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This research is concerned with long-term facilitation and short-term interference and facilitation in identification of pictures and words. The long-term facilitation occurs when subjects are exposed to some representation of the item during a study episode, and then show improved identification of that item during a retention test. This type of facilitation is known as priming (or long-term priming) and the retention test is known as an implicit or indirect test because subjects are not instructed to think back to the prior study episode during the test.

Much of our recent research has concerned the relationship between performance on the implicit test of picture fragment completion and the explicit test of recognition memory. Our major interest has been on the importance of maintaining the same surface features between study and test on performance in both implicit and explicit tests. Contrary to previous findings that explicit tests are impervious to surface changes and only sensitive to changes in meaning, we have found performance decrements from changes in surface features in explicit as well as implicit tests (continued on next page)

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These surface changes have been as subtle as differences in the level of fragmentation between study and test and as extreme as differences in the form of item (picture vs. word) between study and test. The research carried out under the grant has exploited this similarity between explicit and implicit tests within a components-of-information model of memory which accommodates both associations and dissociations between the two classes of tests.

We have studied short-term interference in identification by giving subjects degraded information about a target item just prior to the identification test. We have interpreted the interference as the operation of a top-down process in perception of meaningful stimuli. This interpretation is supported by finding that interference turns into facilitation for meaningless stimuli (nonwords). In some very recent research, we have also studied short-term interference and facilitation in identification of fragmented pictures and in naming of intact pictures when various kinds of prior information is presented (information about perceptual features, category membership, and first letter of name). We found that the usefulness of these various types of information interacts with the perceptual task. We hope through continued exploration of this short-term semantic priming procedure to gain new insights into how meaningful objects are identified.

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Facilitation and Interference in Identification of Pictures and Words

(F49620-92-J-0119)

Joan Gay Snodgrass

New York University

6 Washington Place, Room 857

New York, NY 10003

5 October 1994

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Attachments

Luo, C. R., & Snodgrass, J. G. (1994). Competitive activation model of perceptual interference in picture and word identification. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 50-60.

Snodgrass, J. G., & Hirshman, E. (1994). Dissociations among implicit and explicit memory tasks; The role of stimulus similarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 150-160.

Snodgrass, J. G., & Luo, C. L. (1993). Components of information: A framework for memory research. Paper presented at the November, 1993 meetings of the Psychonomic Society, Washington, D. C.

Abstract

This research is concerned with long-term facilitation and short-term interference and facilitation in identification of pictures and words. The long-term facilitation occurs when subjects are exposed to some representation of the item during a study episode, and then show improved identification of that item during a retention test. This type of facilitation is known as priming (or long-term priming) and the retention test is known as an implicit or indirect test because subjects are not instructed to think back to the prior study episode during the test.

Much of our recent research has concerned the relationship between performance on the implicit test of picture fragment completion and the explicit test of recognition memory. Our major interest has been on the importance of maintaining the same surface features between study and test on performance in both implicit and explicit tests. Contrary to previous findings that explicit tests are impervious to surface changes and only sensitive to changes in meaning, we have found performance decrements from changes in surface features in explicit as well as implicit tests. These surface changes have been as subtle as differences in the level of fragmentation between study and test and as extreme as differences in the form of item (picture vs. word) between study and test. The research carried out under the grant has exploited this similarity between explicit and implicit tests within a components-of-information model of memory which accommodates both associations and dissociations between the two classes of tests.

We have studied short-term interference in identification by giving subjects degraded information about a target item just prior to the identification test. We have interpreted the interference as the operation of a top-down process in perception of meaningful stimuli. This interpretation is supported by finding that interference turns into facilitation for meaningless stimuli (nonwords). In some very recent research, we have also studied short-term interference and facilitation in identification of fragmented pictures and in naming of intact pictures when various kinds of prior information is presented (information about perceptual features, category membership, and first letter of name). We found that the usefulness of these various types of information interacts with the perceptual task. We hope through continued exploration of this short-term semantic priming procedure to gain new insights into how meaningful objects are identified.

Facilitation and Interference in Identification of Pictures and Words

Research Objectives

This research project is concerned with long-term facilitation and short-term interference and facilitation in identification of pictures and words. The long-term facilitation occurs when subject are exposed to some representation of the item during a study episode, and then show improved identification of that item during a retention test. Short-term interference occurs when subjects are presented with degraded information about a target item just before being asked to identify it. Short-term facilitation occurs when subjects are given a prime which gives advance information about various aspects of the target item.

1. Short-term Interference in Picture and Word Identification

Imagine that you are walking down a street and several blocks away you see a person who appears vaguely familiar coming toward you. You would like to be able to identify the person correctly when you are within hailing distance so as to avoid either missing a friend or falsely recognizing a stranger. What should you do? Should you begin to scrutinize the face immediately and continuously as the person approaches and his facial features are slowly clarified? Or should you look away and only scrutinize the face during the last hundred feet or so before you need to make a decision? We suspect most people would opt for the first solution, even though experimental literature suggests that the second will produce better identification.

Several studies have shown that subjects' ability to identify a moderately blurred image is undermined if subjects have been cued with partial features of that image beforehand. This phenomenon, the perceptual interference effect, was explored by Bruner and Potter (1964) who showed that identification of objects which were gradually brought into focus became progressively worse as initial levels were made more blurred. They attributed this interference effect to subjects' erroneous hypotheses about the object which interfered with correct perception.

Although this phenomenon would appear to have enormous theoretical and practical implications, the perceptual interference effect was largely ignored until fairly recently. Snodgrass and Hirshman (1991) explored the perceptual interference effect in a picture fragment completion paradigm. We generated interference by preceding a moderately fragmented (level 4) picture with more fragmented levels (levels 1, 2, and 3) in an ascending method of limits procedure. This interference or ascending condition was compared to a fixed or control condition in which only a level 4 picture was presented. In a series of five experiments, we tested a number of different hypotheses about the properties of the interference, which we interpreted as due to transient activation in features common to both target and distractor items. We concluded that this activation of competitors (distractors) to the target was not accessible to subjects' introspections because feedback that their erroneous guesses about the target were incorrect did not diminish the

interference whereas engaging in an unrelated activity between ascending presentations removed it.

More recently, we (Luo & Snodgrass, 1994a) showed that the limited set hypothesis proposed by Peynircioglu and Watkins (1986) and Peynircioglu (1987) to account for why interference occurred in word fragment completion was not correct. Peynircioglu and Watkins (1986) and Peynircioglu (1987) observed that interference occurred only for words selected from limited sets (previously studied words or words from a target category) and suggested that limitation of set was a necessary condition for the observation of interference. We showed that the crucial variable was not whether words came from a limited set but rather whether some performance threshold had been reached. Interference only occurred when identification performance was above some moderate level. We accounted for these results with a competitive activation model, derived from the Snodgrass and Hirshman (1991) connectionist model, which requires that activation of competing responses attain sufficient strength to produce interference. These studies also showed that perceptual interference for words appears to follow the same principles as perceptual interference for pictures.

The competitive activation model is a specific instantiation of a top-down processing model of perception because it asserts that interference occurs across memorial representations of known objects. This suggests that in order to obtain the interference, the subject needs to access elements of a set of items, such as pictures of common objects or known words, which have representations in semantic memory. To test this, we compared the effectiveness of perceptual interference on words compared to nonwords in a between-subjects design. The usual perceptual interference effect was obtained for words (ascending presentations produced worse performance than fixed presentations) but the reverse pattern was found for nonwords (ascending presentations produced better performance than fixed presentations). This is consistent with a top-down processing model in general, and the competitive activation model in particular, because nonwords have no memorial representation in semantic memory and thus cannot interfere with one another.

2. Long-term Facilitation of Picture and Word Identification

In a series of experiments supported by a previous AFOSR grant (Snodgrass & Feenan, 1990), we had subjects study pictures which were very fragmented, moderately fragmented, and intact and then tested them for perceptual identification by presenting old and new pictures with the ascending method of limits (most fragmented level first). Across five experiments, we consistently found that the moderately fragmented study picture produced the most robust priming. We accounted for this phenomenon by the mechanism of perceptual closure — when subjects are presented with stimuli which are just on the threshold of identification, and they experience closure by filling in the missing pieces, this provides a more powerful priming experience than either seeing a complete picture, so that no closure is experienced, or seeing a picture which is so fragmented that no closure is possible.

In a recent series of experiments (Snodgrass & Hirshman, 1994a), we investigated whether the perceptual closure phenomenon would generalize across various types of implicit and explicit tests. The implicit tests were picture fragment identification, intact picture naming, and speeded identification of a rapidly completing series of fragmented images; the explicit test was Yes/No recognition memory. Study pictures were varied across three levels of fragmentation, from very fragmented to complete. Test pictures were either complete or moderately fragmented. As expected, subjects performed better on the old than the new pictures (i.e., there was priming or implicit learning on the implicit tests and there was explicit learning on the recognition memory tests). However, regardless of whether the test was implicit or explicit, the best performance was obtained when the study stimulus matched the test stimulus in fragmentation level. Strikingly, even for the explicit test of recognition memory which is normally thought to be conceptually driven, testing a fragmented study item with a fragmented test item produced *better* performance than testing it with an intact test item. Thus, explicit recognition memory in these experiments was exquisitely sensitive to subtle surface changes between study and test. Furthermore, the two implicit memory tests of picture fragment identification and intact picture naming were dissociated by the fragmentation level of the study item: picture fragment identification was best for a moderately fragmented study item but intact picture naming was best for an intact study item — that is, the perceptual closure effect did not generalize from picture fragment identification to intact picture naming..

Snodgrass and Hirshman interpreted these dissociations in terms of compatibility or transfer-appropriate processing effects between study and test conditions. More recently, we have interpreted the surface effects in explicit memory as stemming from two processes in recognition memory: familiarity, which is sensitive to surface differences between study and test forms of the same item; and retrieval, which is insensitive to surface differences and more dependent upon context-to-item associations. According to this view, the extent to which surface effects are observed in recognition memory will depend upon the extent to which recognition relies on familiarity as opposed to retrieval.

In a series of experiments carried out in collaboration with one of my graduate students, Miriam Mintzer, we investigated a much more profound surface change in recognition memory — whether an item is tested in the same or a different surface form (picture versus word) as studied. Contrary to previous research in our laboratory, we were able to show surface change costs (worse performance when an item is tested in a different form than studied) on both recognition accuracy and speed. We attributed these costs to our procedure of presenting each study item three times. We also showed that surface change costs did not increase when subjects directed their attention to the surface features of a stimulus (judged the shape of pictures or the rhyme of words) as opposed to when they directed their attention to more semantic features of a stimulus (judged

the rhyme of a picture's name or the shape of a word's image). We were able to show that surface change cost can be eliminated in this situation when subjects are encouraged to dually-encode the study items (through either explicit instructions or preexposure to both the picture and word form of the item). A paper reporting these results is presently being revised for resubmission for publication (Mintzer & Snodgrass, 1994).

3.Specificity of Priming — Stimulus Similarity or Process Similarity?

As described earlier, Snodgrass and Hirshman (1994a) found stimulus similarity effects on the explicit task of recognition memory as well as on the implicit task of fragment identification and picture naming. It is thus clear that similarity between study and test pictures is crucial for determining optimum performance in both implicit and explicit tests. But what is the nature of this similarity? One possibility is that the similarity resides in the visual similarity of the study and test stimuli. A second possibility is that the similarity resides in the similarity of processing applied to study and test stimuli of the same fragmentation level. When a moderately fragmented item is presented at study subjects must apply the process of perceptual closure to it to complete it. When the same stimulus is presented at test, the same perceptual closure will be experienced, and this specific experience of perceptual closure to this item will reinvoke the study experience and lead to more effective or faster identification for implicit tasks or more accurate and faster recognition of oldness for explicit tasks. This process explanation is closely related to the transfer-appropriate-processing hypothesis first proposed by Morris, Bransford, and Franks (1977) for recognition memory performance, and later adopted by Roediger and his colleagues (see Roediger, 1990) to account for performance on implicit memory tasks.

Is there some way to distinguish process similarity from stimulus similarity? One way which we recently explored is to compare study and test pictures which are fragmented to the same degree (e.g., display only 20% of their picture elements) but vary in exactly which fragments are displayed. In the same fragments condition, exactly the same fragments are displayed during study and test. In the different fragments condition, a different 20% of the fragments are displayed at test. Both fragments conditions presumably induce the same process between study and test because they both require perceptual closure for their perception. However, the two fragments conditions differ markedly in the similarity of picture elements between study and test. In a strict sense, the different fragments condition has 0% similarity because none of the picture elements are in common, whereas the same fragments condition has 100% similarity because all of the picture elements are in common.

Remarkably, across three experiments we found absolutely no decrement in priming effect between the same and different fragments conditions. Below I present data from one of these experiments. The data shown are the priming effect, computed by subtracting the baseline or new identification performance from the primed performance. All conditions were within subjects.

There were two study conditions — one presenting 40% of the fragments (40% Study Condition) and one presenting 20% of the fragments (20% Study Condition).   There were three test conditions — one presenting the same 20% of the fragments as the 20% study condition (20% Same), one presenting a completely different 20% of the fragments as the 20% study condition (20% Diff), and one presenting only 10% of the study fragments (a subset of both the 20% and 40% study condition).   For the 40% study condition, the Same and Diff test conditions are not meaningful as they represent the two halves of the 40% study stimulus. They just confirm that the two sets of fragment halves are equally identifiable.

For our purposes, the important comparison is the 20% Same and 20% Diff test conditions for the 20% study condition. Here, the priming effect is identical between completely overlapping and completely disjoint sets of fragments. This suggests that it is the process of completion that is primed by the study episode rather than the actual fragments or pictorial elements themselves.

Priming Effect: The enhancement of performance produced by the study experience.

Study Condition

		40%	20%
Test	20% Same	0.26	0.16
Condition	20% Diff	0.25	0.17
	10%	0.23	0.14

In two subsequent experiments, we showed that recognition memory *was* affected by the change in fragments, but that the advantage enjoyed by recognition memory for same over changed fragments came from recognition of the item in the absence of identification — i.e., surface recognition unaccompanied by identification.   In a paper reporting the results of these experiments, we discuss their implications for the perceptual fluency hypothesis of recognition memory (Snodgrass & Hirshman, 1994b).

4. Short-term Facilitation of Picture Identification and Naming

In the short-term priming experiment, a prime precedes a target which is to be classified in some way or other.   In word recognition, the task is usually lexical decision or naming, the dependent variable is usually RT, and a priming effect occurs if a related prime produces a faster response than an unrelated prime does for the same item. The most effective primes are the item itself (repetition priming), followed by a semantically related prime. Interestingly, an unrelated prime tends to inhibit responding compared to a neutral condition (Balota, 1983; Becker, 1979; Neely, 1976; Seidenberg, Waters, Sanders, & Langer, 1984). In picture recognition, the task is usually picture identification or picture naming. In our research, we have used both tasks.

4.1. Picture Naming Norms

Before carrying out these short-term priming tasks, we first conducted a normative picture naming study to obtain baseline picture naming times and to determine which item characteristics predicted picture naming times. Picture naming has been shown to be affected by a number of variables, including various item characteristics of the pictures such as frequency in print of the picture's name, how many names the picture can have (codability), age of acquisition of the picture's name, etc.

The following variables have been reported to significantly affect naming latencies: Frequency in print of the picture's name (Goodglass, Theurkauf, & Wingfield, 1984; Humphreys, Riddoch, & Quinlan, 1988; Lachman, 1973; Lachman, Shaffer, & Hennrikus, 1974; Oldfield and Wingfield, 1964; 1965); age of acquisition of the picture's name (Carroll and White, 1973; Lachman, 1973; Lachman, et al., 1974; Morrison, Ellis, & Quinlan, 1992); codability, or the number of names a picture can have (Lachman, 1973; Lachman, et al., 1974); and length, as measured by the number of phonemes (Morrison, et al., 1992). In addition, Humphreys, et al. (1988) found that Snodgrass and Vanderwart (1980) pictures from structurally distinct categories were named faster than pictures from structurally similar categories, and that category structure interacted with frequency; specifically, name frequency had an effect only for structurally distinct categories. This interaction forms the basis for their proposal that the three stages of picture naming are not strictly serial but work in cascade. It should be noted that some studies failed to find effects of frequency in print while others have failed to find effects of length when length was measured either by number of letters or number of syllables.

Recently, one of my graduate students, Tanya Yuditsky, and I collected naming latencies from 250 of the 260 Snodgrass and Vanderwart (1980) pictures. Voice-key naming times were measured in Experiment 1 and keypress naming times (i.e., press the key as soon as you know what the picture is) in Experiment 2. The resulting naming times and error rates were well predicted in multiple regression analyses by one or another measure of codability (name or concept agreement) and by age-of-acquisition ratings collected specifically for the study. Voice key responses appeared to be somewhat more sensitive indicators of naming difficulty, although keypress responses did remarkably well. Although our results correlated highly with two other papers in the literature which used the Snodgrass and Vanderwart pictures, some results were not replicated in our larger set of pictures. A paper reporting these results (Snodgrass & Yuditsky, 1994) has been submitted for publication and is in the process of being revised.

4.2. Experiments in Semantic Priming

Next we turn to the effects of various kinds of semantic priming on picture naming and picture identification. Results from primed picture naming have often been interpreted in terms of stage models of picture naming. Most models propose that the process entails at least three

stages— accessing the visual features of the item or its stored structural description; accessing the item's meaning or its semantic representation; and accessing its pronunciation or phonological representation (Humphreys, Riddoch, & Quinlan, 1988; Lachman, 1973; Snodgrass, 1980, 1984). Although no exact analogue of the prime conditions we used exists in the literature, two comparisons are of interest in picture naming. One compares the priming efficacy of semantically related pictures with semantically related words, and the second compares the priming efficacy of semantically related words with phonologically related words (rhymes).

The first comparison is of interest for the following reason. Most semantically related primes are selected to be from the same category. Pictures from the same category are visually similar to one another, particularly if they are from structurally similar categories. Thus, a picture prime should prime both stage 1 - structural description, and stage 2 - meaning. The second comparison is of interest because it contrasts stage 2 or meaning priming with stage 3 or phonological priming.

Two studies have reported that picture primes are more effective in priming pictures than word primes are (Carr, McCauley, Sperber, & Parmelee, 1982; Sperber, McCauley, Ragain, & Weil, 1979). This would suggest that the additional visual information provided by a related picture prime also facilitated naming. This is also consistent with some data reported by Pollatsek, Rayner, and Collins (1984) who showed that peripherally presented primes which are visually but not semantically similar to the prime can facilitate target naming.

However, the Carr et al. (1992) study was somewhat peculiar in that semantic priming actually inhibited performance compared to the control or no prime condition. This was due in part to the requirement on the subject to report the prime after naming the target. In addition, some of the primes were at or below threshold, and the "full threshold" condition led to significant slowing of naming times. The dual task requirements on the subject to name both the target and prime when related or unrelated primes were presented apparently acted to slow naming times.

In contrast to these studies, Lupker (1988) found no differences between picture and word primes on picture latencies when the prime/target pairs were equated on ratings of degree of relationship. He therefore concluded that priming of visual features is not an important variable in picture naming. Although Lupker also had subjects name the prime, this naming was accomplished prior to presentation of the target, not afterwards, and his results showed an overall facilitation from related primes compared to the control (no prime) condition.

