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Recall-based inhibition in recognition.

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RECALL-BASED INHIBITION IN RECOGNITION

A Thesis Presented

by

HYE-WON LEE

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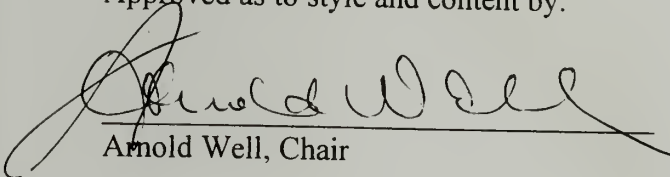
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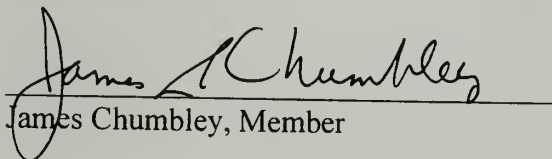
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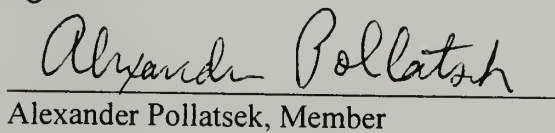
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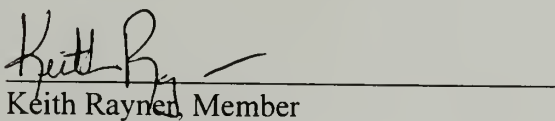
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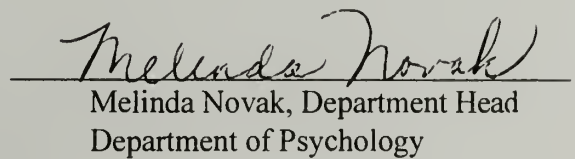

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CHAPTER I

INTRODUCTION

Recall in Recognition

A standard recognition paradigm consists of a study phase and a test phase. In the study phase, subjects are presented with the study items and asked to memorize them for a later memory test. In the following test phase, subjects are presented with the test items, some of which are old ones presented in the study phase, and some are new ones not presented in the study phase. For each test item, subjects are asked to judge whether it was presented in the study phase. If they believe the test item was presented in the study phase, they are instructed to respond positively by pressing the key labeled 'yes' or 'old', and if it was not, they are instructed to respond negatively by pressing the key labeled 'no' or 'new'. The response is assigned to one of the following four categories: (1) hit, a correct response of 'old' to an old item; (2) correct rejection, a correct response of 'new' to a new item; (3) false alarm, an incorrect response of 'old' to a new item; (4) miss, an incorrect response of 'new' to an old item.

Whether recall plays a role in the recognition process has been a long standing important theoretical question in recognition memory. The traditional view of recognition has been that it is a familiarity-based decision process and does not include a retrieval component (see Mandler, 1980, 1989). The traditional view can be characterized as a unitary familiarity-based view. Most recognition models incorporate the traditional view by assuming that recognition decisions are based on values on a unitary scale often

characterized as familiarity, but also called strength, similarity, matching, perceptual fluency, echo intensity, log likelihood ratio, and so on (see Hintzman & Curran, 1994).

Within the framework of signal detection theory, most recognition models assume that the familiarities of old and new items form two separate distributions of familiarity, analogous to the hypothetical distributions of signal and noise, respectively. Because the familiarity of old items, on average, is greater than that of new items, the familiarity distribution of old items is located to the right of the distribution of new items on a familiarity scale. A criterion is assumed to be located along the familiarity scale at fixed points between the two distributions. If the familiarity of a test item is above the criterion, an 'old' response is produced, whereas if the familiarity of a test item is below the criterion, a 'new' response is produced. Because the two familiarity distributions are assumed to overlap to some degree, it is possible that the familiarity of a new item can sometimes be above the criterion and therefore produce an incorrect 'old' response (false alarm). Likewise, the familiarity of an old item can sometimes be below the criterion and therefore produce an incorrect 'new' response (miss).

Within the signal detection framework, the recognition decision is influenced by two factors: the placement of the criterion and the distance between the two distributions relative to the variability of the distributions. First, consider the criterion. Subjects can set either a high or a low criterion depending on the extent to which they are conservative in their decision to respond 'old'. A high criterion will lead to fewer positive (i.e., 'old') responses, whereas a low criterion will lead to more positive responses. In this way, the criterion setting can influence the recognition decision. Second, consider the distance

between the two distributions. The distance between the two distributions reflects the sensitivity of the recognition decision (d'). The smaller d' is, the more the two distributions will overlap. The more the two distributions overlap, the more likely incorrect responses will be produced. In other words, when d' is large, recognition decisions will be more accurate, but when d' is small, recognition decisions will be less accurate.

Most recognition models incorporating the unitary familiarity-based view adopt the theoretical framework described above. In this framework, once the criterion is decided upon, the recognition decision depends on the familiarity value of a test item: whether the response is positive or negative is determined by whether the familiarity of a test item is above or below the criterion. One prediction of the unitary familiarity-based view is that when the familiarity of a new item is high, a false alarm is more likely to be produced than when the familiarity of a new item is low. The theoretical basis for this prediction is as follows: because of the item's high familiarity, the distribution of a new item is shifted to the right along the familiarity scale, nearer to the distribution of an old item. It leads to an increase in a false alarm rate.

An examination of the time course of the recognition process, however, has revealed that the situation is not as simple as assumed by the unitary view. Studies using the response-signal method have shown that recognition decisions cannot be explained simply in terms of familiarity, providing evidence against the unitary familiarity-based view. The response-signal method makes it possible to examine the time course of the recognition process by asking subjects to respond at various times from the onset of the

test item (SOA). For example, subjects can be asked to respond at 200, 500, 1000, or 2000 ms SOA.

In a study by Doshier (1984), the familiarity of new items was manipulated by using pre-experimental associations. The task was to discriminate between pre-experimentally familiar word pairs such as 'open-close' and word pairs learned in a study phase of the experiment. In the test phase, subjects were asked to judge if a test pair was presented in the study phase. The key manipulation in this study was that some new test pairs were pre-experimentally (semantically) associated (e.g., evil-sin, open-close). That is, although it was not learned in the study phase, the new pair was likely to look familiar to the subject because of its semantic relationship. In terms of the familiarity-based view, this means that a higher false recognition rate would be expected. The interesting finding was that for these semantically-related new test pairs, a nonmonotonic function was found in the false alarm rate: the false alarm rate increased with SOA up to a point but then decreased. In other words, subjects tended to respond positively when forced to do so quickly, but respond negatively later in the time course of recognition.

A similar phenomenon was found by Hintzman and Curran (1994). In their study, they manipulated the familiarity of certain new items to be high by using the singular and plural form of the words. For example, in the study phase, 'frog' was presented, and in the test phase, the subject was asked to judge if the test item 'frogs', the plural form of 'frog', had been presented in the study phase. Although 'frogs' was the new item, it would be familiar to the subject because of its similarity to the old item 'frog'. Thus, more false alarms could be expected for this kind of new item. Interestingly, the results

were similar to Doshier (1984); that is, until a certain point (around 600 ms) from the onset of the test item, false alarms increased, but after that point, false alarms decreased.

Although Doshier (1984) and Hintzman and Curran (1994) used different recognition paradigms, associative and single recognition paradigms, respectively, their studies share important features. First, when the familiarity of new items is high, they found that false alarms for those new items revealed a nonmonotonic function over the time course of the recognition decision. False alarms increased early but decreased later in the recognition process. This phenomenon cannot be explained by familiarity alone, because the familiarity would monotonically increase across the time course of recognition. One might expect this value to reach an asymptote, but there is no reason to expect it to decrease. Thus, this nonmonotonic function of positive responses for the familiar new item strongly implies that another process proceeds with a different time course than the familiarity evaluation. If so, what is the underlying process responsible for the decreased positive responses for the familiar new item?

Doshier (1984) argued that positive responses decreased because subjects recalled information from episodic memory that mismatched the test item. For example, suppose that a pair, 'open-vegetable', was presented in the study phase, and that a new pair 'open-close' was presented in the test phase. Because of the familiarity of the 'open-close' pair in pre-experimental experience, subjects might respond positively, but with more time, they can sometimes recall the old pair, 'open-vegetable', presented in the study phase. They then perceive the mismatch between the old pair 'open-vegetable' and the new pair 'open-close', leading to a decrease in positive responses to the new pair, 'open-close'.

Hintzman and Curran (1994) also provided a similar recall-based explanation. They argued that positive responses to the familiar new item 'frogs' decreased over time because subjects recalled the old item 'frog' from their episodic memory. Once the old item 'frog' was recalled, subjects came to recognize the mismatch between the old item 'frog' and the new item 'frogs', leading to the decrease in positive responses to the new item 'frogs'.

The idea that recall is involved in recognition dates back to the classical dual process theory of recognition (e.g., Atkinson & Juola, 1973, 1974; Mandler, 1980, 1981, 1989). The dual process theory assumes that recognition is based on both a rapid familiarity-based process and a slower recall process. Although the key idea that recall is involved in recognition has been shared by most dual process theorists, slightly different views could be found among researchers in some points. One point of difference is about how a criterion is set for invoking recall. Mandler (1980, 1981, 1989) assumed a single criterion, positing that an event is judged 'old' if its familiarity exceeds a certain specific criterion, but that recall is invoked if its familiarity fails to exceed that criterion. On the other hand, Atkinson and Juola (1973, 1974) assumed two criteria, a high criterion and a low criterion, positing that when the familiarity of an item is either above the high criterion or below the low criterion it is judged 'old' and 'new', respectively, but when the familiarity of an item lies between the two criteria, subjects begin to search the memory traces of the presentation list before responding.

The other point of difference is about whether familiarity and recall are sequential or parallel processes. In the sequential view, the familiarity of the test item is assessed

first, and only when its familiarity fails to reach the criterion, is recall invoked (Atkinson & Juola, 1974). In other words, the initiation of recall is assumed to be later than the initiation of the familiarity-based process. Similarly, Hintzman and Curran (1994) characterized recall as a secondary process, suggesting that familiarity alone is usually sufficient to discriminate between old and new items, but when the new item is highly similar to the old item, recall is necessary in order to discriminate them. In contrast, the parallel view suggests that both processes are initiated simultaneously as soon as the event is encountered, but that the recall process is markedly slower than the familiarity-based process (Mandler, 1981, 1989).

To summarize, recent studies examining the time course of the recognition process provide evidence that two separate processes proceed with different time courses during the recognition process: the early time course reflects the influence of familiarity, and the later time course reflects the influence of another process different from familiarity. The other process has been described by various terms such as “search process” (Atkinson & Juola, 1973, 1974), “intentional process” (Jacoby, 1991), “retrieval process” (Mandler, 1980, 1981, 1989), and “recall process” (Doshier, 1984; Hintzman & Curran, 1994).

