimental manipulations that yield evidence for inhibition from those that do not, given the use of the independent probe method and a parametric design.[3]

Conclusion

In this chapter, we have argued that retrieval-induced forgetting provides an informative and well-developed model of inhibition in long-term memory that may be applied to the study of these processes in the lexical ambiguity resolution. Although much of the work on retrieval-induced forgetting has focused on episodic retrieval, its properties appear to be quite general. Because meaning selection can be regarded as a special case of long-term memory retrieval, the analysis of inhibition in retrieval-induced forgetting may provide a more suitable basis for theoretical development than negative priming.

The studies reported in this chapter help to link retrieval-induced forgetting with the issue of inhibitory processes in meaning selection. They demonstrate that the core properties of retrieval-induced forgetting apply equally well when the meanings of homographs are the targets to be retrieved from long-term memory. Although only a beginning, these findings suggest that the theoretical analysis we have developed to characterize inhibition is likely to be adaptable to the study of meaning selection. Applying the insights deriving from this analysis—that is, the notion of cue independence, considerations of the activation–inhibition balance, and the sensitivity of inhibition to the degree of interference—may help to clarify the role of inhibition in lexical ambiguity resolution and in language comprehension generally.

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[3]An experiment reported by Simpson and Adamopoulos (chapter 7, this volume) found that making a double lexical decision on a prime composed of two words—a homograph and a word related to one of its meanings (e.g., *bank–money*)—slowed reaction time to name a probe word related the alternative meaning. This suggests that active recall of the prime may not be essential to find inhibition. Although this suggests that inhibition works differently in ambiguity resolution and retrieval-induced forgetting, this does not follow. A prime that *did* require active recall might show more inhibition than one in which active recall was less necessary. Recall might also generate more lasting inhibition, which could have caused the dissociation between recall and extra presentations reported here.