To my knowledge, there is only one study which has investigated facilitation in picture naming from phonemic cues (although a number of studies have looked at the effect of rhyming or phonemically related cues on word retrieval). McEvoy (1988) compared the priming ability of strongly and weakly related phonemic primes (rhymes) to strongly and weakly related semantic primes. Although all primes were presented as words, McEvoy used only concrete words which

could have been presented as pictures. In contrast to the studies cited above, subjects were not required to name the prime. There were two conditions: identical primes present and identical primes absent. In the identical primes absent condition (the condition which is relevant to our purposes), approximately equal amounts of facilitation were obtained for both semantic and rhyme primes compared to the no prime control condition. Thus, it appears from this brief review of the literature that priming effects can be obtained from all three types of cues — visual, semantic, and phonemic.

Our experiments in semantic priming have used two target tasks — picture naming for which response latency is the dependent variable, and fragment identification for which response accuracy is the dependent variable. The purpose of this research was to investigate various models of object identification, most particularly those which postulate the existence of three stages. Our manipulations were designed to differentially affect the durations of each of the three stages — (1) accessing a stored structural description, (2) accessing a semantic representation, and (3) accessing a phonological representation.

Three types of cues were used: cues about the visual appearance of the object, cues about the meaning of the object, and cues about the name of the object. The cue about the visual appearance of the object was an arrow indicating the direction in which the picture faces; the cue about the meaning of the object was the category name; and the cue about the name of the object was the picture name's first letter. In addition, each experiment used a control or baseline condition in which a string of XXXX's served as a prime.

We predicted that cues which emphasize the pictorial features of the stimulus will be more useful to fragment identification than to speeded naming, whereas cues which emphasize the name of the stimulus will be more useful to speeded naming than to fragment identification. The reason for this differential prediction is that the major slowdown in intact picture naming, we believe, is accessing the picture name, whereas the major difficulty in fragmented picture naming is identifying the pictorial features so as to identify what the object is. Because fragmented picture naming is untimed, subjects can locate the picture name at their leisure.

In a series of two experiments, subjects named pictures (Experiment 1) or identified fragmented pictures (Experiment 2) that were preceded by one of seven types of primes: neutral (a string of X's); a related visual cue (an arrow pointing in the direction which the picture faces); an unrelated visual cue (an arrow pointing in another direction); a related category cue (the correct name of the picture's category); an unrelated category cue (the name of another picture's category); a related letter cue (the first letter of the picture's name); and an unrelated category cue (the first letter of another picture's name). We predicted that first letter cues would be more effective for picture naming than for fragment identification, whereas arrow cues would be more effective for fragment identification than for picture naming. We thought that category cues might be equally

effective for both tasks. Both groups of subjects named the same set of 60 pictures, selected so as to be unambiguously named and unambiguously categorized. The results from this experiment are shown below, expressed as interference or facilitation scores with respect to the neutral prime condition . A positive score means facilitation (a decrease in naming time or an increase in fragment identification), whereas a negative score means interference (an increase in naming time or a decrease in fragment identification). Priming scores for identification have been multiplied by 8 to produce equal standard deviations to the priming scores for naming:
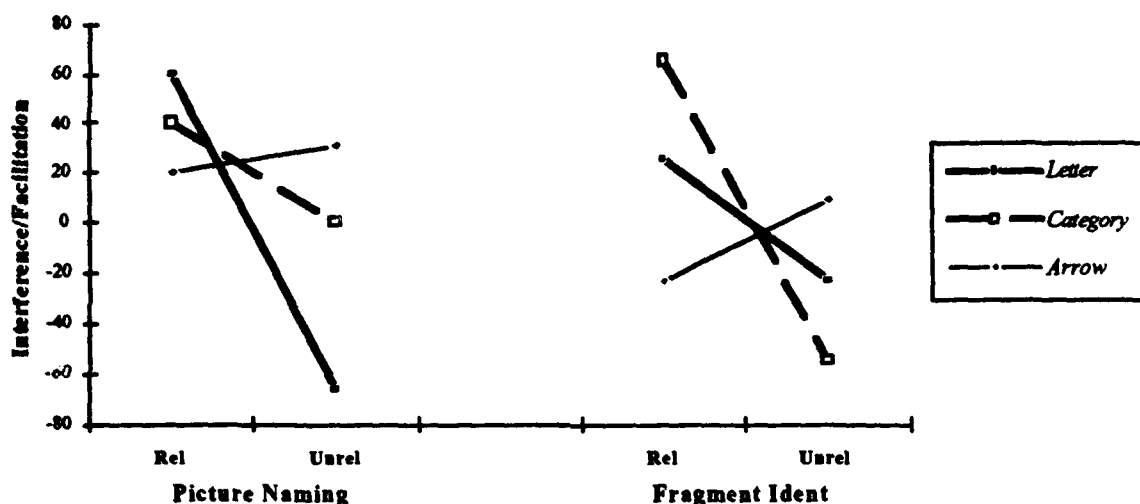
As predicted, picture naming showed the biggest effects (both facilitatory and interfering) from letter cues; however contrary to predictions, fragment identification showed the biggest facilitatory and interfering effects from category cues rather than from arrow cues. The arrow cues had no significant effects in either task. We suspect that the arrow cue is simply not an effective cue, and plan in future work to explore other visual cues. These might include a very fragmented image, or a dot indicating where in the forthcoming picture an important visual cue might appear.

The large effect of letter cues in picture naming supports our belief that accessing the name of the object constitutes an important component of picture naming times. The fact that the category cue was so important in fragment identification can be interpreted in one of two ways: either accessing the meaning of an object is more important in fragment identification than in picture naming or knowing the category of an object gives important information about its appearance, and hence the category cue actually acts as a visual cue. We tend towards the second explanation. Previous work in our laboratory has demonstrated that visual characteristics are important in picture categorization but not in word categorization (Snodgrass & McCullough, 1986). One way to test this interpretation is to repeat Experiment 2 with word fragment

identification to see whether the category cue continues to be important. If the meaning aspects of the category cue make it effective, then we would expect to replicate the pattern of results with fragmented words. However, if category is acting as a visual cue for pictures, we would not expect to observe the same strong effect of the category cue with words.

The important point about the above research is that we have succeeded in showing that priming cues differ in their effectiveness depending upon the task. We view this procedure as an important tool in delineating the processes underlying these two cognitive operations.

5. *The Components-of-Information Framework.*

One of my former graduate students, Chun Luo (now a postdoctoral fellow in the laboratory of Alfonso Caramazza at Dartmouth), and I have developed a components of information framework to account for dissociations and associations between pairs of implicit and explicit memory tests (Luo & Snodgrass, 1994b; Snodgrass & Luo, 1993).

We assume that during a study episode, subjects can encode two types of information about an item: information about the item per se, and information about the item's association with its study context or with another item presented at the same time. Item information, in turn, can be divided into surface information about the item, and semantic information about the item.

Surface item information is encoded swiftly and automatically, while semantic item information and the two types of associative information are encoded more slowly and effortfully. Thus, encoding instructions and subject capacities will determine the types and amounts of information encoded. Most important for the present arguments, the usefulness of these informational components varies across memory tests. Performance on implicit memory tests is primarily determined by the availability of item information (surface and semantic information), while performance on explicit memory tests is primarily determined by the availability of associative information (context-to-item associations and item-to-item association). However, explicit memory tasks will vary in their dependence on item versus associative information. Free recall performance relies almost completely on associative information, while recognition relies on item as well as associative information. Thus, recognition memory can show surface form effects if associative information is weak or surface information has been emphasized during encoding.

In addition, the components of information useful for successful performance can also differ across memory tests regarded as implicit. We propose that performance on perceptual identification is almost completely dependent upon the surface information of the test item, while performance on word stem or fragment completion may also depend on the semantic information of the test item. This assumption explains why a levels of processing manipulation has a small effect on stem or fragment completion, but has little or no effect on perceptual identification (Challis & Brodbeck, 1992), and why conceptual or cross-modality priming is observed in fragment completion but not in perceptual identification (Hirshman, Snodgrass, Mindes, &

Feenan, 1990; Weldon, 1991).

      According to this components-of-information framework, the observed dissociations and associations across memory tasks reflect differences and similarities in their informational requirements. When a variable affects the availability of a particular component of information that is important in one memory task but not in another, a dissociation will be demonstrated. When a variable affects the availability of a particular component of information that is important in both memory tasks, an association will be demonstrated.

      We recently showed that the components-of-information framework accounts for a number of results in the literature which are unaccounted for by the two most popular proposals for implicit/explicit dissociations — separate memory systems and transfer-appropriate processing. Furthermore, in an empirical test of the framework, we showed that two commonly-used independent variables, levels of processing and explicit retrieval instructions — which in the separate memories framework are assumed to operate the same way in implicit tasks by encouraging explicit retrieval — actually show different effects on the two implicit tasks of perceptual identification and stem completion. Specifically, perceptual identification showed a reversed levels-of-processing effect (shallow processing produced better performance) whereas stem completion showed no effect of levels-of-processing. Furthermore, awareness of the relationship between study and test had a deleterious effect on perceptual identification under the graphemic (shallow) processing task, whereas it had no effect on stem completion or on perceptual identification under the semantic (deep) processing task. Thus these two variables were dissociated across the two implicit tasks. This pattern of results is difficult to reconcile with a separate memory systems or separate processing systems approach, while it can be easily understood within a components of information approach. Although we have not yet published a paper on this approach, the approach has guided much of our recent research, and has been presented at the 1993 meeting of the Psychonomic Society (Snodgrass & Luo, 1993) and formed the basis of a symposium presented at the 1994 meeting of the Eastern Psychological Association (Snodgrass, et al., 1994).

6. Cattell Equivalence

      In the course of carrying out the experiments described in Snodgrass and Hirshman (1994a), we developed a concept which we call Cattell Equivalence. Cattell Equivalence is a principle designed to unite data on performance error with data on performance speed. Cattell Equivalence says that errors and time are two expressions of the same underlying process. Imagine that two sets of conditions have been constructed so that one set leads to a high error rate so that errors are the dependent variable, while the other set leads to error-free response so that RTs are the dependent variable. Cattell Equivalence is defined as obtaining the same relationship between the manipulated variable of interest and each of these dependent variables.

My students and I carried out a review of three areas of research to see what the status of Cattell Equivalence was in the literature. The three areas were psychophysics, semantic memory (word and picture recognition), and episodic memory. We concluded that there was strong theoretical and empirical support for Cattell Equivalence, and also, that when Cattell Equivalence is violated (as it was in the Snodgrass and Hirshman experiments), this signals that something else is going on. We believe that violations of Cattell Equivalence can be particularly instructive about the particular processes underlying cognitive phenomena. This paper has ju   en submitted to *Psychonomic Bulletin and Review* (Snodgrass, Dalton, Luo, & Mintzer, 1994,

References

Balota, D. A. (1983). Automatic semantic activation and episodic memory encoding. *Journal of Verbal Learning and Verbal Behavior, 22*, 88-104.

Becker, C. A. (1979). Semantic context and word frequency effects in visual word recognition. *Journal of Experimental Psychology: Human Perception and Performance, 5*, 252-259.

Bruner, J. S., & Potter, M. C. (1964). Interference in visual recognition. *Science, 144*, 424-425.

Carr, T. H., McCauley, C., Sperber, R. D., & Parmelee, C. M. (1982). Words, pictures, and priming: On semantic activation, conscious identification, and the automaticity of information processing. *Journal of Experimental Psychology: Human Perception and Performance, 8*, 757-777.

Carroll, J.B., & White, M.N. (1973). Word frequency and age of acquisition as determiners of picture-naming latency. *Quarterly Journal of Experimental Psychology, 25*, 85-95.

Challis, B., & Brodbeck, D. (1992). Levels of processing affects priming in word fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 509-520.

Goodglass, H., Theurkauf, J. C., & Wingfield, A. (1984). Naming latencies as evidence for two modes of lexical retrieval. *Applied Psycholinguistics, 5*, 135-146.

Hirshman, E., Snodgrass, J. G., Mindes, J., & Feenan, K. (1990). Conceptual priming in fragment completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 16*, 634-647.

Humphreys, G.W., Riddoch, M.J., & Quinlan, P.T. (1988). Cascade processes in picture identification. *Cognitive Neuropsychology, 5*, 67-103.

Lachman, R. (1973). Uncertainty effects on time to access the internal lexicon. *Journal of Experimental Psychology, 99*, 199-208.

Lachman, R., Shaffer, J. P., & Hennrikus, D. (1974). Language and cognition: Effects of stimulus codability, name-word frequency, and age of acquisition on lexical reaction time. *Journal of Verbal Learning and Verbal Behavior, 13*, 613-625.

Luo, C. R., & Snodgrass, J. G. (1994a). Competitive activation model of perceptual interference

in picture and word identification. *Journal of Experimental Psychology: Human Perception and Performance*, *20*, 50-60.

Luo, C. R., & Snodgrass, J. G. (1994b). Components of information: A framework for implicit and explicit memory research. Unpublished ms.

Lupker, S. J. (1988). Picture naming: An investigation of the nature of categorical priming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 444-455.

McEvoy, C. L. (1988). Automatic and strategic processes in picture naming. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14*, 618-626.

Mintzer, M. Z., & Snodgrass, J. G. (1994). The cost of surface change in recognition memory. Submitted for publication.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior, 16*, 519-533.

Morrison, C. M., Ellis, A. W., & Quinlan, P. T. (1992). Age of acquisition, not word frequency, affects object naming, not object recognition. *Memory & Cognition, 20*, 705-714.

Neely, J. H. (1976). Semantic priming and retrieval from lexical memory. *Memory & Cognition, 4*, 648-654.

Oldfield, R. C., & Wingfield, A. (1964). The time it takes to name an object. *Nature, 202*, 1031-1032.

Oldfield, R. C., & Wingfield, A. (1965). Response latencies in naming objects. *Quarterly Journal of Experimental Psychology, 17*, 273-281.

Peynircioglu, Z. F. (1987). Inhibition through incremental fragment cuing with primed items. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13*, 569-572.

Peynircioglu, Z. F., & Watkins, M. J. (1986). Cue depreciation: When word fragment completion is undermined by prior exposure to lesser fragments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12*, 426-431.

Pollatsek, A., Rayner, K., & Collins, W. E. (1984). Integrating pictorial information across eye movements. *Journal of Experimental Psychology: General, 113*, 273-282.

Roediger, H. L.(1990). Implicit memory: Retention without remembering. *American Psychologist, 45*, 1043-1056.

Seidenberg, M. S., Waters G. S., Sanders, M., & Langer, P. (1984). Pre- and postlexical loci of contextual effects on word recognition. *Memory & Cognition, 12*, 315-328.

Snodgrass, J. G. (1980). Toward a model for picture and word processing. In P. A. Kolers, M. E. Wrolstad, & H. Bouma (Eds.), *Processing of visible language 2* (pp. 565-584). New York: Plenum.

Snodgrass, J. G. (1984). Concepts and their surface representations. *Journal of Verbal*

Learning and Verbal Behavior, 23, 3-22.

Snodgrass, J. G., Dalton, P., Mintzer, M., & Luo, C. R. (1994). Cattell equivalence: Theory and data. Submitted for publication.

Snodgrass, J. G., & Feenan, K. (1990). Priming effects in picture fragment completion: Support for the perceptual closure hypothesis. *Journal of Experimental Psychology: General, 119,* 276-296.

Snodgrass, J. G., & Hirshman, E. (1991). Theoretical explorations of the Bruner-Potter (1964) interference effect. *Journal of Memory and Language, 30,* 273-293.

Snodgrass, J. G., & Hirshman, E. (1994a). Dissociations among implicit and explicit memory tasks; The role of stimulus similarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 20,* 150-160.

Snodgrass, J. G., & Hirshman, E. (1994b). The Role of Perceptual Fluency in Recognition Memory. Submitted for publication.

Snodgrass, J. G., & Luo, C. L. (1993). Components of information: A framework for memory research. Paper presented at the November, 1993 meetings of the Psychonomic Society, Washington, D. C.

Snodgrass, J. G., Luo, C. L., Mintzer, M., Yuditsky, T., Kinjo, H., & Hirshman, E. (1994). Components of Information: A framework for implicit and explicit memory research. Symposium presented at the April, 1994 meetings of the Eastern Psychological Association, Providence, R.I.

Snodgrass, J. G., & McCullough, B. (1986). The role of visual similarity in picture categorization. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 147-154.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174-215.

Snodgrass, J. G., & Yuditsky, T. (1994). Naming times for the Snodgrass and Vanderwart pictures. (in revision).

Sperber, R. D., McCauley, C., Ragain, R., & Weil, C. (1979). Semantic priming effects on picture and word processing. *Memory & Cognition, 7,* 339-345.

Weldon, M. (1991). Mechanisms underlying priming on perceptual tests. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 17,* 526-541.

Publications resulting from this grant

Snodgrass, J. G., & Poster, M. (1992). Visual word recognition thresholds for screen-fragmented names of the Snodgrass and Vanderwart pictures. *Behavior Research Methods, Instruments, and Computers*, 24, 1-15.

Snodgrass, J. G., & Mintzer, M. (1993). Neighborhood effects in visual word recognition: Facilitatory or inhibitory? *Memory & Cognition*, 21, 247-266..

Snodgrass, J. G. (1993). Translating vs. picture naming: Similarities and differences. In R. Schreuder & B. Weltends (Eds.), *The bilingual lexicon*. Amsterdam: Benjamins.

Luo, C. R., & Snodgrass, J. G. (1994). Competitive activation model of perceptual interference in picture and word identification. *Journal of Experimental Psychology: Human Perception and Performance*, 20, 50-60.

Snodgrass, J. G., & Hirshman, E. (1994). Dissociations among implicit and explicit memory tasks; The role of stimulus similarity. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, 20, 150-160.

Snodgrass, J. G., & Yuditsky, T. (1994). Naming times for the Snodgrass and Vanderwart pictures. *Journal of Experimental Psychology: Learning, Memory, and Cognition*. (in revision).

Snodgrass, J. G., & Tsivkin, S. (1994). Organization of the bilingual lexicon: Categorical vs. alphabetic cuing in Russian-English bilinguals. *Journal of Psycholinguistic Research*. (In press).

Mintzer, M. Z., & Snodgrass, J. G. (1994). The cost of surface change in recognition memory. *Memory & Cognition* (in revision).

Snodgrass, J. G., & Hirshman, E. (1994). The Role of Perceptual Fluency in Recognition Memory. Submitted for publication.

Snodgrass, J. G., Dalton, P., Mintzer, M., & Luo, C. R. (1994). Cattell equivalence: Theory and data. Submitted for publiction.

Luo, C. R., & Snodgrass, J. G. (1994). Components of information: A framework for implicit and explicit memory research. Unpublished ms.

Corwin, J., & Snodgrass, J. G. (1994). Pragmatics of measuring priming. Submitted for publication.

Conference Presentations resulting from this grant

Snodgrass, J. G., & Sheynkman, Y. (1994). Second Language Vocabulary Learning: Conceptual Mediation vs. Word-to-Word Association. Paper presented at the third meeting of the Practical Memory Conference, College Park, Md., August, 1994.

Snodgrass, J. G., & Hirshman, E. (1994). The Role of Perceptual Fluency in Recognition

Memory. Paper presented at the meetings of the November, 1994 meetings of the Psychonomic Society, St. Louis, Mo.

Snodgrass, J. G., Luo, C. L., Mintzer, M., Yuditsky, T., Kinjo, H., & Hirshman, E. (1994). Components of Information: A framework for implicit and explicit memory research. Symposium presented at the April, 1994 meetings of the Eastern Psychological Association, Providence, R.I.

Snodgrass, J. G., & Luo, C. L. (1993). Components of information: A framework for memory research. Paper presented at the November, 1993 meetings of the Psychonomic Society, Washington, D. C.