Although recall is highly likely to be involved in the recognition process, there is a need for more conclusive evidence for its existence. One way is to find a characteristic uniquely belonging to a recall process and not to a familiarity-based process, and to demonstrate the existence of that characteristic in a recognition memory task. The existence of such a characteristic would provide converging evidence for the recall

process in recognition. What is a recall-specific characteristic? The following review regarding the issue of inhibition suggests an answer to this question.

Inhibition in Recall

A major issue in memory research is how the memory for a target item is affected by the presence of related items preceding it. However, there have been contradicting findings and arguments. One line of studies has found that the retrieval of a target item could be facilitated when it is immediately preceded by a related item. Facilitation from related items has been found both in semantic and in episodic memory. For example, in a lexical decision task, subjects tend to be quicker to judge that 'nurse' is a word when 'nurse' is immediately preceded by a related word 'doctor' than when preceded by an unrelated word 'bread' (Meyer & Schvaneveldt, 1971). Similarly, in a recognition task, subjects tend to be faster to judge that 'juice' was in the study list when the preceding test item is 'water' rather than 'horse' (McKoon, Ratcliff, & Dell, 1985). Related items producing facilitation might be a free associate of the critical word (e.g., hot-dog; Meyer, Schvaneveldt, & Ruddy, 1975; Neely, 1976), a member of the same category (e.g., cat-dog; McKoon & Ratcliff, 1979), or a category label (e.g., animal-dog; Neely, 1977).

Facilitation from a related item has been generally explained in terms of the spreading activation model (Collins & Loftus, 1975; Posner & Snyder, 1975; Schvaneveldt & Meyer, 1973; Neely, 1976). In this model, it is assumed that the retrieval of a concept activates the node representing the concept, with this activation spreading to related nodes. Thus, a related item presented prior to a target item is assumed to increase

the activation of the target item, thereby facilitating the immediate accessibility of the target item.

On the other hand, another line of studies has found that the retrieval of a target item can be inhibited, not facilitated, when it is immediately preceded by a related item. This inhibition effect has been found both in semantic memory (Brown, 1979, 1981; Blaxton & Neely, 1983; Neely, Schmidt, & Roediger, 1983; Roediger, Neely, Blaxton, 1984) and in episodic memory (Anderson & Bjork, 1994, Anderson & Spellman, 1995; McKoon & Ratcliff, 1979; McKoon, Ratcliff, & Dell, 1985; Neely & Durgunoglu, 1985). For example, in Brown's experiment (1979), subjects were presented with a definition (e.g., to swallow up or eat greedily) and asked to retrieve a target word corresponding to the definition (e.g., gobble). The key manipulation was that prior to the presentation of a definition, a prime word was presented. There were four types of prime words: correct (e.g., gobble), semantically related (S prime, e.g., cram), orthographically related (O prime, e.g., goggle), and unrelated (U prime, e.g., feud) to the target word. Brown (1979) found that when a definition was preceded by a S prime, the retrieval probability of the target word was lowest. Retrieval time was also slower for the target word when the definition was preceded by a S prime than when it was preceded by O or U primes. These data indicate that it is more difficult to retrieve a target word when semantically related word is presented prior to the target word. This inhibition from the related item seems exactly opposite to the facilitation expected by the spreading activation model.

One possibility for why this opposite priming effect of a related item occurs is that, inhibition is observed when active or intentional search in memory is used by the

subject (Brown, 1979). Studies demonstrating facilitation have mostly used a lexical decision task or naming task in which a prime is presented in intact form, so that search for the prime in memory is rather unnecessary (Meyer, Schvaneveldt, & Ruddy, 1975; Neely, 1976, 1977; Schvaneveldt & Meyer, 1973). In contrast, studies demonstrating inhibition have mostly used a self-generation task or a recall task in which effortful, intentional search for the prime in memory is necessary (Brown, 1979, 1981; Blaxton & Neely, 1983).

Blaxton and Neely (1983) provided some evidence for this hypothesis. This study was composed of a prime trial followed by a target trial. There were two possible types of prime trials: the read-prime and generate-prime conditions. In the read-prime condition, subjects were given a category name (e.g., fruit) which was followed by an exemplar of that category (e.g., orange). Subjects were asked to read both the category name and the exemplar aloud during their presentation. In the generate-prime condition, subjects were given a category name (e.g., fruit) which was followed by a single letter (e.g., o). Subjects were asked to generate an exemplar beginning with that letter (e.g., orange). Similarly, there were also two types of target trials: the read-target (experiment 2) and generate-target conditions (experiment 1). The procedure of the read-target condition was identical with the read-prime condition, and the procedure of the generate-target condition was identical with the generate-prime condition. Within a 2 (prime trials) x 2 (target trials) combination, two variables were manipulated: first, the target trial was either related (e.g., fruit apple) or unrelated (e.g., sports baseball) to the previous prime trial (e.g., fruit

orange), and second, the number of prime trials was varied from one to four trials before the target trial.

Results showed that when the subjects read the prime, they were faster to read or generate the related target than the unrelated target in both the one and four prime trials, indicating facilitation. By contrast, when the subjects generated the prime, inhibition was inferred from two sources: first, the facilitation observed in the read-prime condition was eliminated. That is, the subjects were not faster to read or generate the related target than the unrelated target (except in the one prime condition). Second, subjects were much slower to generate the related target given four consecutive related prime trials than given one related prime trial. This results suggest that in a situation like a read-prime condition in which an effortful search is not necessary, related items might yield facilitation, but in a situation like a generate-prime condition in which an effortful search is necessary, related items might yield inhibition, reflected in the cancellation of the facilitation effect.

Recently, the study by Anderson and Spellman (1995) provides further evidence for the inhibition of the related item. This study is noteworthy in two aspects: first, while most studies addressing inhibition in memory retrieval were carried out in a semantic memory paradigm, this study approaches the issue in an episodic memory paradigm, thus providing evidence that inhibition of the related item occurs in episodic memory as well as in semantic memory. Second, this study used a recall paradigm, thus providing evidence that the inhibition of the related item occurs in the recall process. The evidence for inhibition in recall has a critical implication in relation to the recognition process. It will be discussed later.

This study was composed of four phases: a learning phase, retrieval practice, a distractor phase, and a final test phase. In the learning phase, subjects were given a booklet containing a category-exemplar pair on each page and asked to remember them. The learning phase was followed by retrieval practice. In the retrieval-practice phase, subjects were given a booklet containing one category name seen in the learning phase on each page together with the first two letters of one of the exemplars of that category (e.g., fruit ap_____). Subjects had to remember the example from the learning phase and to complete the blank. After retrieval-practice, subjects were given an unrelated reasoning task for 20 mins. In the final test phase, subjects were given a cued-recall test. They were given recall booklets containing one category name studied during the learning phase on each page. Subjects had to recall all examples of that category that they had seen in the experiment and write them down. Before going further, it needs to be noted that what was tested in this study is episodic memory. That is, all the examples subjects were asked to recall from the category cue were the ones studied in the experiment.

The important finding was that when an exemplar of a category was recalled in the retrieval-practice, another exemplar of that category was harder to recall in the final recall test compared with the exemplars of a category which was not included in the retrieval-practice. For example, suppose that in the learning phase, 'fruit-apple', 'fruit-strawberry', 'animal-sheep', and 'animal-pigeon' were studied. In the retrieval-practice phase, 'fruit ap_____' was given and subjects had to recall 'apple' but there was no retrieval practice trial involving 'animal'. In the final recall test, category 'fruit' and 'animal' were given and subjects had to recall all the exemplars of each category which

they saw in the experiment. The result was that the recall of 'strawberry' was harder recall than either 'sheep' or 'pigeon'. In other words, the recall of 'strawberry' was inhibited.

Two possible explanations could be considered for this inhibition. One is based on an inhibition mechanism during the practice phase. According to this, 'strawberry' would compete with 'apple' during the recall of 'apple' in retrieval practice, because 'strawberry' was also paired with 'fruit' in the learning phase, and inhibited, resulting in a lower activation level of 'strawberry'. The other explanation is based on a noninhibitory mechanism. According to this, during the recall of 'apple' in retrieval-practice, 'strawberry' was not inhibited at all. However, the access to 'strawberry' might be harder in the final recall test due to the following reasons: (1) heightened accessibility of 'apple' might lead 'apple' to block or occlude 'strawberry' (occlusion), (2) 'fruit' might spread less activation to 'strawberry' due to limited activation resource (resource diffusion), and (3) the weight of the link between 'fruit' and 'strawberry' might be weakened (associative decrement) (Anderson, Bjork, & Bjork, 1994; Anderson & Spellman, 1995).

While the inhibition-based explanation assumes that the ability to recall 'strawberry' decreased because the representation of 'strawberry' itself was inhibited, the noninhibition-based explanation assumes that the ability to recall 'strawberry' decreased, not because of inhibited representation of 'strawberry' itself, but because of occluded access, limited activation resources, or a weaker link. The noninhibition-based explanation is different from the inhibition-based explanation, because it is based on the premise that both 'apple' and 'strawberry' are linked with the same category, here, 'fruit'.

Unless they share the same category, the noninhibition-based explanation will not make much sense. In contrast, the inhibition-based explanation does not require such a premise.

Based on this point, Anderson and Spellman (1995) paired 'apple' and 'strawberry' with different categories in the learning phase: 'apple' was paired with the category, 'fruit', and 'strawberry' paired with another category, 'red'. In this condition, the access to 'strawberry' could not be occluded by the previous recall of 'apple', because 'strawberry' could be accessed by the different cue ('red') from that of 'apple' ('fruit'). Likewise, the possibilities of limited activation resource or weight of the link could be ruled out. The result was that the recall of 'strawberry' in the final recall test was still harder even when 'apple' and 'strawberry' were paired with different categories. This indicates that 'strawberry' was actually inhibited during the recall of 'apple' during the retrieval practice.

So far, the literature on the influence of a related item in memory retrieval was reviewed including both semantic and episodic memory paradigms. It seems clear that a related item does not merely yield facilitation. A previously retrieved item can yield either a facilitation or inhibition effect toward a following related item. Whether facilitation occurs or inhibition occurs seems to depend on how the previous item is proceed. When the previous item is simply read, activation seems to spread from the item to related items, thus facilitating the processing of them. When the processing of the previous item demands more effortful search as in generation or recall, a related item is likely to be inhibited as a competitor. In particular, the study of Anderson and Spellman (1995) shows that when the previous item is recalled from episodic memory, a related

item which is also encoded in episodic memory is likely to be inhibited. Because they did not find this inhibition effect in recognition, they argued that inhibition occurs in recall but not in recognition. Their rationale was that the target item to be recognized is presented in intact form in recognition, and subjects do not have to search their episodic memory. However, as claimed earlier in the review of the recognition memory, it is highly likely that recall plays a role in recognition. As a result, if a similar inhibition phenomenon can also be found in the recognition paradigm, it would be evidence for the involvement of recall in recognition.

Recall-based Inhibition in Recognition

The review of research on recognition and inhibition in memory suggests that these two different fields of research share one common thing, recall. Recall underlies the dispute between a unitary vs. dual process assumption in recognition. Also recall underlies the dispute between facilitation vs. inhibition phenomena among related items in memory. This synthesis suggests the hypothesis that recognition includes an inhibition phenomenon caused by the role of recall. This hypothesis will be called 'recall-based inhibition in recognition'. The present study will address this hypothesis.

Before developing the hypothesis, it needs to be clarified which conditions in recognition involve recall. Specifically, is recall involved only in specific recognition situations or universally in all recognition situations? One possibility is that recall occurs only when a new item is highly similar to an old item, so that its familiarity is very high (Hintzman & Curran, 1994). High familiarity of a new item leads to the necessity for a discrimination between a new item and an old item, so that a recall process is initiated.

On the other hand, in the recognition of an old item, recall is necessary in only a small fraction of the trials. Because the mean of the familiarity distribution for an old item is above the criterion value, the familiarity value on a given trial exceeds the criterion and will produce a positive response based on familiarity alone. In this respect, the role of recall is conditional on the characteristic of a test item: an old item rarely leads to recall, but a new test item, particularly a familiar new item, usually leads to recall in recognition.

The other possibility is that recall occurs equally in the recognition of both old and new items. Given instruction emphasizing the accuracy of the decision or given enough decision time, subjects will attempt to recall a test item from their episodic memory (memorized studied items) before responding. The importance of instructions or response time in triggering recall has been mentioned or actually manipulated (Atkinson & Juola, 1974; Mulligan & Hirshman, 1995). In this respect, therefore, recall can be involved in all the test items regardless of whether it is an old or new item given appropriate conditions.

The hypothesis of recall-based inhibition proposed in the present study takes the position that recall is involved in the recognition of both old and new items as long as the situation is one in which recall could play a role, such as when there is enough decision time, or when there are instructions emphasizing accuracy. The next step is to specify how recall would proceed for old and new test items, respectively. For this, it is necessary to combine the findings from two fields, the findings from recognition studies and findings from inhibition studies. The reason is as follows: although recall is common to both, the findings come from rather different focuses. First, consider the Anderson and

Spellman (1995) study regarding recall and inhibition. In their experimental paradigm, all the exemplars that subjects were asked to recall in both the retrieval-practice and the final recall test were the old items which had been studied in the learning phase. There were no new items in their paradigm. Thus, to describe their finding specifically, the previous recall of an old item (an exemplar of a category studied in the learning phase) inhibits a related old item (another exemplar of that category also studied in the learning phase). Second, consider the Hintzman and Curran (1994) study regarding recall and recognition. The focus here lies on the new items, because they had the view that recall occurs only in a new item highly similar to an old item. To describe their finding specifically, a related new item (e.g., frogs) leads to the recall of an old item (e.g., frog). The recall of an old item decreases the tendency to respond 'old' to related new items. In short, a related new item leads to the recall of an old item.

Under the present assumption that recall is involved in both old and new items, therefore, it is necessary to combine the findings about the old items and the new items from the two different fields, inhibition and recognition studies, respectively. The combined picture is as follows: suppose that in a recognition task, there are two test items, and they are related to each other in meaning. Actually they could be 'related' in many ways, but it will be just assumed that they are related in meaning. Now, consider two different recognition situations: (1) both items are the old items presented in the study phase, and (2) only one of the items is old and the other is new. The two different situations lead to quite different predictions. In the first situation, an attempt to recall one old item will lead to the inhibition of the other old item. For example, an attempt to recall

'apple' in retrieval practice led to the inhibition of 'strawberry' in the final recall test (Anderson & Spellman, 1995). Here, both 'apple' and 'strawberry' were old items presented in the learning phase. In contrast, in the second situation, an attempt to recall a new item will lead to the recall of the other old item. For example, an attempt to recall a new item, 'frogs', from episodic memory led to the recall of 'frog', an old item (Hintzman & Curran, 1994).

In brief, according to whether a test item is old or new, the fate of a related old item is changed: in the former case, a related old item is inhibited, and in the latter case, a related old item is recalled. What is implicated by this recall process? First, a recalled item can never be inhibited, because it is now being accessed (no inhibition prediction). Second, the accessibility of a recalled item might be facilitated relative to the accessibility of an unrecalled item (facilitation prediction). One clear prediction is that when a test item is a new item in a recognition task, the inhibition of a related old item is unlikely, because that old item is being recalled.

To summarize, the review of the literature regarding recognition and inhibition has provided one common ground, recall. One hypothesis is that if recognition includes the recall process, recall-based inhibition will be found in recognition. To predict how recall-based inhibition proceeds in a recognition paradigm in which test items usually consist of old and new items, findings from two fields were combined, presenting the whole picture of the situation. One important prediction is that recall-based inhibition in recognition will be characterized as a contrasting pattern between the presence and

absence of the inhibition in a related old item according to the characteristic of a test item, old or new. A series of studies was planned to examine this prediction.

CHAPTER II

EXPERIMENT 1

This study was motivated by noticing the possibility of a link between the idea that recall might play a role in recognition and the idea that recall might generate inhibition. Combining these two ideas, the following hypothesis was derived: if recall plays a role in recognition and recall causes inhibition, the recognition process should show recall-based inhibition. The finding of recall-based inhibition in recognition should have two important implications for recognition: (1) It should provide evidence for the role of recall in recognition, and (2) It should provide evidence for the existence of inhibition in recognition.

A standard single recognition paradigm is divided into a study phase and a test phase. In the study phase, a series of study items is presented and subjects are asked to memorize them. The study phase is followed by the test phase in which test items are presented one at a time and subjects are asked to make a recognition decision for each test item. If the test item was presented in the study phase, a positive response ('yes' response) is correct, and if it was not, a negative response ('no' response) is correct. A test item presented in the study phase is called an 'old' item, and a test item not presented in the study phase is called a 'new' item. Usually in a recognition task, half of the test items are old items and half are new items.

How can recall-based inhibition be examined in recognition? To examine recall-based inhibition in this study, the logic of a priming paradigm was employed. The logic was as follows: suppose X and Y are two adjacent test items in a recognition paradigm.

The processing activity that occurred during the recognition of X should be reflected in the immediately following recognition of Y. For example, if Y was inhibited during the recognition of X, one should observe inhibition through a lowered positive response rate for Y in immediately following recognition of Y. On the other hand, if Y was facilitated during the recognition of X, one should observe facilitation through an increased positive response rate for Y. Thus, observing the response pattern of Y would make it possible to understand what actually occurred during the recognition of X. Although the present paradigm is a little different from the standard priming paradigm in which the prime is usually exposed without requiring any response, it shares the same logic as in the standard priming paradigm as mentioned above. For this reason, in this study, X has been termed as 'prime', and Y as 'target'. It should be emphasized that the ultimate interest of the study is in capturing what occurred during the recognition of the prime by analyzing the response to the target.

Four factors were manipulated in this study. First, the recognition time of the prime was manipulated. One group of subjects was told to respond very quickly after the presentation of the prime (fast condition), while the other group of subjects was allowed to respond more slowly (slow condition). Second, the relation between the prime and the target was manipulated. Half of the prime-target pairs were synonyms (related condition) and half were not (unrelated condition). Third, the prime was either an old or new item. Half of the primes were presented in the study phase (old-prime condition) and half were not (new-prime condition). Fourth, the target was either an old or new item. Half of the

targets were presented in the study phase (old-target condition) and half were not (new-target condition).

The above theory of recall-based inhibition makes the following predictions. First, recall-based inhibition will depend on the time course of recognition. Previous findings have strongly suggested that the assumed two processes of recognition, familiarity and recall, proceed along different time courses during recognition: the familiarity-based process occurs early and recall occurs more slowly in recognition (Hintzman & Curran, 1994). Under conditions in which subjects are forced to respond quickly, the recall process may be aborted, so that recall-based inhibition may be found only in the slow condition and not in the fast condition. One possible prediction for the fast condition is that, in the absence of recall, facilitation will occur for related targets by a process of spreading activation making the related target item more familiar, leading to more positive responses (facilitation prediction). Facilitation for related items based on spreading activation has been found in an episodic memory task, item recognition (McKoon, Ratcliff, & Dell, 1985).

Second, recall-based inhibition is predicted to depend on the prime-type. A prime may be either old or new. As discussed in the introduction, whether a prime is old or new may lead to a different priming pattern. Table 1 illustrates this. Suppose X and Y are two adjacent test items, such that X is a prime and Y is a target. Also suppose they are related in meaning.

Table 1. Illustration of a recall-based inhibition hypothesis in Experiment 1

Study phase	[X,Y]	X, [Y]
Test phase		
Prime	X	X
(Recalled)	X ,Y	X, Y
Target	Y	Y
Prediction for Y facilitated)	Inhibited	Not inhibited (or

note. Characters in a bracket indicate the items which are presented in the study phase. Characters in bold indicate the items which are recalled during the recognition of the prime.

As seen in Table 1, a different priming pattern is expected according to whether a prime is old or new, because the recalled item is different in each case. Consider the left side of the table. In this case, both X and Y are presented in the study phase, thus both are old items. Now, suppose X is presented as a test item in prime trial. Subjects will search for X in episodic memory (memory for the study phase), and finally recall X. During the recall of X, the related item Y, also presented in the study phase and thus present in episodic memory, is likely to interfere with the recall of X. That is because the accessibility of Y is also high because of its relation with X, although not greater than that of X. As a result of competition between X and Y, Y is inhibited. When Y is presented as a test item in the immediately following target recognition trial, the previous inhibition for Y will yield some inhibition effect in the form of a decreased positive response rate for Y. In contrast, consider the right side of the picture. In this case, only Y

is presented in the study phase, thus X is a new item and Y is an old one. Now, suppose X is presented as a test item in prime trial. Subjects will begin search for X in their episodic memory. Because X is not present in their episodic memory, the related old item Y, stored in episodic memory, is most likely to be recalled, because its accessibility will be the highest due to the relation with X. When Y is presented as a test item in the immediately following recognition trial, the previous recall of Y will not yield an inhibition effect for Y. Even some facilitation effect might be yielded in increased positive response for Y. Thus, in the present study, recall-based inhibition is predicted to occur only in the old-prime condition but not in the new-prime condition. Recall-based inhibition will be represented in an interaction of prime-type x relatedness.

Combining the two characteristics of recall-based inhibition view mentioned above, the following prediction is derived: In the fast condition in which there is presumably little recall, no inhibition will be found in related targets. There may even be facilitation based on spreading activation theory. In contrast, in the slow condition in which there is presumably recall, inhibition will be found in related targets depending on prime-type: that is, inhibition will be found in the old-prime condition but not in the new-prime condition.