Names of participating professionals

1. Elliot Hirshman, Assistant Professor, Department of Psychology, University of North Carolina at Chapel Hill (consultant, co-author on one or more papers, collaborator)

2. Chun Luo, Postdoctoral Fellow, Dartmouth University, former graduate student, doctoral program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).

3. Pamela Dalton, Postdoctoral Fellow, Monell Chemical Senses Center, former graduate student, doctoral program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).

4. Miriam Mintzer, graduate student, doctoral program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).

5. Tanya Yuditsky, graduate student, doctoral program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).

6. Hikari Kinjo, graduate student, doctoral program, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).

7. Yulia Sheynkman, undergraduate student, Department of Psychology, New York University (collaborator, research assistant, co-author on one or more papers).

Dissociations Among Implicit and Explicit Memory Tasks: The Role of Stimulus Similarity

Joan Gay Snodgrass and Elliot Hirshman

This article compares the effect of picture fragmentation level at study on performance on a variety of implicit and explicit memory tests. Consistent with previous research, a moderately fragmented study picture produced the most learning on the implicit memory task of picture fragment completion (Experiment 1) and speeded picture identification (Experiment 4). In contrast, an intact study picture produced the most learning on the implicit memory task of naming intact pictures (Experiment 3). These results suggest that performance on 2 implicit memory tasks can be dissociated by differences in visual similarity between the study and test forms of a stimulus. More surprising, parallel effects were observed in recognition memory. Recognition memory was best when fragmentation levels of the study and test pictures matched (Experiment 2) or were comparable (Experiment 1). In contrast to many results in the literature, recognition memory was acutely sensitive to surface form differences. We discuss the results in terms of 2 types of study–test similarity—stimulus similarity and process similarity.

Manipulating perceptual processing during study constitutes a powerful method for understanding the similarities between, and differences among, various memory tests. Snodgrass and Feenan (1990) recently examined the effects of fragmenting study pictures on later memory tests. Snodgrass and Feenan presented subjects with very fragmented, moderately fragmented, or intact pictures at study and examined their performance on an implicit memory test (fragment completion) and an explicit memory test (free recall).

Surprisingly, Snodgrass and Feenan (1990) found a nonmonotonic relation between the amount of fragmentation at study and performance on the later fragment completion test. Test performance for pictures presented at study at a moderate level of fragmentation was superior to test performance on both intact and very fragmented study pictures. This relation held even when the test picture was identical to the very fragmented study picture. Snodgrass and Feenan explained these results by arguing that a perceptual closure process (Mooney, 1954, 1957) was critical to performance on the fragment completion test and that this process was maximized in the moderately fragmented study condition.

Interestingly, the free-recall results were quite different; manipulating the level of fragmentation at study had no effect on free recall. These contrasting results on fragment completion and free recall present another example of a dissociation between performance on implicit and explicit memory tests (see Hintzman, 1990, and Richardson-Klavehn & Bjork, 1988, for reviews). Fragmenting pictures at study affects later fragment completion (an implicit memory test) but not free recall (an explicit memory test).

Whereas many theorists (Squire, 1992; Tulving & Schacter, 1990) might assume that this dissociation arises because performance on implicit and explicit memory tests relies on distinct memory systems, another approach is to assume that such dissociations arise because of the relations between the processing engaged in various study conditions and required on various tests. These approaches have been called transfer-appropriate processing (Morris, Bransford, & Franks, 1977; Roediger, 1990; Roediger & McDermott, 1993); component processes (Masson, 1989); or compatibility (Hintzman, 1990).

In the transfer-appropriate processing framework, one can explain Snodgrass and Feenan's (1990) results by hypothesizing that the fragment completion test relies on processing that differs across study conditions but that the free-recall test does not. Snodgrass and Feenan rejected the processing explanation for their data because it would seem to predict that transfer should be optimum when the study and test forms of the picture were identical (the very fragmented study condition), whereas they found that the moderately fragmented study condition produced optimum transfer to the very fragmented test stimulus. However, there is a way in which the processing explanation can account for optimum transfer from the moderately fragmented picture. Briefly, the assumption is that when subjects experience perceptual closure of the study stimulus, which is most likely to a moderately fragmented stimulus, this produces an item-specific learning experience that endows the more fragmented version of the picture with the ability to evoke the perceptual closure experience when it is presented again. Although the study and test pictures in the optimum priming condition differ in their physical similarity, they both evoke the same process of perceptual closure.

One purpose of the present research is to see whether study fragmentation level has effects on an explicit memory test—recognition memory—thought to be sensitive to both the surface and the conceptual aspects of the study stimulus. A comparison between implicit and explicit memory tests on the importance of surface changes of the study stimulus is particularly instructive because previous research has suggested that implicit tests are more sensitive to surface aspects of the study items than explicit tests are. Differences in the amount of stimulus processing at study have large effects on implicit memory performance but minimal effects on explicit memory performance. Conversely, differences in the amount of conceptual processing at study have large differences on explicit memory performance but minimal differences on implicit memory performance. These differences have often been accounted for by the difference between data-driven and conceptually driven processing (Jacoby, 1983; Roediger, 1990; Roediger, Weldon, & Challis, 1989; Weldon & Roediger, 1987). According to this distinction, success on explicit tests such as recognition and recall depends on conceptual processing at study—on having stored the meaning of the studied item; whereas success on implicit tests such as perceptual identification and fragment completion depends on data-driven processing at study—on having stored the surface form of the studied item. This analysis fits in well with prevailing views of recognition and recall as dependent on memory for gist or meaning rather than memory for surface form. For example, cross-form (picture to word) transfer effects are virtually perfect in recognition memory (Snodgrass & McClure, 1975), whereas they are almost nonexistent in fragment completion (Weldon & Roediger, 1987). One can hardly imagine a more profound surface change than that between the picture and word forms of a concept, yet this profound change apparently has very little effect on recognition memory. Recently, however, this view has been challenged by results showing that recognition memory may be more sensitive to certain physical changes between study and test forms of stimuli—namely, size and orientation—than a variety of implicit memory tasks (Biederman & Cooper, 1992; Cooper, Schacter, Ballesteros, & Moore, 1992).

Accordingly, we explore the role of stimulus similarity between study and test forms in explicit memory performance by examining the effects of study fragmentation on a recognition memory test as well as on a fragment completion test. We chose these two tests because the logic of the two tests requires that test stimuli be presented at different fragmentation levels. For fragment completion, the test stimulus must be presented in a fragmented form so that identification accuracy can be measured. For recognition memory, the test stimulus is normally presented in an intact form so that identification of the stimulus is perfect and only the oldness or newness of the stimulus need be evaluated. This difference in visual form means the test stimuli will vary in their visual similarity to the study stimuli. The test stimuli in recognition memory will be more similar to the intact study items than to the moderately fragmented study items, whereas the test stimuli in fragment completion will be more similar to the moderately fragmented than to the intact study items. If the similarity of study and test

processing depends on the visual similarity of study and test stimuli, the process approach predicts better recognition memory for intact study items and better fragment completion for moderately fragmented study items.

In Experiment 1, we repeated the study conditions of Snodgrass and Feenan (1990) but tested recognition memory as well as fragment completion. During the study phase subjects attempted to identify fragmented pictures presented at each of the three levels of fragmentation. Subjects were given feedback about whether they were correct or not, and when they were incorrect they were told the name of the picture. After a brief distractor task the recognition memory test was presented, followed by a fragment completion test. We expect to replicate our prior findings that accuracy on the fragment completion task will be an inverted U-shaped function of priming level. In contrast, according to the transfer-appropriate processing hypothesis, accuracy on the recognition memory task should be a monotonically increasing function of priming level with the best performance occurring for the most intact study stimulus.

Experiment 1

In Experiment 1, the study pictures were presented at three levels of fragmentation: from *most fragmented* (Level 1) to *intermediate* (Level 4) to *almost complete* (Level 7). For the recognition test, the study items were tested in their *complete* (Level 8) forms along with an equal number of new pictures also shown in their complete forms. For the fragment completion test, subjects were shown each stimulus at Level 3.

Method

Stimuli, Apparatus, and Design

Stimuli were 63 pictures of objects and animals selected from Snodgrass and Vanderwart (1980) that had been prepared for presentation on the Apple Macintosh microcomputer. Each picture had been prepared as a series of fragmented images at eight levels of completion, in which Level 1 was the most fragmented image and Level 8 was the complete picture. Details of the fragmentation procedure can be found in Snodgrass, Smith, Feenan, and Corwin (1987). Figure 1 shows examples of pictures fragmented at selected levels.

During the study phase only Levels 1, 4, and 7 were presented; during the recognition test, the complete (Level 8) picture was presented; and during the fragment completion test a moderately fragmented (Level 3) picture was presented. During the study phase subjects saw a total of 30 pictures, 10 at each of the three levels of fragmentation (1, 4, and 7). During the recognition and fragment completion tests subjects saw a total of 60 pictures: the 30 studied (or old) pictures and an additional 30 new pictures. To counterbalance items across conditions, we divided new items into three dummy sets of 10 items each so as to produce six groups of 10 items, three for the old items (one group for each level of completion) and three for the new items. These six sets were rotated across the six conditions to produce six counterbalancings. Equal numbers of subjects were assigned to each counterbalancing.

There was one independent variable, level of fragmentation of studied pictures, with three levels, so the experiment had a one-way repeated measures design. There were two dependent variables,

Figure 1. Examples of selected levels of fragmented pictures: from top to bottom, Levels 1, 3, 4, 7, and 8.

recognition accuracy for the recognition memory test and identification accuracy for the fragment completion test.

Subjects

Subjects were 24 students in the introductory psychology course who volunteered as part of a course requirement. They were tested individually on Apple Macintosh Plus microcomputers in individual chambers. They were told that they would be asked to identify pictures that would appear on the screen of the computer as fragmented images. Subjects then signed a consent form that assured them of anonymity and informed them that they had the right to withdraw from the experiment at any time and to ask that their responses not be used.

Procedure

The experiment consisted of three phases. The first phase was the study phase, the second phase was the recognition memory test, and the third phase was the fragment completion test.

Study phase. For the study phase, subjects were instructed that the experiment was concerned with how people identify pictures and that they would be shown pictures of common objects and animals. Some of the pictures would be complete, and some would be incomplete. Each picture would be shown for 2 s, and at the end of each presentation the picture would be erased and they would be asked to name the picture. They were told to type their best guess of the picture's name and then press the return key and that if they had no idea what the picture was,

Table 1

Performance on the Perceptual Identification and Recognition Memory Tests for Each Study Condition in Experiment 1

Measure	Study condition			
	Level 1	Level 4	Level 7	New
Identification accuracy (%)	74	83	78	65
Recognition accuracy (%)	89	93	98	95

Note. Recognition accuracy refers to hit rates for studied items and correct rejection rates for new items.

to type "blank" as the program would not go on until they had typed something. They were told that they needed to type only the first four letters of the picture's name to be correct and that some pictures may have more than one correct name.

The study sequence consisted of 33 trials; the first three were practice trials distributed equally across the three levels of fragmentation and were not scored. The remaining 30 were the experimental trials: 10 at Level 1, 10 at Level 4, and 10 at Level 7. Pictures at the three levels were randomly intermixed. Each fragmented picture was presented for 2 s; it was then erased, and the subject was asked to type the name. Subjects were forced to type something or the program would not go on. Subjects were given information feedback at the end of each trial. They were told whether they were correct or incorrect, and when they were incorrect, they were shown the correct name of the picture. Correctness was determined with reference to a list of possible correct names for each picture. These names included common misspellings, abbreviations (TV for television and bike for bicycle), and synonyms (slacks for pants). There was a 1-s intertrial interval.

After the study sequence subjects received a computer-administered distractor task. During the distractor task subjects were presented with 10 pairs of abstract visual patterns randomly selected from a larger set and were asked to decide whether they were the same or different by clicking one of two buttons. The program beeped once if the response was correct and beeped twice if the response was incorrect. At the end of the distractor task, each subject was informed of his or her percentage of correct responses. The distractor task lasted about 1 min.

Recognition memory test. The next phase was the critical recognition memory test. Subjects were instructed that they would be tested on their memory for the pictures from the experiment. They were told that they would be shown pictures one at a time. If they thought the picture was old, that they saw it in the first part of the experiment, they should press the bottom right-hand key (the question mark/slash key), and if they thought the picture was new, that they did not see it during the first part of the experiment, they should press the bottom left-hand key (the Z key). The subjects were encouraged to respond as quickly as possible. Response times were recorded in the recognition memory test phase but are not reported here.

The recognition test consisted of 63 trials. The first 3 were practice trials and were not scored. These 3 trials presented the three practice pictures presented during study. The next 60 trials were the experimental trials; they comprised 30 stu. pictures mixed randomly with 30 new pictures. All pictures were shown as complete (Level 8) images. The labels *new* and *old* were shown at the bottom of the screen to the far left and right, respectively, during the entire test to remind subjects of which key went with which response. No feedback for correctness was given. The picture was presented until the subject responded and then was erased 0.5 s after the response was recorded. There was an additional 0.5-s intertrial interval before the next picture was presented.

After the recognition test subjects were given the same visual

discrimination distractor task that had followed the study phase. This distractor task also consisted of 10 same–different trials but with a different random selection from the set of all patterns, and it too lasted about 1 min.

Fragment completion test. The final phase was the fragment completion test. Subjects were instructed that in this phase of the experiment they would see more fragmented pictures and that they would be asked to identify the picture by typing its name on the keyboard. As before, they were told that they could type only the first four letters for long names, that some pictures had more than one name, and that they had to type something or the program would not go on.

During the fragment completion test subjects were shown 60 pictures: 30 old pictures (targets) and 30 new pictures (distractors) from the recognition test. All of the pictures in the fragment completion test had been seen before, but half had been seen twice, during the study and recognition test phases.

Subjects were given correct–incorrect feedback to each response but were told the name of the picture only when they were incorrect. The same criterion for correctness used in the study phase was used here. In addition to this on-line scoring, responses during the study phase and fragment completion test were stored and examined after the experiment, and any response that could plausibly be interpreted as indicating correct identification was scored as correct. At the end of the experiment subjects were thanked and given a written debriefing statement.

Results and Discussion

During the study phase subjects identified more stimuli as the fragmentation level increased. For Levels 1, 4, and 7 the percentages of correctly identified pictures were 12%, 64%, and 99%, respectively.

We first examined fragment completion performance to see whether the perceptual closure hypothesis was confirmed. The top line of Table 1 shows the percentage of correct identifications in the fragment completion test for the three study conditions in comparison with the new condition. As expected, the fragment completion data show the inverted U-shaped function found by Snodgrass and Feenan (1990) for the three levels of priming stimuli. Level 4 produced the best performance (83%), Levels 1 and 7 each produced poorer performance (74% and 78%, respectively), and new pictures produced the worst performance (65%). This result is particularly striking because the fragment completion test took place after the recognition test. The perceptual closure effect survived additional exposure to all items when they were presented in their complete forms during the recognition test.

In the statistical analysis of the identification data we evaluated two effects: first, whether old items were identified better than new items and, second, whether Level 4 primed items did better than the average of Levels 1 and 7. To do this, we performed a one-way within-subjects analysis of variance (ANOVA) on the fragment completion results for the four conditions, and planned comparisons were then carried out. The results of a one-way within-subjects ANOVA showed there were significant differences among the four conditions, $F(3, 69) = 8.71, p < .01, MS_e = 160.32$. Planned comparisons between each of the study levels and the new condition revealed significant effects of study for each level (all ps < .02). Finally, the results of a planned comparison between Level 4 and the average of Levels 1 and 7 showed that Level 4's superiority was reliable, $F(1, 23) = 5.29, p = .03, MS_e = 179.68$.

Having verified that the perceptual closure effect was obtained, we next turn to the results of the recognition memory test. The second line of Table 1 shows the percentage of correct recognitions in the recognition memory test for the three study conditions and the new condition. As predicted, recognition performance is an increasing function of study level. Level 7 study items were recognized better than Level 4 study items, which in turn were recognized better than Level 1 study items. A one-way ANOVA performed on the hit rates for studied items confirmed the reliability of these effects.

There was a significant difference in hit rates among the three study conditions, $F(2, 46) = 9.85, p < .001, MS_e = 46.68$. Planned comparisons between Level 4 and Level 1 and between Level 7 and Level 4 showed that the percentage of hits increased with fragmentation level at study. For Level 4 versus Level 1, $F(1, 23) = 5.28, p = .03, MS_e = 47.74$; for Level 7 versus Level 4, $F(1, 23) = 4.83, p = .04, MS_e = 43.11$.

The important result of Experiment 1 is that explicit memory performance is dissociated from implicit memory performance. In fragment completion, a Level 4 priming stimulus produced the best identification accuracy, but in recognition memory, a Level 7 priming stimulus produced the best recognition accuracy. This pattern of dissociations is understandable within the transfer-appropriate processing framework by assuming that both fragment completion and recognition were affected by the similarity between the test stimulus and the study stimulus. The almost intact Level 7 study stimuli were recognized as old more often on the recognition memory test in which test items were intact, whereas the moderately fragmented Level 4 study stimuli were identified more often on the fragment completion test in which test items were moderately fragmented. Note too that because explicit memory performance is dissociated from implicit memory performance, subjects could not have performed better on fragment completion of the moderately fragmented study items because of explicit retrieval processes.

Experiment 2

If the factor driving recognition memory is the degree of physical match between study and test stimuli, it should be possible to produce better recognition of moderately fragmented study stimuli by using moderately fragmented test stimuli—the opposite pattern of the results found in Experiment 1.

Experiment 2 tested this implication by varying the nature of the test stimulus in recognition memory. In Experiment 2, we presented Level 4 and Level 7 pictures at study and then tested them with both Level 4 and Level 7 pictures at test. If the preceding arguments are correct, we would expect Level 4 study fragments to produce superior recognition memory test performance when Level 4 fragments were used at test. We also expected to replicate the results of Experiment 1 by finding that Level 7 study pictures produce superior recognition memory test performance when Level 7 fragments are used at test. The fragment completion test was omitted in this experiment.

Method

Stimuli, Apparatus, and Design

A total of 70 pictures (64 experimental) were selected from the same source and fragmented in the same fashion as in Experiment 1. Half of the pictures were shown at study, half of these at Level 4 and half at Level 7. During the recognition test, the studied pictures were shown again along with the remaining pictures from the set that served as new items. Half of the Level 4 study pictures were tested at Level 4, and half were tested at Level 7. Similarly, half of the Level 7 study pictures were tested at Level 4, and half were tested at Level 7. Of the 32 new pictures, half were tested at Level 4 and half at Level 7.

The 64 experimental pictures were divided into eight subsets of 8 pictures each and assigned to the eight conditions (four for the studied pictures and four for the new pictures). The eight subsets were rotated across conditions to produce eight counterbalancings. Equal numbers of subjects participated in each counterbalancing.

Subjects

Twenty-four subjects, volunteers from the summer introductory psychology course at New York University or friends of one of the experimenters, participated in the experiment. They were equally divided across the eight counterbalancings.

Procedures

Study phase. During the study phase subjects saw a total of 38 pictures. The first 6 were practice and were not scored. Half of the practice and 32 experimental pictures were presented at Level 4, and half were presented at Level 7; pictures at the two levels were randomly intermixed. Each image was displayed for 2 s, after which it was erased and the subject was asked to type its name on the keyboard. Subjects were given feedback about accuracy and were shown the name of the picture when they were incorrect.