In addition to the above critical prediction, one further prediction could be examined. Previous studies regarding inhibition have implied that there might be inequality in the degree of inhibition according to the strength of the competitor (Anderson & Bjork, 1994; Simpson & Kang, 1994). For example, Anderson and Bjork (1994) showed that the recall of a prime inhibited a related target if the target was a

strong competitor (high frequency word), but did not inhibit it if the target was a weak competitor (low frequency word). Similarly, Simpson and Kang (1994) demonstrated that a strong competitor tends to be more strongly inhibited than a weak competitor. In the present study, an old and new target in the related condition can be considered as a strong and weak competitor, respectively, due to the difference in their activation. Thus, examining recall-based inhibition in terms of the target-type will present a good test of this issue. Also, it will provide a test of the range of recall-based inhibition. If recall-based inhibition is found only in old targets but not in new targets, it means that recall-based inhibition occurs only within items activated in episodic memory. In contrast, if recall-based inhibition is found in both old and new targets, it means that recall-based inhibition occurs not only in episodic memory but also in semantic memory.

Method

Subjects

Sixty-eight University of Massachusetts undergraduate students participated in the study to get additional credits in psychology courses. All subjects were native speakers of English.

Stimuli

Three hundred and seventy-two synonym pairs were extracted from Whitten, Suter, and Frank (1979) and used as stimuli.

Design

Four variables were manipulated in this study. First, the response time for primes was either fast or slow. In the fast condition, subjects were signaled to respond 200 ms after the onset of the prime, whereas in the slow condition subjects were signaled to respond 2 s after the onset of the prime. All subjects were asked not to respond before the signal. Second, the prime was either related or unrelated to the target. In the related condition, the prime and the target shared similar meaning (synonyms), whereas in the unrelated condition they were not related in meaning. Third, the prime was either old or new. Half of the primes were old items that were presented in the study phase, and half were new items that were not presented in the study phase. Fourth, the target was also either old or new. Half of the targets were old items, and half were new items. Response time (fast vs. slow) was a between-subject variable, and relation (related vs. unrelated), prime-type (old vs. new), and target-type (old vs. new) were within-subjects variables.

Table 2 represents the basic structure of the study. A 2 (relation) x 2 (prime-type) x 2 (target-type) design was used (fast and slow condition has the same structure except the response time for primes). The basic unit was 12 synonym pairs, as seen in the table. From the 12 synonym pairs, 8 study words (bold ones) and 8 prime-target test pairs were created. There were 30 such units except 1 unit used as fillers, so that a total of $12 \times 30 = 360$ synonym pairs were used as stimuli. From them, a total of $8 \times 30 = 240$ study words, and a total of $8 \times 30 = 240$ test pairs were created. Randomization was carried out in two levels whenever a new subject participated in the experiment: (1) the order of 360 synonym pairs was randomized, and (2) the order of the first and the second word in each

synonym pair was also randomized. After that, study words and test pairs were systematically assigned by programmed plan.

Procedure

Each subject participated in the experiment individually during a 90 minute session. The experiment was composed of a study phase and a test phase. In the study phase, following the instructions, subjects were presented with 240 study words except the first 4 and the last 4 fillers and asked to memorize them. Study words were presented one at a time in the center of a computer screen for 3 s each.

The study phase was followed by the test phase beginning with some instructions. In the test phase, 496 test words were presented alternately in yellow and white. Because the adjacent yellow and white words were designed as the prime and the target, respectively, 240 test pairs (prime-target) were presented except the first 8 test pairs corresponding to the fillers. For the yellow word (prime), the subjects were signaled to respond 200 ms or 2 s from the onset of the test word according to the assigned condition (fast vs. slow condition). Subjects in the fast condition were required to respond as quickly as possible after the signal (200 ms), whereas subjects in the slow condition were permitted, if necessary, to have more time even after the signal (2 s). For the white word (target), there was no signal so that the subjects could respond at any time when they were ready. Regarding the speed and the accuracy, for the yellow word, accuracy within the time limit was emphasized, whereas for the white word, equal weight was given to both the speed and the accuracy.

Table 2. Structure of Experiment 1

[study phase]

(Bold words were the words presented in the study phase)

autumn

fall

insane

crazy

region

area

courage

bravery

instant

moment

display

exhibit

human

person

dinner

supper

movie

film

taxi

cab

victor

winner

safety

security

[test phase]

related condition

unrelated condition

prime-target condition

prime

target

prime

target

old

old

autumn

fall

instant

display

new

old

insane

crazy

human

dinner

old

new

region

area

movie

taxi

new

new

courage

bravery

victor

safety

There was a 200 ms interval within a test pair, so that the target was presented 200 ms after the subject's response to the prime, and there was a 2 s interval between test pairs, so that the prime of the next test pair was presented 2 s after the subject's response to the previous target. For every test word, yellow and white, subjects were asked to make a recognition judgement for that word. If the subjects judged the word as old (presented in the study phase), they responded 'yes', whereas if they judged it as new (not presented in the study phase), they responded 'no'.

Results and Discussion

Among the total 68 subjects, data from 46 subjects who showed performance above chance level (50% correct) on both old and new targets were analyzed, including 28 subjects in the slow condition and 18 subjects in the fast condition. Data were analyzed in terms of old targets, new targets, and d' , respectively.

Positive responses to old targets (hits)

First of all, to examine the overall pattern, a 2 (response time) \times 2 (prime-type) \times 2 (relatedness) ANOVA was carried out using response time as a between-subject variable, and prime-type and relation as within-subject variables. In this analysis, no significant results were found except the interaction between prime-type and relatedness, $F(1,44) = 4.74$, $p < .05$, indicating a facilitation for related targets when the prime was new but none for related targets when the prime was old. A 3-way interaction did not reach significance, $F(1,44) = 1.51$, $p > .2$.

To examine the data more specifically, separate 2 (prime-type) x 2 (relatedness) ANOVAs were performed in the fast and slow conditions, respectively. The results are presented in Table 3 and also plotted in Figure 1. The results show a very different pattern as a function of time condition.

Table 3. Positive responses (%) to old targets in Experiment 1

prime-type	fast condition (n=18)			slow condition (n=28)		
	related	unrelated	diff.	related	unrelated	diff.
old	66	64	2	59	62	-3
new	68	63	5	67	61	6
average	67	63	4	63	62	1

note. diff. = related - unrelated

In the fast condition, there were no significant effects of prime-type, relatedness, or interaction between prime-type and relatedness. Although it did not reach significance, the percentage of positive responses in the related condition was marginally higher than in the unrelated condition, indicating that related targets had been slightly facilitated relative to unrelated targets (67% vs. 63%), $F(1,17) = 3.61, p < .08$.

In the slow condition, there was a significant main effect of prime-type, indicating that positive responses in the old-prime condition were lower than in the new-prime condition (61% vs. 64%), $F(1,27) = 5.26, p < .05$. However, there was no significant main effect of relatedness, indicating that there was no facilitation in related targets relative to unrelated targets (63% vs. 62%), $F(1,27) = .41, p > .5$. It is noteworthy that the absence of

facilitation in related targets in the slow condition is in contrast to the presence of facilitation in related targets in the fast condition. Most importantly, there was a significant interaction between prime-type and relatedness, $F(1,27) = 7.59$, $p=.01$, indicating that positive responses in related targets were slightly lower than in unrelated targets when the prime was old (59% vs. 62%), but higher when the prime was new (67% vs. 61%). Figure 1 shows this interaction effect clearly.

The present results support the hypothesis that recall-based inhibition might be present in recognition. Recall-based inhibition, represented by the interaction between prime-type and relatedness, was predicted to be obtained in the slow condition but not in the fast condition, because recall was assumed to play a role in the recognition of primes only when the recognition decision was made slowly. In contrast, in the fast condition in which recall was assumed not to play a role in the recognition of primes, overall facilitation was predicted in related targets relative to unrelated targets. Although the present results did not show a three-way interaction which, if found, would be stronger evidence, it does not damage the findings of Experiment 1, because separate analyses according to time condition show quite contrasting patterns of the two-way interaction, absence and presence, respectively, in the fast and slow conditions.

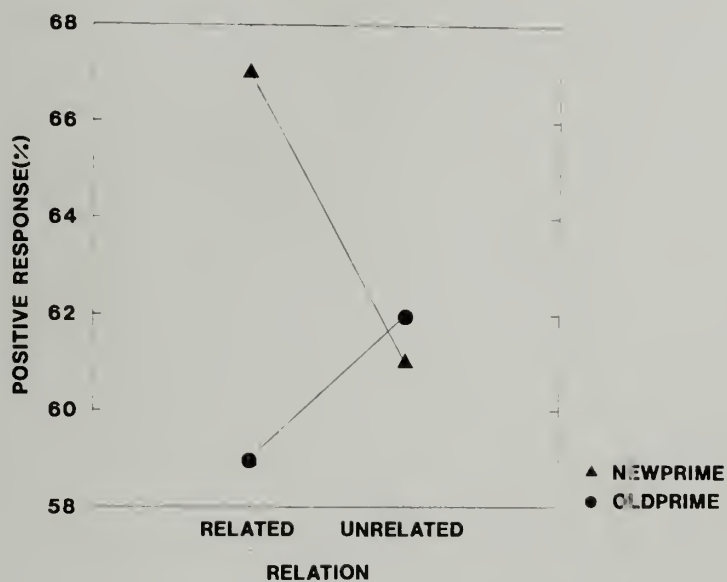
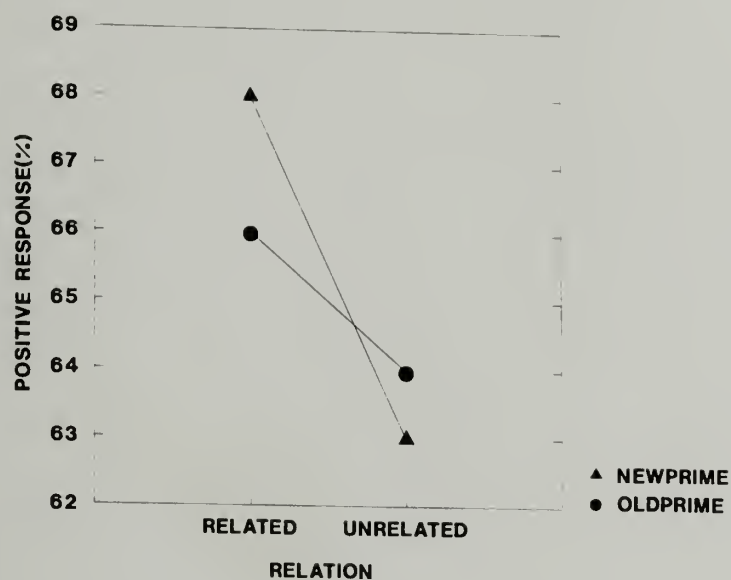


Figure 1. Positive responses to old targets as a function of relation between prime and target (related vs. unrelated) and prime-type (old vs. new) in the fast (upper) and slow (lower) conditions in Experiment 1

Positive responses to new targets (false alarms)

First of all, to examine the overall pattern, a 2 (time) x 2 (prime-type) x 2 (relatedness) ANOVA was carried out using time as a between-subject variable and prime-type and relatedness as within-subject variables. In this analysis, two significant results were found: first, there was a significant main effect of prime-type, indicating that the percent of positive responses in the old-prime condition were overall lower than in the new-prime condition (28% vs. 32%), $F(1,44) = 5.13, p < .05$. Second, there was a significant main effect of relatedness, indicating that the positive response in the related condition was overall higher than in the unrelated condition (33% vs. 27%), $F(1,44) = 16.4, p < .005$.

To examine the data more specifically, separate 2(prime type) x 2(relatedness) ANOVAs were performed in the fast and slow conditions, respectively. The results are presented in Table 4 and also plotted in Figure 2.

Table 4. Positive responses (%) to new targets in Experiment 1

prime-type	fast condition (n=18)			slow condition (n=28)		
	related	unrelated	diff.	related	unrelated	diff.
old	35	32	3	27	22	5
new	37	33	4	34	26	8
mean	36	33	3	31	24	7

note. diff. = related - unrelated

In the fast condition, no significant difference was found according to prime-type, relatedness, or interaction between prime-type and relatedness. However, positive responses to related targets were marginally higher than unrelated targets (36% vs. 33%), $F(1,17) = 3.19, P=.09$.

In the slow condition, there was a significant main effect of prime-type, indicating that the percent of positive responses in the old-prime condition was overall lower than in the new-prime condition (24% vs. 30%), $F(1,27) = 8.67, p < .01$. Also, there was a significant main effect of relatedness, indicating that the percent of positive responses in the related condition was higher than that in the unrelated condition (31% vs. 24%), $F(1,27) = 18.12, p < .001$. However, there was no interaction between prime-type and relatedness, $F(1,27) = .87, p > .3$.

The present results for the new targets can be summarized as follows. First, the positive response rate in the related condition was higher than that in the unrelated condition both in the fast and slow conditions, indicating that facilitation from the prime to the related target extended across the whole time course of prime recognition. This presence of a relatedness effect both in the fast and slow conditions is in contrast with the results shown in old targets in which a marginal relatedness effect in the fast condition disappeared in the slow condition. Second, there was no interaction between prime-type and relatedness in the slow condition, indicating that recall-based inhibition did not occur in prime recognition. This absence of an interaction in new targets is in contrast to the presence of an interaction in old targets. It indicates that recall-based inhibition occurred only in old targets but not in new targets.

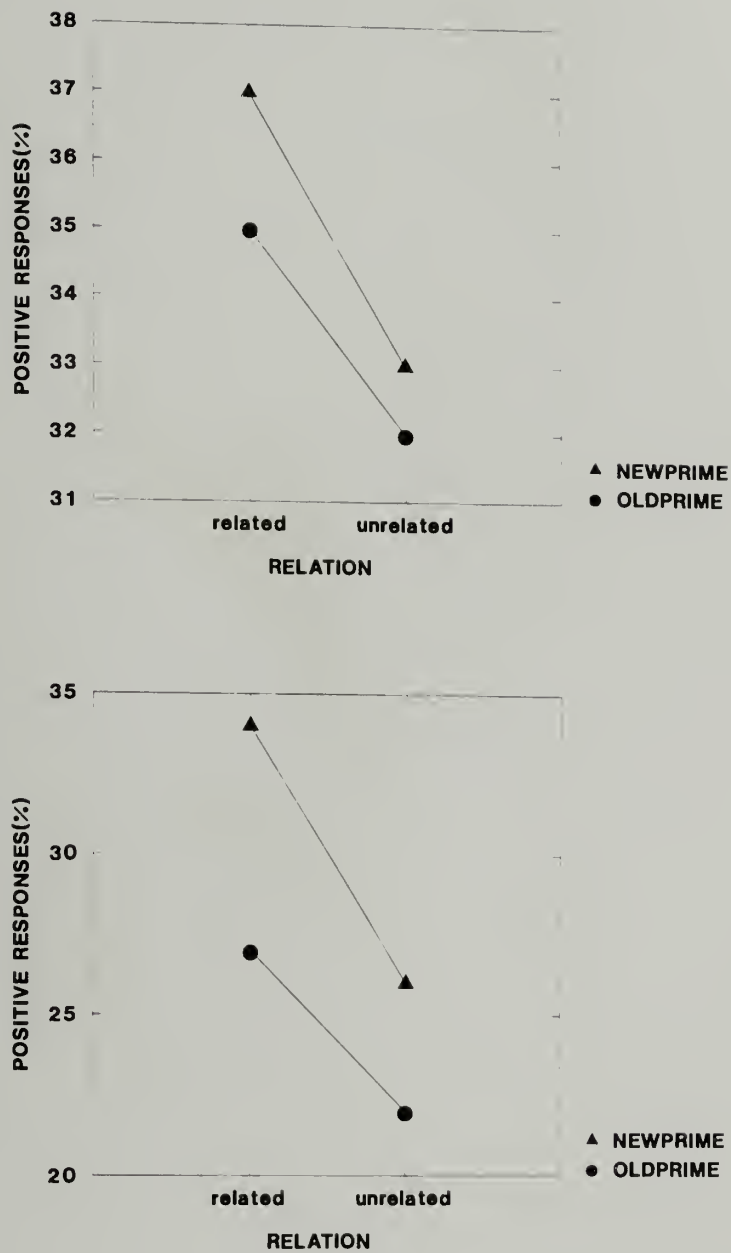


Figure 2. Positive responses to new targets as a function of relation between prime and target (related vs. unrelated) and prime-type (old vs. new) in the fast (upper) and slow (lower) conditions in Experiment 1

Table 5 shows the results from old and new targets comprehensively. As seen in Table 5, the pattern of positive responses in old and new targets appears very similar in the fast condition, but quite different in the slow condition. In the fast condition, although marginally significant, consistent relatedness effect was found but there was no interaction in both old and new targets, indicating that facilitation, not inhibition, occurred in related targets when prime recognition was made fast. On the contrary, in the slow condition, recall-based inhibition, represented as an interaction between prime-type and relatedness, was found in old targets but not in new targets, indicating that the phenomenon of recall-based inhibition was restricted to old targets. An implication from this result is that the strength of a competitor might be a factor triggering recall-based inhibition. That is, relatively weak strength of new targets as competitors may not trigger recall-based inhibition.

Table 5. Summary of the statistical results in Experiment 1

effects	fast condition		slow condition	
	old target	new target	old target	new target
prime-type	x	x	O	O
relatedness	O*	O*	x	O
prime-type x relatedness	x	x	O	x

note. O : significant x : not significant O* : marginally significant

d' in target recognition

Finally, d' was analyzed, combining the data from old and new targets. d' is known as a sensitivity measure and corresponds to the separation of the means of two distributions of noise and signal in signal detection theory. In recognition, d' has been used as a discrimination measure between old and new targets. d' is determined by the difference between the standardized scores of hit rate and false alarm rate. It can be specified as the following equation,

$$d' = z(H) - z(F)$$

where $z(H)$ is the standardized score of the hit rate, and $z(F)$ is the standardized score of the false alarm rate (Macmillan, 1993). In the present study, d' was computed using the above equation. The results are presented in Table 6.

In a 2 (response time) x 2 (prime-type) x 2 (relatedness) ANOVA, there was a significant effect of relatedness (.88 vs. 1.02), $F(1,44) = 5.29$, $p < .05$, indicating that d' was overall lower in related targets than in unrelated targets. In addition, there was an interaction between response time and relatedness, $F(1,44) = 3.91$, $p = .05$, indicating that the difference between related and unrelated targets was larger in the slow condition (.90 vs. 1.11) than in the fast condition (.85 vs. .87).

To examine the data more specifically, separate 2 (prime-type) x 2 (relatedness) ANOVAs were performed in the fast and slow conditions, respectively. The results are presented in Table 6.

Table 6. d' in target recognition in Experiment 1

prime- type	fast condition			slow condition		
	related	unrelated	diff.	related	unrelated	diff.
old	.85	.89	-.04	.87	1.20	-.33
new	.85	.85	0	.92	1.03	-.11
average	.85	.87		.90	1.11	

note. diff. = related -unrelated

In the fast condition, no significant effects were found according to prime-type, relatedness, and prime-type and relatedness (all $p > .5$). On the other hand, in the slow condition, there was a significant effect of relatedness (.90 vs. 1.11), $F(1,27) = 9.17$, $p = .005$, indicating that d' in related targets was overall lower than in unrelated targets. More importantly, there was a marginal interaction between prime-type and relatedness, $F(1,27) = 3.06$, $p = .09$, indicating that the difference between related and unrelated targets was larger in the old-prime condition (-.33) than in the new-prime condition (-.11).

Results from the analysis of d' appears to integrate the previous findings from old and new targets. First, the fact that there was no difference in d' according to prime-type, relatedness, and prime-type and relatedness in the fast condition is well understood considering that in the fast condition, hit and false alarm rates were changed or unchanged together, leading to unchanged d' . For example, positive responses to related targets were increased in both old targets (hits) and new targets (false alarms), resulting in no change in d' . Second, the fact that d' for related targets was lower than for unrelated

targets in the slow condition is clear considering that there was no relatedness effect in the hit rate, whereas there was a relatedness effect in the false alarm rate (the false alarm rate was higher in related targets), resulting in a decreased d' in the related condition. Third, the fact that there was an interaction between prime-type and relatedness in the slow condition is well understood considering that in the old-prime condition, related targets showed fewer positive responses to old targets but more positive responses to new targets relative to unrelated targets (see Table 3), whereas in the new-prime condition, related targets showed more positive responses to both old and new targets relative to unrelated targets (see Table 4). This leads to the larger difference in d' between related and unrelated targets in the old-prime condition than in the new-prime condition.

The above results can be understood in terms of the shift in the two distributions of old and new targets, because d' represents the distance between the two distributions. First, the fact that in the fast condition, facilitation in related targets in both old and new targets led to an unchanged d' is consistent with the view that both the old and new distributions were equally shifted to the right. Second, the fact that in the slow condition, d' was overall lower in related targets than unrelated targets is consistent with the view that the new distribution was shifted to the right, but the old distribution is not. Third and most importantly, the fact that there was an interaction between prime-type and relatedness is consistent with the following view: in the old-prime condition, the new distribution was shifted to the right but the old distribution was shifted to the left, whereas in the new-prime condition, both the new and old distributions were shifted to the right. Combining the old-prime condition and new-prime condition led to the overall

relatedness effect in the slow condition, because the amount of the shift of the new distribution was summed, but the amount of the shift of the old distribution was offset.