Recognition memory test. Following the standard distractor task the recognition memory task was presented. To ensure that subjects knew that they were to treat studied pictures tested at a different level as old (i.e., Level 4 pictures tested at Level 7 or Level 7 pictures tested at Level 4); subjects saw the following instructions on the computer screen:

> Some of the OLD pictures are exactly the same as they were in the first part, some of the OLD pictures are more complete, and some are less complete. In all cases, they should be considered OLD if you saw the picture in any version.

Subjects were encouraged to respond as quickly as possible and also received feedback about the correctness and speed of their responses. They were told that they would receive one point for each correct response faster than 1 s but that they would lose two points for each error therefore they should try to be fast but accurate. They were told that the person who earned the most points in that part of the experiment would win $25 00. Although reaction times (RTs) were recorded during the recognition memory test phase they are not reported here.

Prior to the recognition memory test proper subjects were given a brief practice session in which they were presented with the printed words OLD and NEW and instructed to press the slash key to the word OLD and the Z key to the word NEW. During this practice phase they were shown their RT in milliseconds and they were shown how many points they would have won or lost if this were the real experiment. This practice session consisted of 10 trials that could be repeated as many times as the subject wished.

Table 2
Performance on the Recognition Memory Test for Each Study–Test Condition in Experiment 2

| Measure | Study condition | | |
	Level 4	Level 7	New
Level 4 test condition			
Recognition accuracy (%)	79	66	79
Recognition accuracy (d_L)	2.78	2.12	—
Level 7 test condition			
Recognition accuracy (%)	81	94	93
Recognition accuracy (d_L)	3.98	4.78	—

Note. Recognition accuracy (%) refers to hit rates for studied items and correct rejection rates for new items, and recognition accuracy (d_L) is averaged d' values based on logistic rather than normal distributions.

During the recognition memory test proper subjects were first given 12 practice trials followed by 64 experimental trials. The experimental trials consisted of the 32 studied pictures mixed with 32 new pictures. Half of the studied pictures were tested at the same level as study, and half were tested at the opposite level: 8 of the 16 pictures studied at Level 4 were tested at Level 4, and 8 were tested at Level 7; 8 of the 16 pictures studied at Level 7 were tested at Level 7, and 8 were tested at Level 4. Half of the 32 new pictures were tested at Level 4, and half were tested at Level 7. Each picture was shown until the subject responded. After each response subjects were shown the number of points they had won for the trial. This feedback simultaneously informed them whether they were correct or not (errors produced a −2 payoff) and if correct whether their RT was less than 1 s (+1) or not (+0). The feedback was displayed in the center of the screen for 2 s. There was a 1-s intertrial interval. At the end of the experiment subjects were thanked and given a written debriefing statement.

Results and Discussion

During the priming phase subjects identified 41% of the study items shown at Level 4 and 94% of the study items shown at Level 7.

Table 2 shows two measures of recognition memory performance. The first is percentage of correct recognitions. The second measure takes into account both hit and false alarm rates. In this experiment it was possible to define two separate false alarm rates: one for the Level 4 test condition and one for the Level 7 test condition. Accordingly, we analyzed accuracy of recognition memory in terms of a d'-like measure as well as in terms of percentage correct. This was done by correcting the hit and false alarm rates for perfect performance and then calculating d_L, a d' measure based on the logistic distribution.[1]

The data in Table 2 show two effects. First, in support of the processing hypothesis, there is better performance for study–test pairs that match on fragmentation level. In addition, there is a large effect of test fragmentation level. Level 7 tests produced more accurate performance than Level 4 tests. The pattern of results for Level 7 tests replicates the pattern found in Experiment 1. That is, when Level 7 is used as the test stimulus, a Level 7 prime produces better performance than a Level 4 prime.

To analyze both study and test conditions and their interaction, we carried out 2 (study level) × 2 (recognition test level) within-subjects ANOVAs on each dependent variable. For hit rates study level was insignificant ($F < 1$); test level was highly significant, $F(1, 23) = 25.80$, $p < .001$, $MS_e = 219$; and the interaction was highly significant, $F(2, 34) = 18.12$, $p < .001$, $MS_e = 215$. Simple tests showed that the two study conditions were significantly different at each test condition.

For d_Ls exactly the same pattern of results was obtained. Study level was insignificant ($F < 1$); test level was highly significant, $F(1, 23) = 83.72$, $p < .001$, $MS_e = 1.07$; and the interaction was highly significant, $F(2, 34) = 14.16$, $p < .001$, $MS_e = .90$. Here, too, simple tests showed that the two study conditions were significantly different at each test condition.

The interaction between study and test levels support the processing hypothesis that says performance will be best when study and test conditions match. In addition, the superiority of the Level 7 study stimulus when Level 7 is the test stimulus replicates the results of Experiment 1 showing that visual similarity between study and test forms of the stimulus enhances recognition memory performance. The poorer performance of the Level 4 test stimulus may be attributable in part to difficulties in identifying it. As we noted previously, the task in recognition memory requires that the subject determine whether the stimulus is old or new, not what the identity of the stimulus is. A Level 4 stimulus cannot always be identified correctly, especially when it is new.

Further Implications of the Current Account

We can explain the results of Experiments 1 and 2 by assuming that the similarity of study and test processing, which often increases with the visual similarity of study and test stimuli, is a powerful determinant of memory performance. Following the lead of Roediger and his colleagues (Roediger, 1990; Roediger & Blaxton, 1987; Roediger et al., 1989; Weldon & Roediger, 1987), we have assumed that this principle applied to both explicit memory tests such as recognition memory and implicit memory tests such as fragment completion. If this is so, it should be possible to produce better implicit memory performance on intact study stimuli when the implicit memory test uses intact test stimuli. Experiment 3 explores this implication by using a picture-naming task in which the test stimulus was presented at Level 7. We used a naming task so that the target response would be identical to the target response in fragment completion. It is well known that picture naming is sensitive to repetition priming effects and also shows dissociations with recognition memory (Carroll, Byrne, & Kirsner, 1985; Mitchell & Brown, 1988).

Experiment 3

During the study phase subjects were shown pictures at Levels 1, 4, and 8 to identify. During the test phase subjects named pictures presented at Level 7 as quickly as possible.

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[1] Note that $d_L = \ln\{[H(1 - FA)]/[(1 - H)FA]\}$; Snodgrass and Corwin (1988) showed that results based on the d_L measure computed across a wide range of recognition memory data sets were virtually indistinguishable from results that were based on the standard d' measure.

Method

Stimuli, Apparatus, and Design

The same set of 64 pictures used in Experiment 2 served as stimuli. To obtain more accurate timing, pictures were stored and displayed as bit-mapped images rather than in Pict format as they had been in previous experiments. This permitted us to display pictures virtually instantaneously and, more important, with virtually no variability. Because bit-mapped images take more space than Pict files, images were shrunk from 246 × 246 square pixels to 200 × 200 square pixels. The display of the picture was synchronized with the beginning of the vertical retrace. The average name agreement based on the Snodgrass and Vanderwart (1980) norms was 97.5% (range: 83%–100%).

The 64 pictures were divided into four equal sets; one set was presented at Level 1, one at Level 4, one at Level 8, and one was not presented during the study phase but served as the new set during the naming task. Because there were four sets of stimuli, four counterbalancings were required to assure that all items were rotated across all conditions. So that the experimenter could monitor the subjects' correctness during the naming test, test pictures were presented in one of four fixed random orders. This resulted in a total of 16 counterbalancing–test order combinations. Two subjects were assigned to each combination.

Subjects spoke their responses into a hand-held microphone (the microphone supplied with the MacRecorder software program) plugged into the serial port of an Apple Macintosh SE/30. A subroutine written in Microsoft BASIC monitored the input through this serial port and timed the onset of the first activity. The minimum time for any activity to be registered (105 ms) was subtracted from all naming times. An experimenter sitting next to the subject recorded any false triggers of the voice key and any naming errors. Naming times were recorded to the nearest 16 ms.

Subjects and Procedure

Thirty-two subjects, volunteers from the introductory psychology course at New York University, participated in the experiment. Two subjects were assigned to each of the 16 counterbalancing–test order combinations.

Study phase. During the study phase a total of 48 experimental pictures and 6 practice pictures were shown. The 6 practice pictures preceded the experimental sequence and did not enter into the data analysis. One third of the practice and experimental pictures were presented at each of the three levels. Each image was displayed for 2 s, after which it was erased and the subject was asked to type its name on the keyboard. Subjects were given feedback about accuracy and were shown the name of the picture when they were incorrect.

Naming test. Immediately following the study phase the naming test was presented. Subjects were given 20 trials of naming practice to familiarize them with the voice key, to show them how false responses such as "uh"s and "ah"s would stop the clock prematurely, and to give them feedback about their naming latencies. During the naming practice subjects were shown 20 words to name. The words were concrete nouns such as *hero* and *yellow,* which did not name any of the pictures they were to see. During the naming practice they were shown their naming latency in milliseconds.

Prior to the picture-naming task subjects were informed that they would be awarded five points for each correct naming response that was faster than 800 ms and that the person with the highest number of points would win a $25.00 prize. During the picture-naming test subjects were shown a "get ready" message that was displayed for 0.5 s followed by a 0.5-s blank interval. The picture was then presented and the naming latency recorded. If subjects' naming times were faster than 800 ms, they heard a beep; otherwise, no feedback was given.

Table 3
Performance on the Naming Test for Each Study Condition in Experiment 3

Measure	Study condition			
	Level 1	Level 4	Level 8	New
Naming accuracy (%)	96	95	98	92
Naming RT (GM)	909	889	833	1,017
Naming RT (AM)	976	931	863	1,084

Note. GM = geometric mean; AM = arithmetic mean; RT = reaction time.

Prior to the experimental trials, there were four practice naming trials. There was a 2-s intertrial interval. Halfway through the naming trials (after 30 trials) subjects were given a short break. At the end of the experiment subjects were informed of their total points, were thanked, and given a written debriefing statement. Naming errors included any response that did not occur more than twice in the Snodgrass and Vanderwart (1980) naming norms and any false triggers of the voice key.

Results and Discussion

During the study phase subjects correctly identified 6% of Level 1 items, 55% of Level 4 items, and 97% of Level 8 items.

Table 3 shows the two measures of naming performance—accuracy and RT. Both geometric and arithmetic mean RTs are shown. Both accuracy and speed measures show repetition priming effects; studied items were named more accurately and faster than unstudied items. In addition, Level 8 studied items were named faster and more accurately than Level 4 studied items, which in turn were named faster (although not more accurately) than Level 1 studied items.

One-way within-subjects ANOVAs were performed on each dependent measure. Planned comparisons were then carried out between the combined study conditions and the new condition and among selected study conditions.

For accuracy, the main effect of study condition was significant, $F(3, 93) = 5.66, p = .0013, MS_e = 37.10$. Studied items were significantly more accurate than new items, $F(1, 31) = 6.19, p = .02, MS_e = 77.48$. Level 8 was marginally more accurate than Level 1, $F(1, 31) = 3.53, p = .07, MS_e = 19.29$, and Level 8 was significantly more accurate than Level 4, $F(1, 31) = 9.54, p = .004, MS_e = 15.10$.

For geometric mean RT, the main effect of study condition was significant, $F(3, 93) = 16.37, p < .001, MS_e = 80,883$. Studied items were significantly faster than new items, $F(1, 31) = 23.81, p < .001, MS_e = 19,593$. Level 8 was significantly faster than either Level 4 or Level 1, $F(1, 31) = 8.85, p = .006, MS_e = 5737$, and $F(1, 31) = 12.10, p < .001, MS_e = 7731$, respectively. Exactly the same pattern of results was obtained for the arithmetic means.

The results of this implicit naming task, in which intact pictures were shown at test and RTs were the main dependent variable, show clear dissociation with the results of the implicit fragment completion task, in which moderately fragmented pictures were shown at test and accuracy was the main dependent variable. We hypothesized that the critical variable in determining performance in naming an intact picture was

the visual similarity between the study stimulus and the test stimulus, and thus that a picture studied at Level 8 would be named more quickly than a picture studied at a more fragmented level when it was presented again at Level 7 during test. That is exactly what happened in this experiment. These results contrast with the results of the picture fragment completion test in Experiment 1, which showed that a moderately fragmented Level 4 study picture produced the most accurate identification. Taken together, the results of these two experiments show that two implicit tasks can also show dissociation. The reason for their dissociation appears to be the difference in visual similarity between the test and study stimuli. For fragment completion, similarity is maximal for the moderately fragmented study stimulus because a moderately fragmented test stimulus was used during test, whereas for picture naming, the similarity is maximal for the intact study stimulus because an intact test stimulus was used during test.

However, one might argue that the dissociation between fragment completion and naming arises because the two tests use different measures (accuracy vs. speed), not because they use test stimuli at different levels of fragmentation. To test the importance of using RT as the dependent variable, we sought a procedure that would present fragmented images at test but permit perfect performance so that speed rather than accuracy could be used as the dependent variable.

Experiment 4

We adopted a procedure for measuring identification speed similar to one used by Feustel, Shiffrin, and Salasoo (1983). In this speeded identification task subjects were shown a series of fragmented images that were presented rapidly. Their task was to stop the series as soon as they could identify the picture. The dependent variable was the amount of time elapsing before the series was stopped. We predicted that in this task, pictures studied at Level 4 would produce faster identification responses than pictures studied at Level 8. This is because in this speeded task fragmented levels of the pictures constitute part of the stimulus display, unlike the naming task in Experiment 3, which used intact test pictures.

Method

Stimuli, Apparatus, and Design

Stimuli were the 70 pictures (64 experimental and 6 practice) used in Experiment 2. During the study phase 54 pictures (6 practice) were presented at Levels 1, 4, and 8 for identification in exactly the same manner as in previous experiments. During the speeded identification test the fragmented images were presented with the ascending method of limits, but the series of increasingly complete images was presented rapidly. The speeded identification test included all 48 of the studied experimental items plus an additional 16 new items that had not been studied.

So that items could be rotated across all possible combinations of study–test conditions, the 64 experimental items were divided into four groups of 16 items each. This produced a total of four counterbalancings. Six subjects participated in each counterbalancing.

Subjects and Procedure

Twenty-four subjects, volunteers from the introductory psychology course at New York University, participated in the experiment. Data from an additional 2 subjects were discarded because of excessive error rates. Subjects were tested individually on Apple Macintosh Plus microcomputers and were run in groups of 2 or 3 in the same room.

Study phase. Instructions to subjects prior to the study phase were identical to those given in Experiment 1. The study sequence consisted of 54 trials; the first 6 were practice trials distributed equally across the three levels of fragmentation and were not scored. The remaining 48 were the experimental trials: 16 at Level 1, 16 at Level 4, and 16 at Level 8. Each fragmented picture was presented for 2 s and was erased, and the subject was then asked to type the name of the picture. Subjects were permitted to hit the return key if they had no idea what the picture was. At the end of each trial subjects were told whether they were correct or incorrect and were shown the correct name of each picture when they were incorrect. To ensure that the incorrect picture name was visible and distinctive, the message when they were incorrect ("Sorry, the name is XXXX") was printed in large boldface type. There was a 0.5-s intertrial interval. The standard distractor task followed the study phase.

Speeded identification test. Because the speeded identification test was a novel procedure that required full attention of the subjects for success, subjects were presented with a fairly extensive set of instructions. They were informed that they would be shown more fragmented pictures and that each picture would be presented as a sequence of fragmented images that would become increasingly more complete. They were told to hit the space key as soon as they could identify the picture and were warned that the images would be presented rapidly so they needed to be "on their toes." They were also informed that once they hit the space key the picture would be erased, and they would be asked to type the name of the picture. They were instructed to hit the space bar as soon as they could but not before they knew what the picture was.

They were awarded points according to how quickly in the series they hit the space key. They were given eight points for stopping the series at Level 1, seven points for stopping it at Level 2, and down to one point for stopping it at Level 8. However, they were awarded the points only if their subsequent response was correct. They were told that the subject with the highest score would win $25.00. Before the experimental trials began subjects were permitted to practice on the picture of a lobster for as many trials as they wished. During this practice trial subjects were given feedback about whether they were correct or incorrect and were advised of the number of points they earned when they were correct.

The speeded identification test consisted of 68 trials. The first four were practice trials and were not scored. The following 64 trials were the experimental trials. They consisted of the 48 study pictures mixed randomly with 16 new pictures. Prior to each speeded trial the message "get ready" appeared in the center of the screen and was erased after 0.5 s. Each level of fragmented image was presented for 320 ms so that the entire series of eight fragmented images required 2,560 ms for presentation. As soon as the subject hit the space key the level of fragmentation shown at that instant was recorded, the clock was stopped, and the image was erased. The subject was then instructed to identify the picture by typing its name.

Three dependent measures were obtained on each trial. These measures were whether the picture was identified correctly (accuracy), the fragmentation level at which the clock was stopped (stop level), and the RT. Naming accuracy was determined as in Experiments 1 and 2. The feedback was displayed for 1 s followed by a 1-s intertrial interval.

At the end of the experiment subjects were informed of their total

number of points, were thanked, and given a written debriefing statement.

Results and Discussion

During the study phase subjects identified more stimuli as the fragmentation level increased. For Levels 1, 4, and 8 the percentages of correctly identified pictures were 6%, 55%, and 97%, respectively.

Table 4 shows the three measures of identification performance for each study condition. RTs longer than 4 s have been truncated to 4 s. Although the accuracy measure shows a slight advantage for study Level 8 over study Level 4, the two measures of speed—stop level and RT—show a clear advantage for study Level 4 over study Level 8.

Each dependent measure was submitted to a one-way within-subjects ANOVA. Three planned comparisons were then carried out. The first compared new items with studied items to see whether prior exposure had an effect on identification performance, the second compared Level 1 with the average of Levels 4 and 8, and the third compared Levels 4 and 8.

For accuracy, study condition was highly significant, $F(3, 69) = 9.01, p < .001, MS_e = 37.22$. Studied items were more accurately identified than new items, $F(1, 23) = 15.67, p < .001, MS_e = 55.39$; Levels 4 and 8 were marginally more accurately identified than Level 1, $F(1, 23) = 4.02, p = .06, MS_e = 26.99$; but there was no difference between Levels 4 and 8 ($F = 1.00$).

For stop level, study condition was highly significant, $F(3, 69) = 59.13, p < .001, MS_e = .086$. Studied items were identified more quickly than new items, $F(1, 23) = 148.33, p < .001, MS_e = .089$; Levels 4 and 8 were identified more quickly than Level 1, $F(1, 23) = 20.57, p < .001, MS_e = .075$; and Level 4 was identified more quickly than Level 8, $F(1, 23) = 4.61, p = .04, MS_e = .093$.

The same pattern of results was observed for RT. For RT, study condition was highly significant, $F(3, 69) = 62.96, p < .001, MS_e = 13,305$. Studied items were identified more quickly than new items, $F(1, 23) = 145.42, p < .001, MS_e = 15,492$; Levels 4 and 8 were identified more quickly than Level 1, $F(1, 23) = 17.88, p < .001, MS_e = 12,461$; and Level 4 was identified marginally more quickly than Level 8, $F(1, 23) = 3.12, p = .09, MS_e = 11,962$.

The reason that RT and stop level did not show exactly the same pattern of results was that for each stop level there was a range of RTs that could occur. This range was essentially unlimited when the stimulus was not identified until Level 8 (which occurred on 21% of the trials) although these RTs were truncated at 4 s. Also, the ranges of RTs overlapped somewhat, presumably because different hard disks had slightly different access times, which caused the activity occurring between presentations of each fragmentation level to take somewhat different amounts of time. Nonetheless, the pattern of results for RTs was virtually identical to the pattern for stop level.