Summary

The major findings of Experiment 1 can be summarized in the following way: (1) recall-based inhibition was found in the slow condition but not in the fast condition, (2) a slight, but overall, facilitation was found in the fast condition, and (3) a clear pattern of recall-based inhibition was found in the old-prime condition but not in the new-prime condition.

These results provide several implications for a recall-based inhibition hypothesis. First, recall-based inhibition in related items actually occurs in recognition. Second, its time course is consistent with a later stage of the recognition process, whereas facilitation in related items is consistent with an early stage of the recognition process when recall does not play a role. Third, recall-based inhibition is restricted to old targets. It may be either because recall-based inhibition is triggered only by a strong competitor, or because the range of recall is restricted to episodic memory. In terms of the former, relatively weak strength of new targets cannot trigger recall-based inhibition. In terms of the latter, new targets cannot be an object of recall-based inhibition, because they are not present in episodic memory.

CHAPTER III

EXPERIMENT 2

The results of Experiment 1 provide some evidence for the existence of recall-based inhibition in recognition. Based on this result, Experiment 2 was planned to provide another test of the effects of recall-based inhibition.

The logic used in Experiment 1 was that the response pattern in target recognition reflects the recognition process of the prime. That is, an increase or a decrease in positive responses to targets can be interpreted as an indication of the previous facilitation or inhibition which occurred during the recognition of the prime. Based on this logic, the interaction between prime-type and relatedness can be interpreted as evidence for the existence of recall-based inhibition in recognition.

However, there is an alternative view which can provide a possible account of the interaction between prime-type and relatedness. Jacoby and Whitehouse (1989) have suggested that an attribution process might be involved in recognition decisions. In their experiment, when the target was preceded by a short exposure of a semantically related prime, positive responses for the target decreased relative to the control condition in which the prime was unrelated to the target. This finding was explained in terms of the following attribution process: the subject is likely to attribute the familiarity evoked by the target to its association with the previously presented prime and not to the target itself, thereby responding less positively to the target.

A similar account could be made in interpreting the results of Experiment 1. The interaction between prime-type and relatedness might occur not because recall-based

inhibition had occurred during the recognition of the prime, but because subjects had differently attributed the familiarity of the target. For example, in the old-prime condition, the familiarity of a related target can attributed not to the target but to its relatedness to the prime, thereby leading to a decrease in positive responses to that target. However, this tendency to attribute the familiarity of the target to its relatedness to the prime can be weaker or nonexistent in the new-prime condition in which the initial familiarity value of primes is lower than in the old-prime condition.

The point is that, in terms of the attributional view, increased or decreased positive responses to the target need not be interpreted as a reflection of inhibition or facilitation for the target in activation level but to what its familiarity is attributed. This analysis suggests that using a recognition memory test to indicate levels of activation of the memory trace may have been inappropriate, because the response pattern may be influenced by other factors, such as attribution of familiarity. For this reason, it is necessary to employ a new target task which can reflect the recognition process of the prime more clearly.

The purpose of Experiment 2 was to obtain further evidence for recall-based inhibition in activation level using a different probe. For this purpose, a naming task replaced the recognition task for measuring target performance. The naming task is supposed to be a more sensitive paradigm, and thus may reflect the activation level of the target better than the recognition task. Except for the employment of the naming task for targets, the basic priming paradigm was the same as in Experiment 1. Accordingly, the following priming logic was still maintained. Suppose the prime is X and the target is Y,

and that the recognition of X will be immediately followed by the naming of Y. If Y was inhibited during the recognition of X, naming for Y will show the sign of some inhibition for Y in slower naming time. In contrast, if Y was facilitated during the recognition of X, the naming task of Y will show the sign of some facilitation in faster naming time.

In Experiment 2, three within-subject variables were used: (1) relatedness between a prime and a target (related vs. unrelated), (2) prime-type (old vs. new), and (3) target-type (old vs. new). To avoid complexity in analysis, in Experiment 2, only the slow condition was used. Accordingly, all the subjects in Experiment 2 were asked to wait 2 seconds before making a recognition decision for the prime.

Method

Subjects

Twenty-seven undergraduate students at University of Massachusetts participated in the experiment to get additional credit in their psychology courses.

Stimuli

Three hundred and sixty synonym pairs that were used in Experiment 1 were used as stimuli.

Design

Three within-subject variables were manipulated: target-type (old vs. new), prime-type (old vs. new), and relatedness (related vs. unrelated). Thus, it was a 2 x 2 x 2 repeated design and consisted of 8 conditions. Subjects were asked not to respond before 2 seconds from the onset of a prime. Instead of the single long study-test phase used in

Experiment, this experiment consisted of 5 short study-test cycles with a 3-4 minute break between cycles in order to improve performance in prime recognition.

Among a total of 360 synonym pairs, 72 synonym pairs were used in each cycle to create study words and test pairs (for the basic structure, see Table 2 in Experiment 1). Each cycle consisted of 48 study words and 48 test pairs, with each test pair composed of a prime and a target. Among 48 study words, the first 4 and the last 4 words were fillers, so that the actual study words in each cycle were 40 words. Among the 48 test pairs, the first 8 test pairs were the counterparts of the fillers and excluded from the analyses, so that the actual test pairs in each cycle were 40 pairs. 40 study words and 40 test pairs were allotted to 8 conditions, with 5 study words and 5 test pairs in each condition.

Whenever a new subject participated, randomization occurred in the following steps: (1) the order of the 360 synonym pairs were changed randomly, (2) the order within the synonym pair was also changed randomly, (3) 360 synonym pairs were divided into 5 groups of 72 synonym pairs, (4) from the 72 synonym pairs, 48 study words and 48 test pairs were created, and (5) the presentation order of study words was randomized within a study phase, and the presentation order of test pairs also randomized within a test phase.

Procedure

Subjects participated individually in the experiment for about one and a half hours. After being given general instructions about the experiment, they were introduced to the experimental room. In each cycle, the study phase began with instructions, followed by the presentation of 48 study words. Each study word was presented for a

duration of 3 seconds. After the study phase was completed, the test phase began with instructions, followed by the presentation of 48 test pairs. As in Experiment 1, the prime and target trials were signaled to the subject by collars: prime (yellow) and target (white). For the prime, subjects made a recognition decision with a 'yes' or 'no' response when they were signaled (beep sound) 2 s from the onset of the prime. If necessary, they were allowed more time before responding. However, it was emphasized that they were not to respond before the signal. For the target, subjects pronounced the name of the target as quickly and loudly as possible. Pronunciation was monitored in another room. There was a 200 ms interval within a test pair, so that the target was presented 200 ms after the subject's response to the prime. There was a 2 s interval between test pairs, so that the prime of a next test pair was presented 2 s after the subject's response to the previous target.

Results and Discussion

Recognition for Primes

The results of the prime trials are presented in Table 7. The average recognition latency on all responses was 2899 ms (SD=460), ranging from 2304 - 4172 ms. The average error rate (percentage of false recognition) was 15% (SD=8), ranging from 0 - 30%. In a 2 (prime type) x 2 (target type) x 2 (relatedness) ANOVA, the recognition of the old prime was overall better than that of the new prime in terms of response latency and error rate. Response latency of the old prime (presented in the study phase) was faster than that of the new prime (not presented in the study phase) by around 100 ms (2830 vs.

2968 ms), $F(1,26) = 7.27$, $p < .05$. An error rate for old primes (miss rate) was lower than that for new primes (false alarm rate), 12 vs. 19%, $F(1,26) = 10.55$, $p < .005$. As one would expect, there were no differences among conditions produced by the type of target.

Table 7. Response latency (ms) and error rate (%) in recognition for primes in Experiment 2

prime-target condition	related		unrelated	
	latency	error	latency	error
old-old	2812 (457)	11 (12)	2818 (401)	11 (12)
old-new	2825(409)	12 (10)	2863 (456)	13 (10)
new-old	2987 (559)	19 (13)	2964 (590)	20 (13)
new-new	2922 (569)	16 (12)	3001 (591)	18 (11)

note. standard deviation in a parenthesis

Naming for Targets

The average pronunciation error rate derived from mispronunciation or repeated pronunciation was 4.8%, and excluded from the analysis. The average naming latency was 614 ms (SD=74), ranging from 474 ms to 758 ms.

To examine the overall pattern of the data, a 2 (target type) x 2 (prime type) x 2 (relatedness) 3-way repeated ANOVA was carried out. In this analysis, three significant effects were found. First, there was a significant main effect of target type, indicating that the naming time for old targets was faster on average than for new targets (606 vs. 622 ms), $F(1,26) = 24.9$, $p < .005$. Second, there was a significant effect of relatedness,

indicating that the naming time for related targets was faster on average than for unrelated targets (609 vs. 620 ms), $F(1,26) = 10.5$, $p < .005$. Third, and most importantly, there was a significant 3-way interaction effect of target type x prime type x relatedness, $F(1,26) = 6.9$, $p < .02$.

To examine this 3-way interaction effect more thoroughly, separate 2 (prime type) x 2 (relatedness) ANOVAs were carried out for old and new targets, respectively. The results are presented in Table 8 and also plotted in Figure 3. The results were quite contrasting, as seen in Figure 3. For old targets, there was a significant interaction between prime type and relatedness, $F(1,26) = 9.4$, $p = .005$, indicating that recall-based inhibition had occurred, whereas there were no main effects of prime type, $F(1,26) = 1.2$, $p > .2$, or relatedness, $F(1,26) = 2.3$, $p > .1$. For new targets, by contrast, there was a significant main effect of relatedness, indicating that naming time for related targets was faster than for unrelated targets (614 vs. 630 ms), $F(1,26) = 7.6$, $p < .02$. But, neither the main effect of prime type, $F(1,26) = 1.4$, $p > .2$, nor the interaction between prime type and relatedness, $F(1,26) = 1.3$, $p > .2$, was significant. In fact, for new targets, the effect of the prime was in the opposite direction to that for old targets (i.e., larger facilitation for old primes).

The present results are consistent with the results in Experiment 1, leading to important implications for the recall-based inhibition view. First, the existence of an interaction between prime-type and relatedness for old targets provides support for the idea that recall-based inhibition occurred during the recognition process. In terms of recall-based inhibition, it was assumed that recognition of an old prime and new prime

would have different influences on the immediately following related target. That is, an old prime was assumed to inhibit the related target, but a new prime was assumed not to inhibit and presumably facilitate the related target. Accordingly, recall-based inhibition was predicted to produce an interaction between the prime type and the relatedness. The interaction effect found for old targets is consistent with the prediction. Furthermore, paired t-tests show that the naming time for the related old target was faster than for the unrelated old target when preceded by the new prime, 595 ms vs. 613 ms, $t(26) = 3.4$, $p < .005$, whereas the naming time for the related old target was not faster and even slightly slower than for the unrelated old target when preceded by the old prime, 610 ms vs. 607 ms, $t(26) = 3.7$, $p > .5$. This is exactly what would be expected under the assumption of recall-based inhibition in recognition.

Table 8. Naming latency (ms) for targets in Experiment 2

prime-target condition	related	unrelated	diff.
old-old	610 (81)	607 (73)	-3
new-old	595 (82)	613 (76)	18
old-new	609 (74)	630 (82)	21
new-new	619 (73)	630 (76)	11
average	608 (78)	620 (77)	12

note. diff. = unrelated - related, standard deviation in a parenthesis

The second implication from the present results was that the interaction between prime-type and relatedness was found only in old targets and not in new targets, which

was the same result as in Experiment 1. These results indicate that recall-based inhibition is restricted to the situation in which a strong competitor is present. They also indicate that recall-based inhibition seems to be restricted to semantically related items that are activated in episodic memory. Furthermore, the presence of an overall relatedness effect in new targets indicates that semantic relatedness between prime and target has a facilitative effect on the naming of the target that is not influenced by recall-based inhibition.

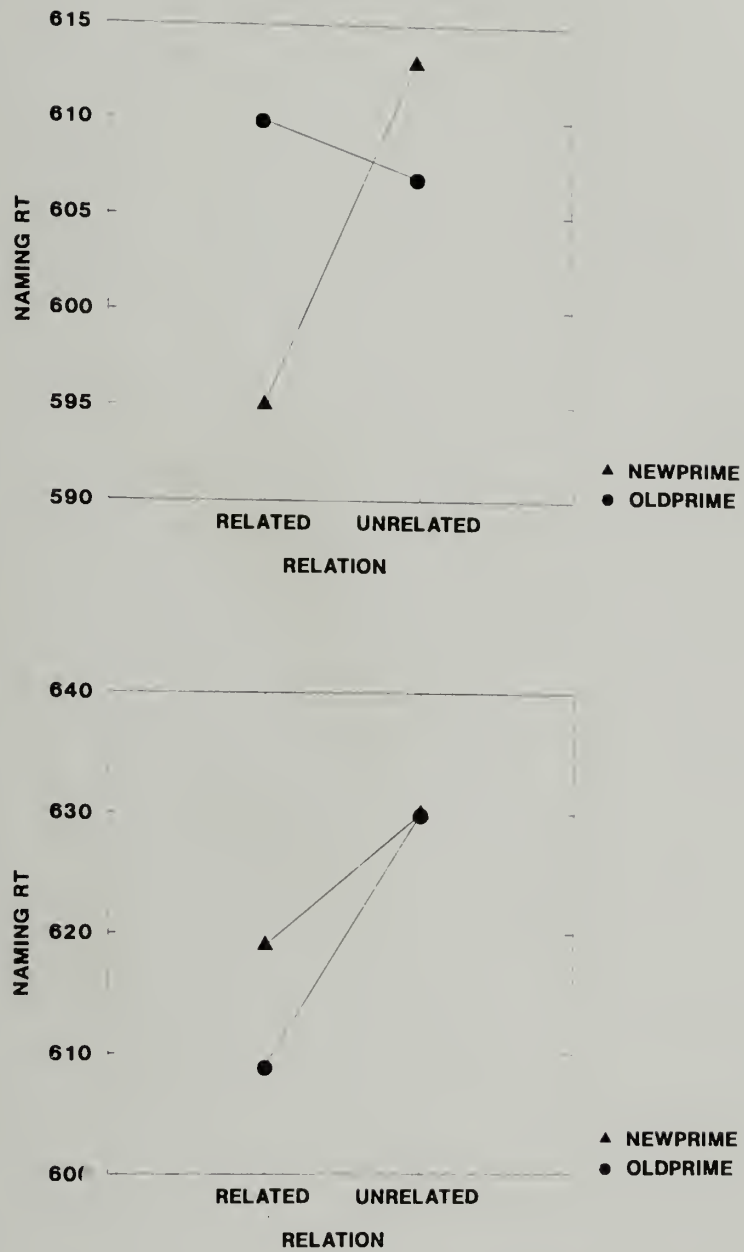


Figure 3. Naming RT for old targets (upper) and new targets (lower) as a function of relation between prime and target (related vs. unrelated) and prime-type (old vs. new) when prime recognition was made slowly in Experiment 2

CHAPTER IV

EXPERIMENT 3

The results of Experiments 1 and 2 both support the hypothesis of recall-based inhibition. In Experiment 1, there were two different time conditions for prime recognition, fast and slow. The prediction was that recall-based inhibition would be found only in the slow condition but not in the fast condition, because the fast condition did not allow the recall process to develop. In addition, recall-based inhibition was predicted to produce an interaction between prime-type and relatedness, because old and new primes yield different priming patterns: an old prime will lead to the inhibition of the related target, but a new item will not. A new item is more likely to lead to the facilitation of the related target. The rationale for these predictions was already specified in introduction. The result of Experiment 1 was consistent with the predictions.

In Experiment 2, to rule out the possibility of the alternative view in the interpretation of the results of Experiment 1 and also to provide more convincing evidence for recall-based inhibition, naming time was used as the measure of target strength. The results of Experiment 2 were consistent with the results of Experiment 1. Again as in Experiment 1, recall-based inhibition represented as the interaction between prime-type and relatedness was found in old targets but not new targets. This was represented by a 3-way interaction between prime-type, relatedness, and target-type.

In Experiment 2, all the subjects were given enough response time, as in the slow condition in Experiment 1. The obvious next question is whether the pattern observed in the fast condition of Experiment 1 would be seen using naming time as the index of

activation level. Thus, Experiment 3 was planned to be exactly identical with Experiment 2 except for the response time allowed for the recognition of primes. All the subjects in Experiment 3 were asked to respond very quickly, as in the fast condition of Experiment 1. The prediction is that in the fast condition, there would be no recall-based inhibition. One interesting question is, in the absence of recall-based inhibition, what happens? The results of Experiment 1 imply that there might be facilitation from a prime to a related target. This question, together with the absence of recall-based inhibition, was examined in Experiment 3.

Method

Subjects

Twenty undergraduate students at University of Massachusetts participated in the experiment to get additional credit in their psychology courses.

Stimuli

The stimuli were three hundred and sixty synonym pairs used in Experiment 1 and Experiment 2.

Design

The same design as in Experiment 2 was used.

Procedure

The same procedure was used except that subjects were signaled to respond to a prime 200 ms after the onset of the prime.

Results and Discussion

Recognition for Primes

The purpose of Experiment 3 was to examine the pattern of naming of targets when the recognition of a prime is made quickly. For a direct comparison with Experiment 2 in which the recognition of a prime is made more slowly, only responses falling between 200 - 800 ms from the onset of the prime were included in the analysis. The average percentage of excluded responses was 6%, ranging from 1 - 18%. The results of the recognition of primes are presented in Table 9. The average response latency was 556 ms (SD=69), ranging from 375 - 639 ms. The average error rate (the percentage of misses and false alarms) was 27% (SD=10), ranging from 0 - 45%. In a 2 (prime-type) \times 2 (target-type) \times 2 (relatedness) repeated ANOVA, no significant effect was found in either response latency or error rate, although there was a slightly higher error rate in the related condition than in the unrelated condition in new targets (27 vs. 24%).

Table 9. Response latency (ms) and error rate (%) in recognition for primes in Experiment 3

prime-target condition	related		unrelated	
	latency	error	latency	error
old-old	561 (74)	29 (22)	548 (65)	29 (22)
old-new	553 (77)	30 (18)	549 (84)	31 (21)
new-old	558 (68)	26 (13)	565 (72)	22 (18)
new-new	562 (70)	28 (17)	550 (69)	26 (23)

note. standard deviation in a parenthesis

Naming for Targets

The average pronunciation error rate derived from mispronunciations, incomplete pronunciations, or repeated pronunciations was 3%. They were excluded from the naming time analysis. The average naming time was 506 ms (SD=50), ranging from 424 - 585 ms.

In a 2 (target-type) x 2 (prime-type) x 2 (relatedness) repeated ANOVA, the results were as follows. First, there was a significant effect of target-type, indicating that the naming time for old targets was faster than that for new targets (499 vs. 512 ms), $F(1,19) = 7.43$, $p < .02$. Second, there was a significant effect of relatedness, indicating that the naming time for related targets was faster than that for unrelated targets (499 vs. 512 ms), $F(1,19) = 34.56$, $p < .001$. Third, the 3-way interaction was not significant, indicating that recall-based inhibition did not occur in the present experimental paradigm, $F(1,19) = .18$, $p > .5$. In fact, the facilitation effect on old targets caused by a related prime was actually larger for old primes than for new primes. Other effects did not reach significance.

To examine the data more specifically, separate 2 (prime-type) x 2 (relatedness) ANOVAs were carried out for old and new targets, respectively. The results are presented in Table 10 and Figure 4. The results showed the same pattern regardless of target-type. That is, for old targets, a significant main effect of relatedness was found (493 vs. 504 ms), $F(1,19) = 16.20$, $p < .005$, whereas no interaction between prime-type and relatedness was found, $F(1,19) = .50$, $p > .4$. Likewise, for new targets, there was a

significant main effect of relatedness (505 vs. 519 ms), $F(1,19) = 13.08$, $p < .005$, whereas no interaction between prime-type and relatedness was found, $F(1,19) = .03$, $p > .5$.

Table 10. Naming latency (ms) for targets in Experiment 3

prime-target condition	related	unrelated	diff.
old-old	490 (52)	505 (48)	15
new-old	495 (56)	504 (51)	9
old-new	504 (50)	519 (53)	15
new-new	507 (52)	520 (61)	13
average	499 (53)	512 (53)	13

note. diff. = unrelated - related, standard deviation in a parenthesis

The present results can be summarized as follows: First, the naming time for old targets was faster than that for new targets. Second, the naming time for related targets was faster than that for unrelated targets in both old and new targets. Third, there was no interaction between prime-type and relatedness for either old or new targets. Together, these results indicate that when recognition of the prime is rapid, a related target is facilitated regardless of target-type. This pattern is consistent with the prediction of no inhibition or even facilitation under the absence of recall-based inhibition.