Experiment 4 demonstrated that the inverted U-shaped function obtained for fragment completion held when frag-

Table 4

Performance on the Speeded Perceptual Identification Test for Each Study Condition in Experiment 4

Measure	Study condition			
	Level 1	Level 4	Level 8	New
Accuracy (%)	93	95	97	88
Stop level	6.19	5.79	5.98	6.84
Identification RT (ms)	2,025	1,879	1,935	2,300

Note. RT = reaction time.

mented stimuli were presented on the speeded test. Along with the results of Experiments 2 and 3, this result supports the transfer-appropriate processing interpretation of the results of Experiment 1.

General Discussion

This series of experiments has addressed the question of what effect priming level (level of fragmentation of studied pictures) has on various tasks. We began by demonstrating that the effects of priming level on the implicit memory test of fragment completion and the explicit memory test of recognition memory were doubly dissociated. Consistent with previous research by Snodgrass and Feenan (1990), a moderately fragmented priming stimulus produced the best performance on fragment completion. In contrast, an intact priming stimulus produced the best performance on recognition memory.

Although one might assume that this double dissociation reflects the operation of distinct explicit and implicit systems, we considered the possibility that the double dissociation arises because the stimuli used on the two tests vary in their visual similarity to the study items. Specifically, the recognition memory test uses intact stimuli, and performance on intact study stimuli is best on this test. In contrast, the fragment completion test uses fragmented stimuli, and performance on fragmented study stimuli is best on this test.

This visual similarity hypothesis led us to examine performance across a variety of explicit and implicit tests. Experiment 2 examined recognition memory performance when the test presented both relatively intact and fragmented items. Experiment 3 examined naming performance with intact items, and Experiment 4 examined naming performance with fragmented items. In each case performance was best on study stimuli with the greatest visual similarity to the test stimuli.

Across the four experiments there was remarkable similarity between results obtained for implicit memory tasks and those obtained for explicit memory tasks. Even though the optimal fragmentation level of the study stimulus varied as a function of its similarity to the fragmentation level of the test stimulus, the effect of this similarity was the same regardless of whether the memory test was implicit (fragment completion, speeded perceptual identification, or picture naming) or explicit (recognition memory). How can we interpret these striking similarities between explicit and implicit memory tests? We consider several possible interpretations.

Can Explicit Retrieval Processes Account for Implicit–Explicit Associations?

A popular approach to accounting for associations between implicit and explicit memory tasks is to assume that subjects adopt an explicit retrieval process to solve the implicit task. Can this approach account for the associations we observed between the two types of task? We think not. For example, Experiment 1, which used both an explicit task and an implicit task on the same subjects and items, showed dissociations between implicit and explicit memory processes that we attributed to differences in the study–test stimulus items. We observed associations across implicit and explicit memory tasks only when test fragmentation levels were similar to the same study fragmentation level. We would need to assume that explicit retrieval processes are different depending on the stimulus level of the test stimulus. This would seem to strain the bounds of what most people mean by using an explicit retrieval process.

Stimulus Versus Process Similarity

It is clear from the results reported here that similarity between study and test conditions is crucial for determining optimum performance on both implicit and explicit memory tests. But what is the nature of this similarity? One possibility is that the similarity resides in the visual similarity of the study and test stimuli. These are most similar when the study and test fragmentation levels are identical or almost identical and most different when the study and test fragmentation levels are dissimilar (e.g., a Level 1 study stimulus tested with a Level 8 test stimulus). A second possibility is that the similarity resides in the similarity of processing applied to study and test stimuli of the same fragmentation level. Processing of either a Level 1 or a Level 4 stimulus might be described as data driven because subjects must attend to the perceptual features of the stimulus to identify it. In addition, a Level 4 stimulus differs from a Level 1 stimulus in that the latter is much more likely to be perceptually completed and thus to produce an experience of perceptual closure. Snodgrass and Feenan (1990) emphasized the importance of the perceptual closure experience in producing the inverted U-shaped function between study fragmentation level and test performance.

The perceptual closure hypothesis provides two categories of data-driven processes: those which lead to perceptual closure and those which do not. A Level 4 stimulus is more likely to lead to perceptual closure than a Level 1 stimulus, whereas a Level 7 or 8 stimulus is unlikely to produce a perceptual closure experience because the stimulus is already virtually complete and leads to an effortless identification response. When a Level 4 stimulus is presented at study subjects must apply the process of perceptual closure to complete it. When a Level 4 stimulus is presented at test the same perceptual closure will be experienced, and the specific experience of perceptual closure to this item will reinvoke the study experience and lead to more effective or faster identification, if the task is implicit, or more accurate and faster recognition of oldness, if the task is explicit.

Under the hypothesis that it is the similarity of processing

rather than the similarity of stimuli that accounts for the pattern of associations and dissociations observed here, we would argue that processing similarity accounts for effects on both explicit and implicit tasks. Surface form effects are made particularly salient in the recognition memory paradigm because the study conditions emphasize attention to visual features during the identification process at study.

The present approach is very similar to the data-driven versus conceptually driven processing account that has been used to account for dissociations among various types of memory tests. As Blaxton (1989) and Roediger and Blaxton (1987) have pointed out, the data-driven versus conceptually driven distinction is orthogonal to the implicit versus explicit test distinction. Although many implicit tests are data driven and many explicit tests are conceptually driven, one can invent explicit tests that are data driven and implicit tests that are conceptually driven. We assume that processing a fragmented picture during a study episode is more data driven than is processing an intact picture because subjects need to spend more time examining the visual features of the fragmented picture and have less time to spend thinking about the meaning of the picture. Under this interpretation of the data-driven versus conceptually driven distinction, the implicit memory tasks of fragment completion and speeded perceptual identification are data driven, whereas the explicit memory task of picture naming is conceptually driven. Similarly, the explicit memory task of recognizing a fragmented picture as old is data driven, whereas the explicit memory task of recognizing an intact picture as old is conceptually driven.

The question of which is more important in determining the study-to-test similarity effect—stimulus similarity or process similarity—is a question that the present research did not address. Because identical forms of the study and test stimuli were used, stimulus and process similarity were confounded in these studies. One way of disentangling the two is to use two different fragmented stimuli at study and test. Snodgrass and Feenan (1990) compared identical with different fragmentation series and found that changing the fragmentation series produced a small but significant decrement in performance. In contrast, Biederman and Cooper (1991) found that priming in a naming task was identical for same and different fragments as long as the components (geons) of the object were not deleted. More recently, research from our laboratory (Snodgrass, 1993) has shown that priming for the complementary half of the studied fragments was as large as for the identical fragments when at least 25% of the fragments were present. At present, it would appear that the bulk of the evidence favors process rather than stimulus similarity as the critical variable.

The present research has demonstrated yet another surface feature to which recognition memory is sensitive and has shown how complex patterns of associations and dissociations across and within explicit and implicit memory tasks can be produced by a simple manipulation of degree of fragmentation of study and test stimuli. We have also argued how such manipulations of stimulus similarity might themselves produce differences in process similarity across the study–test condi-

tions and how these in turn could be responsible for the patterns we observed.

Characterizing implicit and explicit memory processes has become a central task in contemporary memory theory. No single interpretation of their differences and similarities appears adequate to the task of making sense of the complex patterns of results reported in this literature. Perhaps the most cautious interpretation of the present results is that dissociations found between performance on implicit and explicit memory tests do not necessarily tell us anything about the difference between implicit and explicit retrieval processes when visual characteristics of the stimuli presented on the implicit and explicit memory tests differ.

References

Biederman, I., & Cooper, E. E. (1991). Priming contour-deleted images: Evidence for intermediate representations in visual object recognition. *Cognitive Psychology, 23,* 393–419.

Biederman, I., & Cooper, E. E. (1992). Size invariance in visual object priming. *Journal of Experimental Psychology: Human Perception and Performance, 18,* 121–133.

Blaxton, T. A. (1989). Investigating dissociations among memory measures: Support for a transfer appropriate processing framework. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 15,* 657–668.

Carroll, M., Byrne, B., & Kirsner, K. (1985). Autobiographical memory and perceptual learning: A developmental study using picture recognition, naming latency, and perceptual identification. *Memory & Cognition, 13,* 273–279.

Cooper, L. A., Schacter, D. L., Ballesteros, S., & Moore, C. (1992). Priming and recognition of transformed three-dimensional objects: Effects of size and reflectance. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18,* 43–57.

Feustel, T. C., Shiffrin, R. M., & Salasoo, A. (1983). Episodic and lexical contributions to the repetition effect in word identification. *Journal of Experimental Psychology: General, 112,* 309–346.

Hintzman, D. L. (1990). Human learning and memory: Connections and dissociations. *Annual Review of Psychology, 31,* 109–139.

Jacoby, L. L. (1983). Remembering the data: Analyzing interactive processes in reading. *Journal of Verbal Learning and Verbal Behavior, 22,* 485–508.

Masson, M. E. J. (1989). Fluent reprocessing as an implicit expression of memory for experience. In S. Lewandowsky, J. Dunn, & K. Kirsner (Eds.), *Implicit memory: Theoretical issues* (pp. 123–138). Hillsdale, NJ: Erlbaum.

Mitchell, D. B., & Brown, A. S. (1988). Persistent repetition priming in picture naming and its dissociation from recognition memory. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 14,* 213–222.

Mooney, C. M. (1954). A factorial study of closure. *Canadian Journal of Psychology, 8,* 51–61.

Mooney, C. M. (1957). Age in the development of closure ability in children. *Canadian Journal of Psychology, 11,* 219–226.

Morris, C. D., Bransford, J. D., & Franks, J. J. (1977). Levels of processing versus transfer appropriate processing. *Journal of Verbal Learning and Verbal Behavior, 16,* 519–533.

Richardson-Klavehn, A., & Bjork, R. A. (1988). Measures of memory. *Annual Review of Psychology, 36,* 475–543.

Roediger, H. L., III. (1990). Implicit memory: Retention without remembering. *American Psychologist, 45,* 1043–1056.

Roediger, H. L., III, & Blaxton, T. A. (1987). Retrieval modes produce dissociations in memory for surface information. In D. S. Gorfein & R. R. Hoffman (Eds.), *Memory and cognitive processes: The Ebbinghaus centennial conference* (pp. 349–379). Hillsdale, NJ: Erlbaum.

Roediger, H. L., III, & McDermott, K. B. (1993). Implicit memory in normal human subjects. In H. Spinnler & F. Boller (Eds.), *Handbook of neuropsychology,* Vol. 8 (pp. 63–131). Amsterdam: Elsevier.

Roediger, H. L., III, Weldon, M. S., & Challis, B. H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H. L. Roediger III & F. I. M. Craik (Eds.), *Varieties of memory and consciousness: Essays in honor of Endel Tulving* (pp. 3–41). Hillsdale, NJ: Erlbaum.

Snodgrass, J. G. (1993). *Priming effects across complementary fragments: Evidence for transfer of processes.* Manuscript in preparation.

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General, 117,* 34–50.

Snodgrass, J. G., & Feenan, K. (1990). Priming effects in picture fragment completion: Support for the perceptual closure hypothesis. *Journal of Experimental Psychology: General, 119,* 276–296.

Snodgrass, J. G., & McClure, P. (1975). Storage and retrieval properties of dual codes for pictures and words in recognition memory. *Journal of Experimental Psychology: Human Learning and Memory, 1,* 521–529.

Snodgrass, J. G., Smith, B., Feenan, K., & Corwin, J. (1987). Fragmenting pictures on the Apple Macintosh computer for experimental and clinical applications. *Behavior Research Methods, Instruments, & Computers, 19,* 270–274.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for naming agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215.

Squire, L. (1992). Memory and the hippocampus: A synthesis from findings with rats, monkeys, and humans. *Psychological Review, 99,* 195–231.

Tulving, E., & Schacter, D. (1990). Priming and human memory systems. *Science, 247,* 301–306.

Weldon, M., & Roediger, H. (1987). Altering retrieval demands reverses the picture superiority effect. *Memory & Cognition, 15,* 269–280.

Competitive Activation Model of Perceptual Interference in Picture and Word Identification

Chun Rong Luo and Joan Gay Snodgrass

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Perceptual interference is the finding that prior exposures to a target item's partial features inhibit its later identification. This study tests a competitive activation model of perceptual interference that attributes interference to the activation of competing responses generated by prior cues. We examined 2 sets of data that seemed to be inconsistent or incompatible with the model. The first is the observed positive effect of viewing time of stimuli (J. S. Bruner & M. C. Potter, 1964). The second is the finding that interference occurs only for studied or primed words (Z. F. Peynircioglu, 1987; Z. F. Peynircioglu & M. J. Watkins, 1986). Experiments 1 and 2 showed paradoxical effects of viewing time and found evidence supporting the competitive activation model. Experiments 3-6 failed to replicate Peynircioglu and Watkins' finding and showed that a performance level explanation compatible with the competitive activation model can account for all related results.

Imagine that you are walking down a street and several blocks away you see a person approaching who appears vaguely familiar. You would like to be able to identify the person correctly when you are within hailing distance so as to avoid either missing a friend or falsely recognizing a stranger. What should you do? Should you begin to scrutinize the face immediately and continuously as the person approaches? Or should you look away and only scrutinize the face during the last hundred feet or so before you need to make a decision? We suspect most people would opt for the first solution, even though experimental literature suggests that the second will produce better identification.

Several studies have shown that subjects' ability to identify an ambiguous visual image is undermined if they have been exposed to partial features of that image beforehand. The inhibitory effect of early exposures to a visual image's partial features on its subsequent identification was first demonstrated by Galloway (1946) and was later replicated by Wyatt and Campbell (1951). This phenomenon, the perceptual interference effect, was more systematically investigated by Bruner and Potter (1964). They presented subjects with photographs of common objects that were brought slowly into focus. When a predetermined level of blur was reached, the image was turned off and subjects attempted to identify the

object. Bruner and Potter found that the more blurred the starting point, the worse the identification performance.

More recently, similar effects of interference were reported by Peynircioglu and Watkins (1986) and Peynircioglu (1987) in word fragment completion and by Snodgrass and Hirshman (1991) in picture fragment completion. Peynircioglu and Watkins showed that a word fragment (e.g., r _ i _ _ rop) of a just-studied word (e.g., *raindrop*) was less readily completed if it was presented bit by bit (r _ _ _ _ _ p, r _ _ _ _ r _ p, r _ i _ _ r _ p, and r _ i _ _ rop) rather than all at once. Similarly, Snodgrass and Hirshman showed that a moderately fragmented picture was less readily identified if it was presented by adding more elements each time (ascending procedure) rather than all at once (fixed procedure). In addition, negative effects of prior cues have been found for ambiguous auditory stimuli (Blake & Vanderplas, 1950; Frederiksen, 1967, 1969).

The widespread demonstration of perceptual interference effects suggests that they might have a common basis and be caused by the same process. What, then, is the mechanism underlying these interference effects? One plausible explanation suggested by several investigators (e.g., Blake & Vanderplas, 1950; Bruner & Potter, 1964; Frederiksen, 1967, 1969; Wyatt & Campbell, 1951) is that during cue presentations subjects develop erroneous hypotheses about the stimulus that interfere with its correct perception. For example, Blake and Vanderplas found that the mean identification threshold of spoken words was significantly higher when subjects had produced erroneous hypotheses before identification than when no such hypotheses had been produced. Bruner and Potter also found that subjects who reported their guesses about each object's identity from the beginning of the clarification procedure often expressed wrong hypotheses about its identity, and the incorrect interpretation was maintained even when they were doubtful of its correctness.

Because the erroneous hypothesis notion attributes interference to the activation of competing responses generated by cue presentations, we refer to this notion as the *competi-*

Chun Rong Luo and Joan Gay Snodgrass, Department of Psychology, New York University.

Correspondence concerning this article should be addressed to Chun Rong Luo, who is now at Department of Psychology, 6207 Dartmouth College, Hanover, New Hampshire 03755 (electronic mail may be sent to chun.r.luo@dartmouth.edu), or to Joan Gay Snodgrass, 6 Washington Place, 8th Floor, New York University, New York, New York 10003 (electronic mail may be sent to gay@xp.psych.nyu.edu).

tive activation model. Although the competitive activation model sounds reasonable, the operating principles of the theory are yet to be defined and specified. One problem, for example, is whether subjects need to be conscious of these competing hypotheses in order for interference to occur or whether subconscious hypotheses can also produce interference. The second problem concerns the preconditions for activating a competing hypothesis. Logically, some minimum stimulation or activation would seem to be required to activate a competing hypothesis.

Snodgrass and Hirshman (1991) developed a connectionist model that implemented one version of the competitive activation theory. In their model, distractor and target recognition units compete for output, and the relative activation levels across the target and distractor units determine identification performance. Their stimulation showed that the interference effect can be produced by adding transient activations in perceptual structures that are generated by cue presentations in the ascending procedure. This transient activation incremented the activation of both target and distractor units, which in turn decreased the signal-to-noise ratio and thus hindered the perception of the target item. Their model and their experiments also suggested that interference can be produced by the competition at a subconscious level, because giving informative feedback to subjects about their erroneous hypotheses failed to eliminate the interference.

Although no alternative theories have been proposed to replace the competitive activation model, some research findings seem to be inconsistent or incompatible with this model. In this article, we examine the empirical basis of these findings and their theoretical implications, and we explore whether these findings can be reconciled within the competitive activation model. These findings can provide important constraints on the competitive activation model, even when the reconciliation is successful.

Influences of Starting Point and Viewing Time: A Reexamination

The first set of data that seems to be inconsistent with the competitive activation model comes from Bruner and Potter's (1964) original study. Bruner and Potter showed that the interference effect was related to two variables: the starting point of the ascending series and the total viewing time. They used three starting points of focus (very blurred, medium blur, and light blur) and a common stopping point. These three starting points were factorially combined with three average viewing times—13 s, 35 s, and 122 s. Their procedure was to bring a picture continuously into focus from one of the three starting points, taking one of the three viewing times to traverse the focal range. Once the common stopping point was reached, the projected picture was turned off, and the subject was asked to identify it. Although their report emphasized the effect of starting point (focal range) on identification, Bruner and Potter also found an effect of viewing time—the longer the picture was in view, the better the performance.

This positive effect of viewing time on performance is not expected from the competitive activation model. If interference is due to subjects' development of erroneous hypotheses about what the picture might be, longer viewing time should have a negative effect on performance because subjects would have more time to develop (erroneous) hypotheses.

However, in Bruner and Potter's (1964) study, effects of the viewing time and the start point were partially confounded because they were not manipulated separately. First, for a more blurred start point, the duration of the clearest portion of a picture was shorter. Second, for a longer total viewing time, the duration of the clearest portions of the picture was longer. Thus, the positive effect of viewing time on performance is attributable to viewing the clearest portion of a picture for longer.

In short, the two components of viewing time—the viewing time of the more blurred portions and the viewing time of the clearest portion—may have opposite effects on performance and if the advantage of viewing the clearest portion of a stimulus for longer is greater than the disadvantage of viewing the more blurred portions of the stimulus for longer, an overall positive effect may be expected. If this is the case, Bruner and Potter's (1964) finding of a positive effect of viewing time would no longer be inconsistent with the competitive activation model.

To test this hypothesis, the effects of the three factors—starting point, duration of the clearest part of the stimulus, and duration of the more blurred part of the stimulus—on identification performance must be separately investigated. Accordingly, in Experiment 1 we manipulated both starting point and duration of clearest presentation while keeping durations of prior presentations constant. We expected that decreases in the starting point would produce decrements in performance, whereas increases in duration of the clearest portion of the stimulus would improve performance.

In Experiment 2 we manipulated both duration of prior presentations and duration of clearest presentation while keeping starting point constant. We expected that increases in duration of the prior presentations would reduce performance, whereas increases in duration of the clearest presentation would again improve performance (as tested in Experiment 1). The expected negative effect of prolonged presentation of prior cues is predicted by the competitive activation model: If subjects' development of erroneous hypotheses during prior presentations of less complete pictures is responsible for the interference effect, subjects will have more time to develop their hypotheses with prolonged viewing of very blurred versions. Thus, the interference should be stronger.

Interference Effects in Words Versus Pictures: Are They Different?

The second set of data that seems to be incompatible with the competitive activation model concerns the interference effects in word fragment completion reported by Peynircioglu and Watkins (1986) and Peynircioglu (1987). Their major finding was that the interference effect in word fragment

completion occurs only when the tested words are from a limited set. For example, their interference effect occurred for previously studied words but not for unstudied words. Similarly, their interference effect occurred only when the tested words were blocked by semantic category but not when they were presented in random order. In addition, Peynircioglu has shown that the interference occurred for words from a newly acquired language but not for words from a native language. The crucial variable here appears to be the limitation of the test set; we refer to this notion as the *limited-set* hypothesis.

Because Bruner and Potter (1964) used pictures that their subjects had not studied before and that were not blocked by semantic category, Peynircioglu and Watkins (1986; Peynircioglu, 1987) emphasized important functional differences between their effect and the Bruner and Potter interference effect. They also questioned the possibility of using the erroneous hypothesis notion to interpret their finding, because they argued that the theory does not have a mechanism to explain why interference should occur only for items from a limited set.

However, we think it is possible to reconcile the two sets of data within the competitive activation model. There are two possibilities. The first is to incorporate the limited-set hypothesis within the model. Because Bruner and Potter (1964) and Snodgrass and Hirshman (1991) both used pictures, whereas Peynircioglu and Watkins (1986) used words, the difference in their findings may be attributable to the difference in stimulus materials. It can be argued, for example, that using pictures as stimuli would automatically limit the set of possible concepts to concrete and everyday objects and, thus, could have the same effect as studying a set of words or presenting words from a single category. The idea is that competing activations may only be an important variable when the set of test items is limited by using pictures or by using a limited set of words. We must then explain why the competitive activation model only applies to limited sets. We see no immediate solution to this, so an explanation based on the limited-set hypothesis does not seem very promising.

An alternative is to consider the variable of performance level, which covaries with set limitation to some degree. As argued earlier, it is not unreasonable to assume that some minimum activation is required for a competing hypothesis to become active. Because performance level signals activation level of the target item, the minimum activation requirement may well be manifested by a minimum performance requirement. Thus, the finding that interference occurred only for studied or primed words can mean that interference only occurs when performance is above some threshold. We then need to explain why the interference occurred for unstudied or unprimed pictures. One possibility is that performance level in the studies that used pictures as stimuli happened to reach the threshold level. To test if this is a reasonable explanation, we need to vary the performance level and see whether there is a performance threshold that determines whether interference is obtained. This effect should be independent of the priming–nonpriming manipulation. If the performance level explanation is correct, we should be able to eliminate interference for pictures when

performance level is lowered. We should also be able to demonstrate interference effects for both studied and unstudied words.

In Experiments 3–6, we test whether performance level can better predict the generation of interference than set limitation and whether it applies to both words and pictures. The results of these experiments will determine whether the seemingly incompatible findings from word fragment completion can be reconciled within the competitive activation model.

In all of the experiments reported here, the procedure of Snodgrass and Hirshman (1991) is used. In this procedure, stimuli are rendered difficult to see by fragmenting them. Fragmentation is accomplished by deleting blocks of pixels from a computer image, so as to create a number of different levels of fragmented image. Typically, there are eight levels, ranging from Level 1 (most fragmented) to Level 8 (complete). The subject's task is to identify a moderately fragmented image (usually Level 4), either in the ascending condition in which the image is preceded by a number of more fragmented versions of that image, or in the fixed condition in which it is not preceded by anything. The interference effect is obtained when performance in the ascending condition is worse than that in the fixed condition.

Experiment 1

This experiment had two purposes. The first was to replicate the Bruner and Potter (1964) interference effect in a more controlled procedure in which the start level (the level of fragmentation with which the ascending condition begins) was manipulated separately from the duration of the final (Level 4) presentation. We expected that a lower start level will produce worse performance, whereas a longer final duration will produce better performance. The second purpose was to test the durability of the interference effect by examining if the interference effect diminishes as duration of the final level is made longer—that is, if there is an interaction between the start level and the final duration.

Method

Subjects. The subjects were 27 college students from an introductory psychology course at New York University. They received course credit for their participation in the study.

Materials and design. Eighty-one fragmented line-drawn pictures were used as stimuli. They were selected from the Snodgrass and Vanderwart (1980) picture set and were fragmented on-line. In this on-line procedure, the particular blocks to be deleted from the complete image were selected beforehand, but the fragmentation itself was carried out on-line. (The advantage of this on-line procedure is that it requires less memory space.) The parameter, r, which determined the proportion of blocks shown at each level according to the formula, $P(\text{block, level}) = r^{(8-level)}$, was set at .70 for this experiment. As a result, a series of fragmented images at eight levels of completion could be obtained, in which a picture at Level 1 was most fragmented, a picture at Level 4 was moderately fragmented, and a picture at Level 8 was its intact version. All stimuli were presented on the screen of an Apple Macintosh microcomputer. They were centered within a 246 × 246 pixel square window.

In this experiment two variables were manipulated. The first was the start level of the fragment series. Three starting points (Level 2, Level 3, and Level 4) were used, and the stopping point was always at Level 4. Thus, for the first two starting points, a picture was gradually completed by adding more elements each time (ascending procedure), whereas for the third starting point only the Level 4 fragment was presented (fixed procedure). To make the ascending series appear more continuous and thus make the procedure more analogous to that in Bruner and Potter's (1964) study, we made the step change in a fragment series very small by dividing each level into three smaller steps. A fragment series of Level 3 to Level 4, for example, was presented as a fragment at Level 3 followed by one at Level 3⅓, one at Level 3⅔, and one at Level 4. The duration of each step was 1 s, and there was no interstimulus interval.

The second variable in this experiment was the presentation duration of the last and most complete image. Three durations (2 s, 5 s, and 8 s) were used. A within-subjects factorial design resulted in nine (3 × 3) experimental conditions. Table 1 shows the total viewing time for each condition of this experiment.

Procedure. Subjects were run individually on an Apple Macintosh Plus microcomputer. The subjects were first shown the instructions on the screen of the computer. They were told that they would be shown fragmented images of everyday objects and animals and that their task would be to identify each image. They were also told that for some pictures they would see several presentations, each more complete than the previous, whereas others pictures would be shown at only one level of fragmentation. After stimulus offset, subjects were asked to respond by typing the name of the picture. They were warned that the task was difficult and not to expect to get more than about 50% correct.

After three practice pictures, the 81 experimental pictures were presented. They were counterbalanced across nine experimental conditions. A mixed-list presentation was used, and the order of presentation of items was randomized separately for each subject. Subjects self-initiated each trial by pressing a key. They were instructed that they should respond only after the picture was turned off and that they must type in some response or the program would not go on. They might type "unknown" if they absolutely could not make out what the stimulus was.

Picture names were considered correct if their first four letters matched the first four letters of any of the names stored in a variant file for that picture. The variants included synonyms, abbreviations, and common misspellings. In addition, all responses made by subjects were recorded so that misspellings and alternative names not already stored as variants could be examined and counted as correct. Subjects were instructed that they could identify a picture by typing only its first four letters. On each trial, they received feedback from the computer in the form of the message "Correct" or "Sorry" along with the name of the picture.

Results and Discussion

The percentages of items correctly identified under each of the nine conditions are shown in Table 2. A within-subjects analysis of variance (ANOVA) on the data showed that both variables had significant influences on identification performance, $F(2, 52) = 3.78, p = .029, MS_e = .031$ for the viewing time of the final presentation, and $F(2, 52) = 7.49, p = .001, MS_e = .022$ for the start level. Although the interaction between the two variables did not reach significance, $F(4, 104) = 1.11, p = .355$, a simple effects test showed that the effect of starting point was more reliable at the 8-s final duration ($p = .002$) than at the 5-s ($p = .072$) or 2-s duration ($p = .610$).

As expected, subjects' performance became worse as the starting point decreased and became better as viewing time of the final level increased. This replicated both main effects reported by Bruner and Potter (1964), and it also suggested that the reason Bruner and Potter found a positive effect of viewing time was probably because their subjects profited from being able to view the clearest part of the image for longer times.

The negative effect of decreasing the starting point is consistent with the competitive activation model; as initial presentation becomes more blurred, there is more opportunity for competing responses to be generated. The positive effect of increasing the duration of the clearest part of the stimulus represents a sort of "Bloch's law" of identification performance for near-threshold images. Snodgrass and Feenan (1990) have shown that increases in viewing time improve identification performance for fragmented pictures that are near threshold.

Let us consider in more detail the effect of the duration of final presentation. Although the interaction between the time of the final presentation and the start level did not reach significance, there was a suggestion in Table 2 that the exposure time of the final presentation had a greater effect on identification performance in the fixed conditions than in the ascending conditions. Note that in the fixed conditions, performance continued to improve with viewing time even after 5 s, whereas in the ascending conditions, the viewing time had very small effects after 5 s. This was confirmed by a simple effects test that showed that the effect of viewing time was reliable in the fixed condition, $F(2, 52) = 5.81, p = .005, MS_e = .021$, but not in the two ascending conditions (both $Fs < 1$).

According to the competitive activation model, this pattern of results indicates that in the ascending conditions subjects continued to maintain an incorrect hypothesis about the identity of a picture developed in earlier stages of the presentation, and this interfered with their taking full advantage of prolonged presentation of the most complete image.

In summary, the results of Experiment 1 replicated the findings of Bruner and Potter (1964). They showed that subjects' ability to identify a moderately fragmented image was undermined if subjects had been cued with more fragmented

Table 1
Total Viewing Time in Each Condition of Experiment 1 (in Seconds)

Duration of final presentation (s)	Starting–stopping points		
	Level 2–Level 4 (ascending)	Level 3–Level 4 (ascending)	Level 4 (fixed)
8	14	11	8
5	11	8	5
2	8	5	2

Note. Total viewing time was obtained by adding the duration of the final presentation to the duration of the ascending series, which was 1 s for each step (each level was divided into three equal steps).

Table 2
Percentage of Items Correctly Identified in Experiment 1 as a Function of Starting Point and Duration of Final Presentation (in Seconds)

Duration of final presentation (s)	Starting–stopping points			
	Level 2–Level 4 (Ascending)	Level 3–Level 4 (Ascending)	Level 4 (Fixed)	M
8	34.2	37.0	48.2	39.8
5	33.3	37.0	42.0	37.4
2	30.9	31.7	34.6	32.4
M	32.8	35.:	41.6	

versions of the image, and the more fragmented the initial cue, the worse the identification performance. In addition, this experiment showed that the interference effect was quite durable in that it did not diminish with prolonged presentation of the most complete image. These results are consistent with the competitive activation model.

Experiment 2

We speculated in the introduction that the positive effect of viewing time observed in Bruner and Potter's (1964) study may actually be a mixture of two opposite effects: the positive effect of the viewing time of the clearest part of a stimulus and the negative effect of the viewing time of the more blurred portions of the stimulus. The benefits of viewing a clarified image for longer durations have been demonstrated in Experiment 1. In Experiment 2, we investigate the predicted costs of viewing more degraded prior cues for longer periods and the dynamics of those costs and benefits when both duration of prior cues and that of final presentation increase.

Method

Subjects. The subjects were 24 college students from an introductory psychology course at New York University. They received course credit for their participation.

Design and procedure. The design was again within subjects. Two variables were independently manipulated: the viewing time of each prior presentation (0 s: fixed conditions; 2 s: ascending condition; and 6 s: ascending conditions) and the viewing time of the final presentation (2 and 6 s). In the ascending conditions, the starting point of the ascending series was always Level 1, and the stopping point was Level 4. In this experiment only the fragments at Levels 1, 2, 3, and 4 were used. They were obtained in the same way as in Experiment 1, with the parameter *r* again set at .70. In the fixed condition only pictures at Level 4 were presented. The design resulted in a total of six (3 × 2) conditions. The materials and the procedure were the same as in Experiment 1 except that 84 rather than 81 pictures were used. The 84 items were counterbalanced across six conditions, and the order of their presentations were randomized separately for each subject.

Results and Discussion

The percentages of items correctly identified under each of the six conditions are shown in Table 3. A within-subjects

ANOVA on the data showed that both the viewing times of prior presentations and the viewing times of the final presentation had significant influences on the identification performance, $F(2, 46) = 14.17, p < .001, MS_e = .010$ for the viewing time of each prior cue and $F(1, 23) = 13.00, p < .002, MS_e = .015$ for the viewing time of the final presentation. However, there was no interaction between the two variables $(F < 1)$.

The results of Experiment 2 showed that subjects' performance deteriorated with the increase of viewing time of each prior presentation. Simple effects tests conducted within the ascending conditions also confirmed that the performance was worse when the viewing time of each prior cue was 6 s than when it was 2 s: For the 6-s final presentation, $F(1, 23) = 4.68, p < .05, MS_e = .008$, and for the 2-s final presentation, $F(1, 23) = 4.82, p < .05, MS_e = .007$. Thus, as predicted from the competitive activation model, viewing a degraded image for longer periods of time does have a negative effect when that factor is dissociated from viewing time of the final level. The results of Experiment 2 also replicated two findings in Experiment 1: the inhibitory effect of prior cues (performance was worse in the ascending conditions than in the fixed conditions) and the positive effect of viewing time of the final presentation.

What happened to overall performance when both of the durations were increased? The data in Table 3 showed a small and nonsignificant improvement in performance when the prior and final viewing times were both increased from 2 to 6 s in the ascending conditions (33.6% vs. 36.0%). In contrast, when the final viewing time was increased from 2 to 6 s in the fixed conditions, there was a significant increase in performance (39.9% vs. 46.4%), $F(1, 23) = 5.69, p = .026, MS_e = .013$.

Table 3
Percentage of Items Correctly Identified in Experiment 2 as a Function of Durations of Each Prior Presentation and Final Presentation

Duration of final presentation (s)	Duration of each prior cue (s)			
	6 (Ascending)	2 (Ascending)	0 Fixed	M
6	36.0	41.7	46.4	41.4
2	28.3	33.6	39.9	33.9
M	32.2	37.7	43.2	

Note. Prior cues were picture fragments at Levels 1, 2, and 3 and final presentation was Level 4.

Bruner and Potter (1964) found a positive effect of average viewing time in general, but the data suggested that the effect was greater when presentation started with *light blur* than with *medium blur* or *very blurred*. Because our ascending conditions are equivalent to their *very blurred* conditions, whereas our fixed conditions are similar to their *light blur* conditions, the two sets of results present a similar picture. Therefore we conclude that the positive effect of average viewing time found by Bruner and Potter and by us occurred because the benefits from viewing the clearest part of a stimulus outweighed the costs of viewing the more blurred portions of the stimulus.

The competitive activation model accounts for these findings very well. First, the model predicts that increases in viewing time of prior cues should lead to stronger interference, because with prolonged presentation more competing responses could be activated or the existing ones could be strengthened. Second, the model predicts that the stronger the interference, the less benefit could be obtained from viewing the clearest presentation for longer (because it would be more difficult to dismiss a competing response when it gets stronger).

In summary, the results of the first two experiments are consistent with the results of Bruner and Potter (1964): Decreases in starting point have the predicted negative effect on performance, even when that variable is dissociated from changes in viewing duration. More important, we have shown that viewing duration has paradoxical effects, enhancing performance when it occurs for the most clarified image and depressing performance when it occurs for the more fragmented images. The enhancement for the most clarified image is simply the operation of a well-established psychophysical rule that increasing the duration of a near-threshold stimulus increases its identifiability. The depression for the more fragmented images follows from the competitive activation model of perceptual interference. The observed positive effect of viewing time in Bruner and Potter's study is actually a mixture of two opposite effects, and this result is therefore consistent with the competitive activation model.

We turn to consider another set of data that is seemingly incompatible with the competitive activation model. As we noted earlier, Peynircioglu and Watkins (1986) and Peynircioglu (1987) found an interference effect in word fragment completion that occurred only when the target words had been studied or primed beforehand, when they were presented in a categorized list, or when they were from a newly acquired language. They found no interference effect for new words, for words presented in a random order, or for words from a native language.

Peynircioglu and Watkins (1986) accounted for the selectivity of their interference effect by postulating that it only occurs for items from a limited set. We have argued that their results may be better predicted from a difference in performance level rather than in a limit on the potential size of the test set. Their results can be reconciled with the competitive activation model if the performance level hypothesis is shown to be correct. We report three experiments to show that Peynircioglu and Watkins's results are not well replicated.

Rather, the results of these experiments are better predicted by the performance level hypothesis.

In these experiments, words were used as stimuli, and subjects first studied a subset of the words and then were tested on the studied (old) words mixed with new words. Half of each set (old and new) was presented with the ascending method, and half was presented with the fixed method. Word fragments used in the experiments were obtained by the same procedure used for fragmenting pictures in Experiments 1 and 2.

Experiments 3 and 4

Because Experiments 3 and 4 differed only in their subject population, they are described together.

Method

Subjects. The subjects of Experiment 3 were 20 college students from an introductory psychology course at New York University. They participated as part of their course requirement. The subjects of Experiment 4 were 20 high school students who participated as part of a microcomputer laboratory course requirement.

Materials and design. The stimuli were 60 words that were the names of 60 pictures from Sets 11 and 12 of Snodgrass and Vanderwart (1980). These words were fragmented on-line in a procedure similar to that used for fragmenting pictures in Experiments 1 and 2. The words were printed in uppercase Basel typeface in 48-point size centered within a 246 × 246 pixel square window. No word was longer than 12 letters, and all words fit within the window. The words were 22 pixels high and ranged from 49 to 245 pixels long. Because the words were more compact than the pictures, we chose a smaller unit of deletion—an 8 × 8 pixel square in contrast to the 16 × 16 pixel square used for the pictures. The fragmentation algorithm consisted of identifying the number of pixel blocks containing black pixels (this number ranged from 26 to 118 with a mean of 60 across the words), and then randomly deleting pixels to form eight levels of fragmentation, by the formula: $P = r^{(8-level)}$. The parameter r was set at .80 in the two experiments. (More details on these screen-fragmented words can be found in Snodgrass and Poster, 1992.)

Both experiments used a 2 (studied vs. new) × 2 (ascending vs. fixed) within-subjects design. Sixty test items were counterbalanced across the four experimental conditions in both experiments. The 60 items were first divided into four subsets across which the average word length was equal. Then four counterbalancing sequences were formed so that equal numbers of subjects received each counterbalancing.

Procedure. Subjects in Experiment 3 were run individually in a laboratory at New York University. Subjects in Experiment 4 were run as a group in a large microcomputer laboratory classroom at a local high school. Before the study phase subjects were first shown study instructions on the screen of the computer. They were told that they would be shown slightly fragmented words that would be presented only briefly and that their task was to identify them.