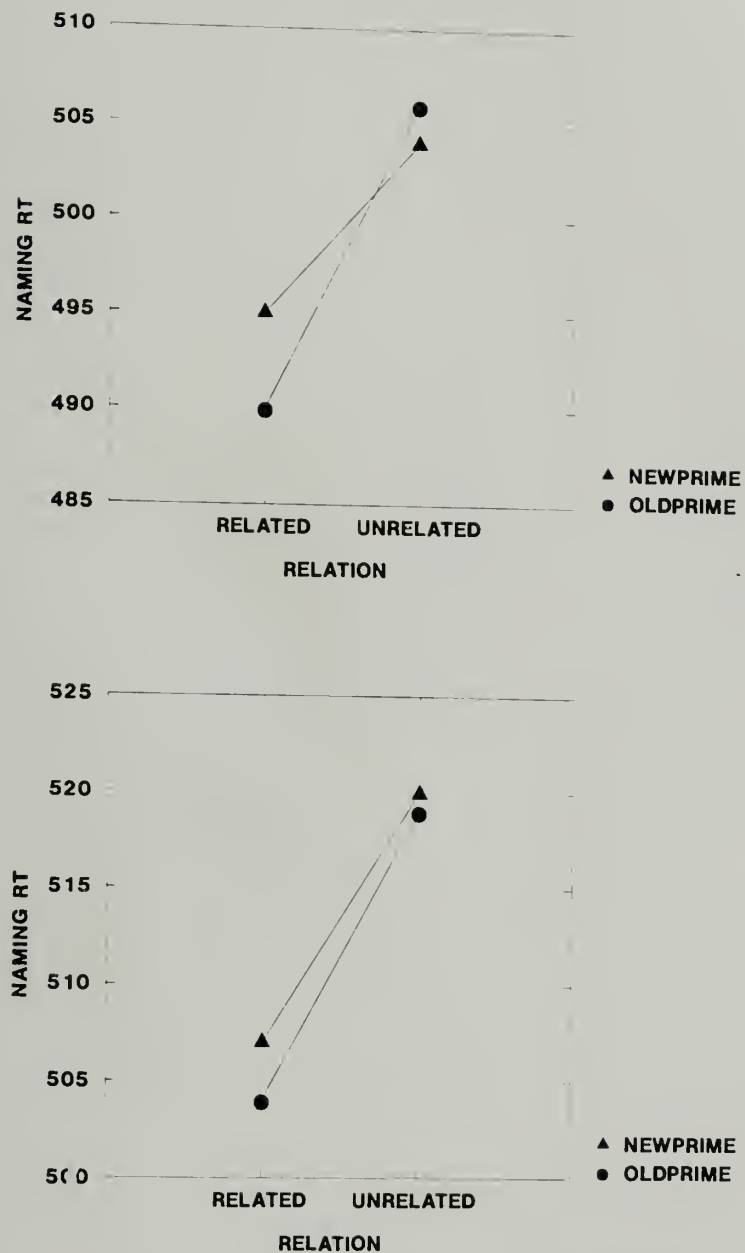


Figure 4. Naming RT for old targets (upper) and new targets (lower) as a function of relation between prime and target (related vs. unrelated) and prime-type (old vs. new) when prime recognition was made rapidly in Experiment 3

Summary of Experiment 2 and 3

The results of Experiment 2 and 3 are consistent with the results of Experiment 1, providing further evidence for a recall-based inhibition hypothesis in recognition. The summary of the major results in Experiment 2 and 3 is presented in Table 11.

Table 11. Summary of the statistical results in Experiment 2 and 3

effects	Experiment 2		Experiment 3	
	old target	new target	old target	new target
prime-type	x	x	x	x
relatedness	x	O	O	O
prime x relatedness	O	x	x	x

note. O : significant x : not significant

Table 11 shows the same pattern as the results of Experiment 1 (see Table 5), except that the prime-type effect only occurred in the slow condition of Experiment 1. It is noteworthy that the marginally significant relatedness effect in the fast condition of Experiment 1 became clearer in Experiment 3.

Of greatest interest is the presence of an interaction between prime-type and relatedness in Experiment 2 (slow prime recognition) and its absence in Experiment 3 (fast prime recognition). This indicates that recall-based inhibition occurs only at a later stage of the recognition process, following the time course of recall. Furthermore, recall-

based inhibition occurs only in old targets. It was represented by a 3-way interaction in target-type, prime-type, and relatedness in Experiment 2.

Finally, an ANOVA combining Experiment 2 and 3 showed a 4-way interaction among target-type, prime-type, relatedness, and experimental factor, $F(1,45) = 4.75$, $p < .05$, integrating all the aspects of recall-based inhibition mentioned to the present. This 4-way interaction could be reduced into the presence or absence of a 3-way interaction in target-type, prime-type, and relatedness in Experiment 2 and 3, respectively, representing the time course of recall-based inhibition. This 3-way interaction could be again reduced into the presence or absence of a 2-way interaction between prime-type and relatedness in old and new targets, respectively, representing the occurrence of recall-based inhibition only in old-targets.

CHAPTER V

GENERAL DISCUSSION

The results of the three experiments support the hypothesis of recall-based inhibition proposed in the introduction. The idea of recall-based inhibition in recognition is based on findings in two different areas of memory research. One source comes from studies dealing with the recognition process, and the other comes from studies dealing with inhibition from related items in memory.

The studies dealing with the recognition process have provided evidence against a unitary familiarity-based view of recognition, thus arguing for a dual process view of recognition. The dual process view assumes that recognition consists of two separate processes, familiarity and recall, that are assumed to proceed along different time courses during recognition. The early stages of recognition seem to be dominated by familiarity, whereas the later stages seem to be influenced by recall. The response-signal method, which asks subjects to respond by different deadlines, has provided good evidence for the distinction between familiarity and recall. As a result, it is important to gather converging evidence for a recall-like process in recognition. Thus, a unique phenomenon only belonging to recall would be good evidence for the role of recall in recognition. If so, what is it?

An answer to this question can be found in inhibition studies. The studies dealing with inhibition in memory have provided evidence that, spreading activation theory, which assumes that related items always facilitate, is wrong, or at least limited, and that a related item can sometimes produce inhibition. Such inhibition has been found in

semantic memory as well as in episodic memory. The finding of inhibition in episodic memory is a particularly important link in combining the studies of the two different areas. The reason is that, in a standard recognition paradigm, what is examined is mainly episodic memory and not semantic memory. That is, subjects in a recognition task usually study some items, and are then tested for their ability to recognize those items in episodic memory. For this reason, the finding of inhibition in episodic memory is possibly connected to the recognition paradigm. The most important finding from this line of studies was that the inhibition phenomenon occurred when there was an attempt to recall the prior related item.

On this basis, the recall-based inhibition hypothesis was developed in the present study. The major point is that the recall process, wherever it exists, should show the same characteristics unique to that process. Thus, if recognition indeed includes recall, an inhibition phenomenon unique to recall should be found in recognition. If recognition does not include recall, an inhibition phenomenon would not be found.

To predict how a recall-based inhibition phenomenon actually occurs in recognition, a more detailed analysis for the recognition situation was necessary. This was discussed in introduction. To specify the predictions, first, recall-based inhibition was predicted to be found in a contrasting priming pattern in old and new primes. Old primes would yield inhibition for related items, but new items would not, thus producing contrasting priming patterns. Second, recall-based inhibition was predicted to occur in a later stage of recognition, consistent with the time course of the recall component of recognition. Third, recall-based inhibition was predicted to appear differently according

to target-type, because some studies provide evidence for the inequality in the amount of inhibition depending on the strength of a related item.

All these predictions were tested in the present study employing a priming paradigm, and were consistently supported. The interaction between prime-type and relatedness was found as predicted. First, it was found only in the slow condition. Second, it was found only for old targets. The results were consistent across all three experiments. In Experiment 1, inhibition was measured in terms of a decrease in the positive response rate for targets, whereas in Experiment 2 and 3, inhibition was measured in terms of an increase in the naming time for targets.

The findings of the present study imply two important things. First, they provide evidence for the role of recall in recognition. Without assuming recall, it would be very difficult to interpret the present findings. The relatedness effect shown generally across all the experiments indicates that in a familiarity-based process, facilitation generally occurs for related items. Second, they provide further evidence for the existence of inhibition for related items in episodic memory by showing that inhibition occurs in an episodic recognition task. There has been a debate regarding priming effects for related items in episodic memory. While a priming effect for related items in semantic memory is almost universally facilitative, indicating something like spreading activation (e.g., McKoon & Ratcliff, 1979), priming effects for related items in episodic memory are mixed. Some studies show facilitation for related targets (McKoon, Ratcliff, & Dell, 1985), whereas other studies show inhibition for related targets (Anderson & Spellman, 1995; McKoon & Ratcliff, 1979, Experiment 4; Neely & Durgunoglu, 1985).

It is interesting to compare the experimental paradigms of the two studies, McKoon et al. (1985) and Neely and Durgunoglu (1985), because both studies provide quite contrasting priming effects for related targets, facilitation and inhibition, respectively, in an episodic recognition task. There are two distinct differences in these studies. One difference is that primes were presented in a different style. In McKoon et al. (1985), both primes and targets were tested in a recognition task. On the other hand, in Neely and Durgunoglu (1985), primes were presented without requiring responding and targets were tested in a recognition task. The other difference is that while there was no control for the prime duration in McKoon and Ratcliff (1985) because there was no deadline in responding to the prime, Neely and Durgunoglu (1985) controlled the prime duration at 150 ms and 950 ms.

It is not easy to compare the results of the present study to these studies, because in the present study, primes were tested in a recognition task (it is the main focus in the present study), which is different from Neely & Durgunoglu (1985), and the prime duration was controlled in the fast (200 ms) and slow (2 s) conditions which is different from McKoon and Ratcliff (1985). However, looking at the previous findings in terms of recall-based inhibition may provide some help in understanding those findings. A cautious look at the results of Neely and Durgunoglu (1985) shows that inhibition for related targets was stronger when the prime duration was 950 ms than when it was 150 ms. The effect was not significant in the 150 ms condition. If so, it would not be unreasonable to conjecture that Neely and Durgunoglu (1985) captured a slowly emerging inhibition for related targets. Of course, this conjecture has a limitation

considering that responses to primes were not required in their study. However, the possibility that a recognition process might have occurred during the presentation of primes cannot be excluded particularly in the prime duration of rather long 950 ms regardless of the instructions. On the other hand, in McKoon et al. (1985), the mean response time for the recognition of primes was 670 ms. If so, it would not be unreasonable to conjecture that McKoon et al. (1985) captured a rapidly emerging facilitation phenomenon for related targets. In short, facilitation and inhibition found in an episodic recognition task in the previous studies might reflect what occurred during the different processes of recognition, familiarity and recall.

Finally, one point regarding the interpretation of inhibition should be noted. Inhibition is usually inferred from a significantly higher value in response time or a significantly lower value in accuracy compared to a control condition. Because of this, one may claim that the present results do not provide sufficiently strong evidence for recall-based inhibition, as the present results did not show a significantly lower value in the condition of interest than the unrelated condition. However, inhibition also can be interpreted in terms of an occurrence of inhibitory behavior. In this sense, a decrease or complete elimination of facilitation can be appropriately interpreted as inhibition, too. It should be noted that in the present study, the facilitation shown in the early stage of recognition was offset in the later stage of recognition. This offset of the early facilitation is most naturally interpreted as a result of an activity of an inhibition mechanism. Thus, the present results, although not ideal, are still quite strong evidence for recall-based inhibition.

In conclusion, in interpreting the present results, a recall-based inhibition hypothesis is considered to be most appropriate. The presence of recall-based inhibition in recognition supports the idea that recall plays a role in recognition, thereby supporting a dual process mechanism of recognition.

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