During the study phase, subjects were shown a total of 33 words, in which the first 3 were for practice. Each word was presented at Level 7 and was somewhat degraded but still easily identifiable. Each item was shown for 100 ms. At the offset of each item subjects attempted to identify the word by typing its letters onto the computer keyboard. If the word was not spelled absolutely correctly, it was classified as incorrect. Subjects received feedback from the computer in the form of the message "Correct" or "Sorry," followed by

the name of the word. This was to ensure that all subjects correctly perceived the study words. All responses made by subjects were recorded so that they could be examined and counted correct if their pronunciation approximated the correct pronunciation of the target items.

Immediately after the study phase, the subjects were presented with a distractor task in which they were asked to compare two similar visual patterns and make a same–different judgment. There were 10 trials of such visual pattern comparisons.

Then subjects were given the test phase of the experiment. At the beginning of the test phase, they were told that they would be shown more words that were much more degraded than before. They were also told that some of the words would be slowly completed on screen, whereas other words would be shown in their most complete form immediately. During the test phase a total of 60 words were presented, including 30 studied (old) and 30 unstudied (new) words. Half of the words were shown with the ascending procedure from Level 1 to Level 4 in four steps, and the other half were shown at the fixed Level 4. Each level before Level 4 of the ascending series was shown for 1 s. In both procedures Level 4 fragments remained visible until subjects responded by typing in their response. If they could not identify a word, they were instructed to type the response "blank." The computer program would not go on until the subjects had typed something. Subjects received feedback about whether they were correct or not after each trial, but they were not told the name of the word.

Results and Discussion

During the study phase, subjects in Experiment 3 identified 92% of the words, and subjects in Experiment 4 identified 82% of the words. The percentages of items correctly identified in the test phase for each of the four experimental conditions are shown in Tables 4 and 5 for Experiments 3 and 4, respectively. In both Experiments 3 and 4, as expected, subjects identified more studied words than new words (64.9% vs. 42.2% in Experiment 3 and 46.5% vs. 25.8% in Experiment 4), indicating implicit, perceptual memory for old words. Most important, in Experiment 3 subjects identified more words presented in the fixed condition than in the ascending condition (57.2% vs. 49.9%). This was true only for studied words (72.7% vs. 57.0%), not for new words (41.7% vs. 42.7%). The pattern of results in Experiment 3 replicated Peynircioglu and Watkins's (1986) finding that interference occurred only for studied words and thus supported the limited-set hypothesis.

In contrast, however, the results of Experiment 4 showed that subjects identified almost the same percentage of items in the fixed condition as in the ascending condition (36.3% vs. 36.0%). This was true for both studied words (46.3% vs.

Table 4

Percentage of Items Correctly Identified in Experiment 3 as a Function of Study Status (Old vs. New) and Presentation Condition (Ascending vs. Fixed)

| Study status | Presentation condition | | M | Difference |
	Ascending	Fixed		
Old	57.0	72.7	64.9	15.7
New	42.7	41.7	42.2	−1.0
M	49.9	57.2	53.6	

Table 5

Percentage of Items Correctly Identified in Experiment 4 as a Function of Study Status (Old vs. New) and Presentation Condition (Ascending vs. Fixed)

| Study status | Presentation condition | | M | Difference |
	Ascending	Fixed		
Old	46.7	46.3	46.5	−0.4
New	25.3	26.3	25.8	1.0
M	36.0	36.3	36.2	

46.7%) and new words (26.3% vs. 25.3%). Therefore, there was no interference effect for either new or studied words. The pattern of the results in Experiment 4 did not support the limited-set hypothesis.

The results of a 2 ×2 within-subjects ANOVA confirmed these observations. In Experiment 3 there was a significant effect of studied versus new words, $F(1, 19) = 96.95$, $p < .001$, $MS_e = .011$; a significant effect of fixed versus ascending condition, $F(1, 19) = 7.89$, $p = .011$, $MS_e = .014$; and a significant interaction between the two variables $F(1, 19) = 13.12$, $p = .002$, $MS_e = .011$. Simple effects tests further showed that the advantage of fixed over ascending presentations was reliable for the studied words, $F(1, 19) = 13.41$, $p = .002$, $MS_e = .018$, but not for the new words ($F < 1$).

In Experiment 4, however, the results of the same 2 × 2 ANOVA showed that the only significant effect was that of studied versus new words, $F(1, 19) = 53.03$, $p < .001$, $MS_e = .016$. There was no significant effect of fixed versus ascending condition, nor was there a significant interaction between the study status and the presentation condition (both Fs < 1).

In short, the results of Experiment 3 replicated the finding by Peynircioglu and Watkins (1986) that the interference effect occurred only when the test items were studied beforehand. However, the results of Experiment 4 failed to replicate their finding. Surprisingly, there was no interference effect at all, either for the studied or the new items.

How can we account for the complete lack of an interference effect in Experiment 4? The obvious difference between Experiments 3 and 4 is in level of performance. In Experiment 3, when the average performance was 64.9% for studied words, interference was obtained; when it was 42.2% for new words, no interference was obtained. In Experiment 4, the average performance was only 46.5% for studied words and 25.8% for new words, and in neither condition was any interference obtained. Because the only difference between the two experiments was in the general level of performance, the pattern of results suggests that performance level is a better predictor of the interference effect than set limitation. It seems that some moderate level of performance (e.g., 50%) is necessary before interference can be demonstrated.

Experiment 5

A logical extension of the performance level argument is that if we can somehow enhance overall performance, we

should be able to demonstrate interference effects for all items, regardless of whether they have been studied or not. The purpose of Experiment 5 was to test this hypothesis.

To enhance overall performance, we gave subjects 10 training trials before the actual experiment. In the training session, subjects were shown fragment series from Levels 1 through 5 and were told the answers at the end. This was intended to familiarize them with the fragment completion task and to improve performance in the later experimental session. The words used in the training session were not used in the experimental session. In addition, all words used in this experiment were no longer than 8 letters, whereas in Experiments 3 and 4 they could be as long as 12 letters.

Method

Subjects. Sixteen college students from an introductory psychology course at New York University participated in this experiment for partial fulfillment of their course requirement.

Materials and design. The stimuli were 70 words selected from Snodgrass and Poster (1992). Ten of them were used in the training session, and the rest were used in the experimental session. No word was longer than 8 letters. The design was the same as in Experiments 3 and 4: A 2 (studied vs. new) × 2 (ascending vs. fixed) within-subjects design was used.

Procedure. The procedure was essentially the same as in Experiment 3, except that subjects were given a training session before the formal experiment. In the training session, subjects were shown 10 fragment series, each from Level 1 through Level 5, and they were told the answer at the end of each trial. Note that in the formal experiment the stopping level of a word fragment series was still Level 4. The Level 5 fragment was included in the training trials to ensure that subjects had a better chance of completing word fragments. Another minor difference between this experiment and Experiment 3 was in the study session. In the study phase of this experiment, subjects were shown intact (Level 8) words, rather than the slightly fragmented (Level 7) words as used in the two previous experiments. Each word was shown for 100 ms, and subjects were asked to read them silently. All other aspects were the same as in Experiments 3 and 4, including the timing parameters and the distractor task.

Results and Discussion

The percentages of correctly identified items in the test phase of this experiment are shown in Table 6. The training session had the intended effect of enhancing overall performance. On average, subjects identified 64.0% of word frag-

Table 6
Percentage of Items Correctly Identified in Experiment 5 as a Function of Study Status (Old vs. New) and Presentation Condition (Ascending vs. Fixed)

Study status	Presentation condition		M	Difference
	Ascending	Fixed		
Old	66.5	75.5	71.0	9.0
New	53.1	60.7	56.9	7.6
M	59.8	68.1	64.0	

ments, well above the performance in Experiments 3 and 4 (53.6% and 36.2%, respectively).

As expected, subjects generally identified more studied items than new items (71.0% vs. 56.9%), indicating implicit, perceptual memory for old words. More important, subjects identified more items presented in the fixed condition than in the ascending condition (68.1% vs. 59.8%), and this was true for both studied words (75.5% vs. 66.5%) and new words (60.7% vs. 53.1%).

The results of a 2 × 2 within-subjects ANOVA confirmed these observations. It showed that there was a significant effect of studied versus new items, $F(1, 15) = 20.34, p < .001, MS_e = .016$, and a significant of effect of fixed versus ascending condition, $F(1, 15) = 7.40, p = .016, MS_e = .015$. However, there was no indication of interaction between the two variables ($F < 1$).

Because we obtained significant interference effects for new items as well as for studied items, we again failed to replicate Peynircioglu and Watkins's (1986) finding that the interference effect occurred only when the test items had been studied beforehand. Taken together, the results of Experiment 3–5 seriously challenge the reliability and generality of Peynircioglu and Watkins's finding and the related limited-set hypothesis. The limited-set hypothesis predicts that we should obtain an interference effect for studied words but not for new words. Although the predicted pattern was obtained in Experiment 3, in Experiment 4 there was no interference effect at all, and in Experiment 5, there was an interference effect for unstudied as well as studied words.

How does this pattern of results relate to the competitive activation model? According to the minimum activation requirement of the model, to interfere with target perception, the fragmented word presented before the final level in the ascending condition (i.e., at Levels 1, 2, and 3) must be sufficiently evocative to produce competing activations. Because poor performance at the final Level 4 indicates even worse performance at levels below 4, the poor final performance means that very little information is available to subjects on which to generate competing hypotheses. Therefore, poor final performance signals low evocativeness of prior cues.

The preceding argument relies on the assumption that final performance can be used as a measure of evocativeness of prior cues. Here we describe our reasons for making this assumption. First, we assume that no matter how fragmentary the prior cue is, it will provide more evidence in favor of the target than in favor of its closest distractor. This means that no matter how low the probability of identifying the target correctly, the probability of identifying the target incorrectly as its closest distractor will be lower. Second, we assume that the probability of identifying the target increases smoothly with fragmentation level, so that if the probability of identifying the target at the final level is a particular value, then the probability of identifying the target at a lower level must be less than that value. This assumption is supported by the data presented in Figure 1. Figure 1 shows the psychometric function obtained in the word fragment completion task of Snodgrass and Poster (1992), in which the ascending method of limits was used to measure the thresholds of 250 words.
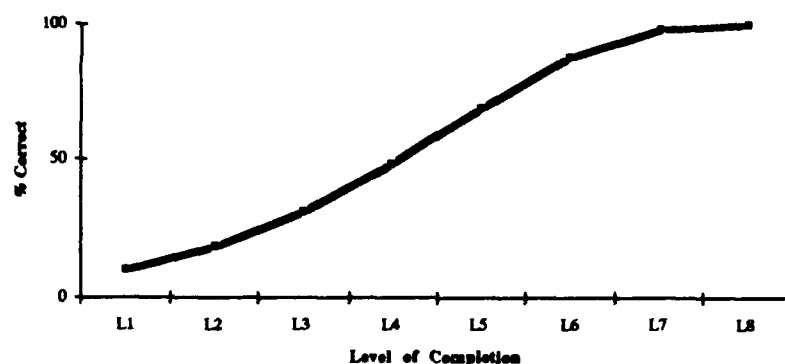
Figure 1. Psychometric function showing percentage of identification of a fragmented word as a function of fragmentation level (L). Data are based on responses of 20 subjects to each of 250 words for a total of 5,000 responses. Adapted from "Visual Word Recognition Thresholds for Screen-Fragmented Names of Snodgrass and Vanderwart Pictures," by J. C. Snodgrass and M. Poster, 1992, *Behavior Research Methods, Instruments, and Computers, 24,* p. 4, Table 1. Copyright 1992 by the Psychonomic Society, Inc. Adapted by permission.

The psychometric function increases smoothly and continuously with fragmentation level.

Considering the pattern of results across Experiments 3–5, level of performance increased in the order of Experiments 4, 3, then 5, and the interference also varied from none at all in Experiment 4, to an effect for old items only in Experiment 3, to an effect for both old and new items in Experiment 5. Thus, the results of Experiments 3–5 seem to be highly consistent with the competitive activation model.

Why is interference always obtained for pictures, even when performance is fairly low (e.g., 40% in Experiments 1 and 2), but not for words at a similar performance level? One possibility is that Experiments 1 and 2 used prolonged presentation of prior cues, which massively increased the amount of interference. Another possibility is that word fragments are less evocative in producing competing responses than picture fragments, and thus study or some other manipulation is needed to enhance their evocativeness before interference can be demonstrated. One possible reason for this is that perceptual features of words, which we assume are their component letters, are more discrete and hence more easily falsified than perceptual features of pictures. Although there might be such differences between words and pictures, the competitive activation model assumes that they are not qualitatively different, and thus the same rule should apply to pictures as well as words. Accordingly, in the next experiment we manipulated performance level for pictures to see whether the interference effect for pictures also disappears when performance is depressed.

Experiment 6

In Experiment 6, pictures were used as stimuli, and the performance level was manipulated by varying the stopping point of each fragment series. The focus of this study was to see whether there was an interaction between the magnitude of the interference effect and the level of performance, which is predicted by the competitive activation model.

Method

Subjects. The subjects were 24 college students from an introductory psychology course at New York University. They participated as part of their course requirement.

Design and procedure. The stimuli were 80 pictures selected from the same source as in Experiments 1 and 2. They were fragmented on-line in the same manner as before. The parameter r was set at .70. The experiment used a 2 (stopping point: Level 5 vs. Level 4) × 2 (presentation: ascending vs. fixed) within-subjects design. In the ascending conditions, the starting point was always at Level 1, and the stopping point was either at Level 4 or at Level 5. The exposure time of each prior presentation except the final presentation was 3 s. The duration of the final presentation was 5 s. To reduce overall performance, we eliminated that part of the instruction that told subjects that the pictures were everyday objects and animals. In addition, during the test phase subjects were not given any corrective feedback about their responses. Other aspects of the procedure were the same as in Experiments 1 and 2. The 80 items were counterbalanced across four experimental conditions, and the order of their presentations was randomized separately for each subject.

Results and Discussion

The percentages of items correctly identified under each of the four experimental conditions are shown in Table 7. The results showed that when the stopping point was Level 4, subjects identified almost the same percentage of items in the

Table 7
Percentage of Items Correctly Identified in Experiment 6 as a Function of Stopping Point (Level 5 vs. Level 4) and Presentation Condition (Ascending vs. Fixed)

| Stopping point | Presentation condition | | M | Difference |
	Ascending	Fixed		
Level 5	68.1	76.0	72.1	7.9
Level 4	36.7	37.7	37.2	1.0
M	52.4	56.9	54.6	

fixed condition as in the ascending conditions (37.7% vs. 36.7%), but when the stopping point was Level 5, subjects identified more items in the fixed condition than in the ascending condition (76.0% vs. 68.1%). Note that performance in the Level 4 condition was lower than that in the similar conditions in Experiment 1. This indicated that our effort to reduce performance by eliminating informative instruction and feedback had the intended effect.

A 2 × 2 within-subjects ANOVA on the data showed a significant effect of stopping point, $F(1, 23) = 291.49, p < .001, MS_e = .010$, and a significant effect of presentation procedure, $F(1, 23) = 4.48, p = .045, MS_e = .011$. The interaction between the two variables approached statistical significance, $F(1, 23) = 3.63, p = .069, MS_e = .008$. A simple effects test confirmed that the advantage of fixed versus ascending presentations was significant in the Level 5 condition, $F(1, 23) = 5.63, p = .026, MS_e = .013$, but not in the Level 4 condition ($F < 1$).

The fact that the interference effect in picture fragment completion also disappeared when performance was lowered, and that it was obtained only when performance was reasonably high, further supported the notion that words and pictures are susceptible to the same type of perceptual interference. The finding provided additional evidence supporting the competitive activation model.

General Discussion

In this study we explored the mechanism of Bruner and Potter's (1964) perceptual interference effect. Specifically, we proposed that the effect can be accounted for by the competitive activation model, which attributes interference to competing activations in perceptual structures resulting from cue presentations. We examined two sets of data that seemed to be inconsistent or incompatible with this model.

In Experiments 1 and 2 we investigated Bruner and Potter's (1964) original findings of the negative effect of prior cues and the positive effect of viewing time. The positive effect of viewing time is puzzling and is not predicted by the competitive activation model. We speculated that the positive effect of viewing time was due to the confounding of the time of viewing prior cues with that of viewing the clearest part of the image in their experiment. We expected that prolonged exposure to prior cues would reduce performance, whereas prolonged exposure to the clearest image would enhance performance.

In Experiment 1 we independently manipulated the time of viewing the most clarified image and the starting point of the ascending series, while keeping the time of viewing prior cues constant. The results show that, in accord with Bruner and Potter (1964), decreases in the starting point have the predicted negative effect on performance. The results also show that the viewing time of the most clarified part of the image has the predicted positive effect on performance. In addition, the fact that the interference effect does not diminish with prolonged presentation of the last and most complete image indicates the durability of the perceptual interference effect. These results are consistent with the competitive activation model.

In Experiment 2 we investigated the predicted negative effect of viewing prior cues for longer periods and the effects of varying both the duration of prior cues and that of the final presentation. The results showed that the interference was stronger with prolonged presentation of prior cues. Thus, as predicted by the competitive activation model, viewing a degraded image for longer periods does have a negative effect. The finding indicates that the effect of viewing time, as manipulated by Bruner and Potter (1964), has two opposite components. Taken together, the findings from Experiments 1 and 2 provide a satisfactory explanation of the dynamics of the negative effects of prior cues and the positive effect of average viewing time. They showed that the observed positive effect of viewing time in Bruner and Potter's study is consistent with the competitive activation model.

In Experiments 3–6, we investigated the relationship between the Peynircioglu and Watkins effect (Peynircioglu, 1987; Peynircioglu & Watkins, 1986) and that reported by Bruner and Potter (1964) and by Snodgrass and Hirshman (1991). Peynircioglu and Watkins's finding that interference occurs only for studied or primed words seemed to be incompatible with the competitive activation model. We explored the possibility of interpreting this finding within the competitive activation model. In Experiment 3, we replicated Peynircioglu and Watkins's finding that the interference effect occurred only when the test words had been studied beforehand, but not when words were new. In Experiment 4, however, we failed to replicate their finding, in that no interference effect was found for either studied or new words. In Experiment 5, we again failed to replicate their study effect; we found an interference effect for new words as well as for studied words. The pattern of results across Experiments 3–5 indicated that interference was not determined by the limited set of target items, but by whether identification exceeded some performance threshold. The results of Experiment 6 showed that performance in picture fragment completion must also be above some threshold to demonstrate interference.

Why, then, did Peynircioglu and Watkins (1986) find a reliable study effect in their experiments? We believe that their results are due to differences in performance level that covaried with study manipulation. In the Peynircioglu and Watkins study, unstudied words were identified about 50% of the time, whereas studied words were identified approximately 80% of the time. And, as noted earlier, interference effects were only obtained in the studied condition. Similarly, in Peynircioglu's (1987) study in which a priming manipulation was used, no interference effects were demonstrated when performance was below 45%. In the present experiments, we found little or no interference for pictures when performance was below approximately 45% except in Experiment 2, in which the long duration of prior cues significantly increased the amount of interference. For words, the performance threshold was about 50%.

In summary, we think that the performance level explanation applies to both pictures and words. Although there does not seem to be a fixed value of performance threshold that separates conditions in which interference is obtained from those in which it is not obtained, the variability we

observe could well be attributable to the procedural and material differences used in different studies.

This study showed that a variety of findings concerning perceptual interference effects can be accounted for by the competitive activation model, which attributes interference to competing activations in perceptual structures. Two seemingly inconsistent or incompatible findings in the literature, the positive effect of viewing time of stimuli in Bruner and Potter's (1964) study and the finding that interference occurred only for studied or primed words (Peynircioglu, 1987; Peynircioglu & Watkins, 1986), were shown not to be at odds with the competitive activation model. Although future study may provide evidence that the model needs to be refined, modified, or even replaced by alternatives, at present we believe that the interference effects observed in visual object recognition (e.g., Bruner & Potter, 1964; Wyatt & Campbell, 1951), picture fragment completion (Snodgrass & Hirshman, 1991), and word fragment completion (Peynircioglu, 1987; Peynircioglu & Watkins, 1986) seem to have the same underlying mechanism and that they are probably due to competing activations in perceptual structures generated by cue presentations

References

Blake, R. R., & Vanderplas, J. M. (1950). The effect of prerecognition hypotheses on veridical recognition thresholds in auditory perception. *Journal of Personality, 19,* 95–115.

Bruner, J. S., & Potter, M. C. (1964). Interference in visual recognition. *Science, 144,* 424–425.

Frederiksen, J. R. (1967). Cognitive factors in the recognition of ambiguous auditory and visual stimuli. *Journal of Personality and Social Psychology Monographs, 7*(1, Whole No. 639).

Frederiksen, J. R. (1969). Response preservation in auditory word recognition. *Journal of Experimental Psychology, 79,* 48–55.

Galloway, D. W. (1946). An experimental investigation of structural lag in perception. *American Psychologist, 1,* 450 (Abstract).

Peynircioglu, Z. F. (1987). Inhibition through incremental fragment cuing with primed items. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 13,* 569–572.

Peynircioglu, Z. F., & Watkins, M. J. (1986). Cue depreciation: When word fragment completion is undermined by prior exposure to lesser fragments. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 12,* 426–431.

Snodgrass, J. G., & Feenan, K. (1990). Priming effects in picture fragment completion: Support for the perceptual closure hypothesis. *Journal of Experimental Psychology: General, 119,* 276–296.

Snodgrass, J. G., & Hirshman, E. (1991). Theoretical explorations of the Bruner–Potter (1964) interference effect. *Journal of Memory and Language, 30,* 273–293.

Snodgrass, J. G., & Poster, M. (1992). Visual word recognition thresholds for screen-fragmented names of Snodgrass and Vanderwart pictures. *Behavior Research Methods, Instruments, and Computers, 24,* 1–15.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for naming agreement, familiarity, and visual complexity. *Journal of Experimental Psychology: Human Learning and Memory, 6,* 174–215.

Wyatt, D. F., & Campbell, D. T. (1951). On the liability of stereotype or hypothesis. *Journal of Abnormal and Social Psychology, 46,* 496–500.

Components of Information: A Framework for Memory Research

Joan Gay Snodgrass

New York University

and

Chun Rong Luo

Dartmouth University

Abstract

A components-of-information framework assumes different memory tasks have different item and associative information requirements. Levels of processing affects whether surface or semantic features of items are stored, while explicit retrieval instructions affect whether context-to-item associations are required. A comparison of perceptual identification and word fragment completion tests under levels-of-processing and explicit retrieval manipulations showed that the two manipulations were separable and that word fragment completion relies less on surface features than perceptual identification does.

Components of Information: A Framework for Memory Research

In this paper we present a new framework for understanding the pattern of dissociations and associations between implicit and explicit memory tasks (see Luo & Snodgrass, 1994, for a fuller development). This framework assumes that various components of information are stored during a study episode, and that memory tests vary in how useful such components are at test.

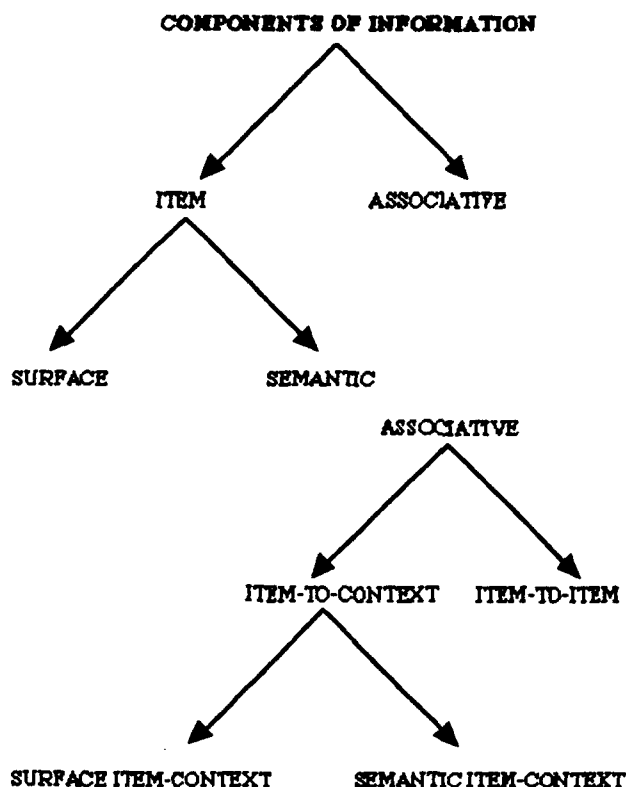These components of information are shown in Figure 1.

COMPONENTS OF INFORMATION

```
        COMPONENTS OF INFORMATION
              /            \
           ITEM          ASSOCIATIVE
          /    \
    SURFACE    SEMANTIC

              ASSOCIATIVE
              /         \
     ITEM-TO-CONTEXT   ITEM-TO-ITEM
        /        \
SURFACE ITEM-CONTEXT   SEMANTIC ITEM-CONTEXT
```

Figure 1. Proposed components of information.

Information is divided into item and associative components. Item information in turn is divided into surface information (information about the physical properties of an item), and semantic information (information about an item's meaning). Associative information in turn is divided into item-to-context associations, and item-to-item associations. For the present purposes, we also divide item-to-context associations into surface item-to-context and semantic item-to-context components.

We use three principles in attempting to use the framework to predict associations and dissociations among memory tests:

A. A study episode can store various components of information;

B. Memory tests vary in which components of information are most useful;

C. Performance will depend on the intersection of which components are stored and which are useful.

If a component of information is stored and it is useful, performance will be good; if a component is stored and it is not useful, or if a component is not stored and it is useful, performance will be poor.

As a corollary to Principle A, experimental manipulations during study (e.g., an orienting task) can affect which components are stored. As a corollary to Principle B, experimental manipulations during test (e.g., explicit retrieval instructions) can affect which components are retrieved.

Figure 2 illustrates how Principle A is applied when two orienting tasks at study are used, one which emphasizes semantic processing and one which emphasizes structural processing. The number of pluses for each component/orienting task combination indicates the amount of each component that is stored under each orienting task. A plus in parentheses means the item is unlikely to be stored, but may be. Only an ordinal scale is assumed.

Principle A. A study episode can store various components of information

| | Item information | | Associative information | | |
	Surface	Semantic	Sur Item-Context	Sem Item-Context	Item-Item
Orienting Tasks					
Semantic	+	+++	+	+++	+
Structural	+++	+	++	+	(+)

Figure 2. Application of Principle A to storage of components of information.

Under a semantic orienting task, more semantic than surface item and associative information will be stored; in contrast, under a structural orienting task, more surface than semantic item and associative information will be stored. In addition, more associative information in general will be stored under semantic than structural orienting tasks, particularly for item-to-item associative information.

Figure 3 shows how Principle B is applied to two implicit and two explicit memory tests. Figure 3 shows the degree to which each component of information is *useful* in the two implicit tasks of perceptual identification and fragment completion, and the two explicit tasks of recognition memory and recall. Here, the number of +'s represent the degree of *usefulness* of each component for the test. Again, only an ordinal scale is assumed.

The most important difference between implicit and explicit memory tests is that implicit tests rely primarily on item information, whereas explicit tests rely on both item and associative information. In an explicit test, the subject needs to determine whether this particular item occurred in a particular study context so he must retrieve the association between the item and its study context. In an implicit test, in contrast, the subject only needs to retrieve the item in response to a perceptual or conceptual cue, so that associative information is not

necessary. The pluses in parentheses indicate that sometimes associative information may be useful. An indication that associative information is useful is given by empirical findings that instructions to think back to the study episode is sometimes useful in implicit tests, particularly in fragment completion tests.

Principle B. Memory tests vary in the most useful components of information

	Item information		Associative information		
	Surface	Semantic	Sur Item-Context	Sem Item-Context	Item-Item
IMPLICIT TESTS					
Perceptual identification	+++	(+)	(+)	0	0
Word fragment completion	++	+	(+)	(+)	0
EXPLICIT TESTS					
Recognition	++	++	++	++	0
Free recall	(+)	+++	(+)	+++	+++

Figure 3 Application of Principle B to usefulness of components of information across tests.

Perhaps the most unique aspect of the present framework is the multiple roles that semantic information can play. A semantic encoding task will encourage the subject to encode both semantic item and semantic associative information. As shown in Figure 3, semantic associative information is very useful in explicit tests, but it is not useful in implicit tests. In addition, semantic item information is useful in explicit tests, and it can also be useful in implicit tests. This suggests that a semantic orienting task can increase the storage of both item and associative information, but only the associative information will be useful in explicit tests. Thus, a retrieval instruction at test should not affect performance on implicit tests (because only associative information can be recovered) whereas semantic encoding at study can affect performance on implicit tests (because more semantic item information will be stored).

The framework also can predict different patterns of performance across the two implicit tests of perceptual identification and fragment completion. Perceptual identification is almost entirely dependent upon surface item information, whereas fragment completion is also dependent upon semantic item information. This is consistent with findings that levels of processing may affect fragment completion performance but not perceptual identification performance. Also, the fragmentary item information is only available briefly during perceptual identification but is available longer during fragment completion. Therefore, subjects during a fragment completion trial may have time to retrieve semantic item information and even associative information.

The framework also permits differences in performance across the two explicit tasks of recognition and free recall. Recognition is dependent on both item and associative information. The item components correspond to the familiarity or fluency route of dual-route theories of recognition, whereas the associative components correspond to the retrieval route. Recognition depends upon both surface and semantic item information, whereas recall depends upon only semantic item information. In addition, recognition depends not at all on item-to-item associations, whereas recall depends heavily on item-to-item associations.

An Experimental Test of the Framework

In order to evaluate the usefulness of the components-of-information framework, we examined the effects of two variables — levels-of-processing at study and awareness of the study-test relationship at test — on the two implicit memory tests of perceptual identification and word fragment completion. According to the components-of-information framework, these two independent variables should have dissociable effects because levels-of-processing affects storage of semantic item information, whereas awareness affects retrieval of item-to-context associations. As far as we know, this is the only approach which makes this prediction. Thus the model predicts that the two processes can be dissociated in their effects.

Method

The subjects were 48 undergraduates from an introductory psychology course at NYU. Half received the explicit retrieval instruction and half did not. All subjects received both orienting conditions (graphemic or semantic) at study. For the graphemic condition, subjects were asked to write down a presented word in its reversed letter order on a piece of paper. For the semantic condition, subjects were asked to write down an associate of a presented word on a piece of paper. Trials in the two conditions were intermixed during the study phase. All subjects participated in two implicit memory tests: perceptual identification and word fragment completion. The two tests were intermixed during the test phase. Subjects were informed of the test type before each trial.

Awareness of the study-test relation was manipulated between subjects by different instructions. Subjects in the aware group were informed at the beginning of the test phase that half of the test items were from the study phase and they were instructed to think back to the study phase in identifying or completing the stimulus. During the test, subjects were also told of the actual status (old or new) of the to-be-identified or completed item before each trial. Subjects in the unaware group were not informed of the relation between the study phase and the test phase. They were simply instructed to identify briefly presented words or complete words with missing letters.

The words and their fragments were selected from Roediger et al. (1992, Experiment 2). Subjects were tested individually on an Apple Macintosh microcomputer. In the perceptual identification test, each word was exposed for 33 ms. and then masked, and subjects were asked to type the word onto the computer keyboard. In

the fragment completion test, each fragment was exposed for up to 12 s, and subjects were instructed to type the completion onto the computer keyboard.

Results

Priming scores (i.e., the difference in performance between old and new items) are shown in Figure 4 for each memory test, orienting condition, and awareness condition.
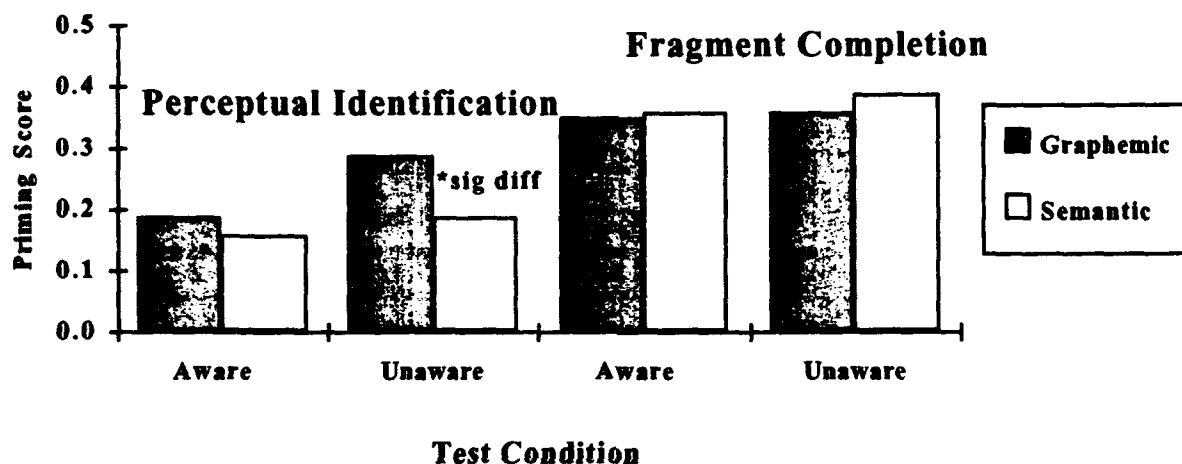

Figure 4. Results of the experiment.

Although more priming occurred in fragment completion than perceptual identification, all priming effects were significant, and in any case the differences in absolute priming between tests is irrelevant to our present purposes. Our major interest lies in the differential effects of the study and test manipulations on the two tests. With regard to the study manipulation, there was little or no levels-of-processing effect in word fragment completion, but a reversed levels-of-processing effect in perceptual identification. Identification performance was worse in the semantic processing condition than in the graphemic condition. With regard to the test manipulation, there was no effect of the aware manipulation on either test. Furthermore, the levels-of-processing effect was not enhanced by increasing awareness of the study-test relation; indeed, just the opposite appeared to occur.

An analysis of variance on the priming data in Figure 4 showed no main effect of retrieval awareness and no main effect of orienting condition. However, there was a significant interaction between test (perceptual identification vs. fragment completion) and orienting task (graphemic vs. semantic), $F(1,46) = 4.49$, $MS_e = .02$, $p < .05$. A simple effects test further showed that the levels-of-processing effect was reliable only in the perceptual identification task under the unaware condition.

Discussion

How can the components-of-information framework account for the results obtained in our experiment?

First, let us be clear that we view the framework as a heuristic device rather than as a full-fledged model. Therefore, we use experimental data to determine which components are stored and useful, and then use the model to see whether a reasonable pattern of results can be predicted.

In the present case, it is possible to combine the pattern of stored components in Figure 2 with the pattern of useful components in Figure 3 to provide an intersection of components which nicely predicts exactly that pattern of results observed in the present experiment. Figure 5 shows the intersection of Figures 2 and 3 for the two implicit memory tasks of perceptual identification and fragment completion, in an application of our third principle.

Principle C. Performance depends on the intersection of storage and usefulness

	Item information			Associative information	
	Surface	Semantic	Sur Item-Context	Sem Item-Context	Item-Item
A. COMPONENTS OF INFORMATION STORED UNDER THE TWO STUDY CONDITIONS					
Semantic	+	+++	+	+++	+
Structural	+++	+	++	+	(+)
B. COMPONENTS OF INFORMATION USEFUL UNDER THE TWO TEST CONDITIONS					
Perceptual identification	+++	(+)	(+)	0	0
Word Fragment completion	++	+	(+)	(+)	0
C. THE INTERSECTION OF STUDY & TEST					
Sem/PI	+	(+)	(+)	0	0
Struc/PI	+++	(+)	(+)	0	0
Sem/WFC	++	+	(+)	(+)	0
Struc/WFC	++	+	(+)	(+)	0

Figure 5. The intersection of components stored and components useful.

The intersection values have been determined by taking the minimum of the the amount stored and the degree of usefulness under the principle that if a component has not been stored, then it cannot contribute to performance, and if a component is not useful in a particular test but has been stored, then it still cannot contribute to performance.

The predictions made by the framework are very simple. First, it predicts that performance on perceptual identification will be better under the structural than the semantic orienting task, but that performance on word fragment completion will be equivalent under the two orienting conditions. Second, it predicts that instructions to think back to the study episode will have no effect because the explicit retrieval instruction will help in retrieval of the associative components, but the associative components are not useful (even though they have been stored).

As we have seen, we did obtain a reversed levels-of-processing effect in perceptual identification. This result is interpreted within the framework to indicate that the graphemic processing condition led to a much stronger memory representation of *surface features* of a word compared to the semantic processing condition. Because perceptual identification is more dependent upon surface item characteristics than fragment completion is, this led to a reversed levels-of-processing effect. The fact that levels of processing had no significant effect is also consistent with the components-of-information framework because surface information plays a predominant role in word fragment completion, although semantic information can also be useful sometimes. According to this framework, significant levels-of-processing effects can be obtained only when surface information is equally strong in the graphemic and semantic processing conditions but semantic information and context-semantic association are strong only in the semantic processing condition. The inconsistent results in the literature therefore may be attributable to the specific experimental conditions and possible contributions of explicit memory in these studies.

The finding of no significant role of explicit memory in implicit tests is new and contrary to the suggestions and expectations of many memory theorists. Many researchers have suggested that the observed levels-of-processing effect in implicit memory tests may be produced by explicit memory retrieval at test (e.g., Schacter et al., 1989; Squire et al., 1987). This interpretation would predict that the levels-of-processing effect should be enhanced by explicit retrieval instructions. Our finding seems to suggest that explicit retrieval processes act not to enhance but rather to reduce the levels-of-processing effect somewhat, although the results did not reach significance.

In summary, the finding of a reversed levels-of-processing effect in perceptual identification and the absence of a levels-of-processing effect in word fragment completion supports the proposal of the components-of-information model that semantic information does not play a role in perceptual identification but that it may play some role in word fragment completion. The finding of no significant effect of explicit retrieval processes on the two implicit memory tests also supports the model. In addition, the finding of a reduced levels-of-processing effect on perceptual identification under the aware condition suggests that subjects in the aware group may not have made full use of surface information in identifying those items studied under the graphemic processing condition because they may occasionally have been induced to use context-to-item association which is much less

useful than the surface information in the perceptual identification task. The results of this experiment thus support the components-of-information framework.

References

Luo, C. R., & Snodgrass, J. G. (1994). Components of information: A framework for implicit and explicit memory research. Under review.

Roediger, H. L., Weldon, M. S., Stadler, M. L., & Riegler, G. L. (1992). Direct comparison of two implicit memory tests: Word fragment and word stem completion. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 18*, 1251-1269.

Schacter, D. L., Bowers, J., & Booker, J. (1989). Intention, awareness and implicit memory: The retrieval intentionality criterion. In S. Lewandowsky, J. C. Dunn, & K, Kirsner (Eds.), *Implicit memory: Theoretical issues*. (pp. 47-65). Hillsdale, NJ:Erlbaum.

Squire, L., Shimamura, A. P., & Graf, P. (1987). Strength and duration of priming effects in normal subjects and amnesic patients. *Neuropsychologia, 16*, 195-210.