INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6" x 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

U·M·I

University Microfilms International
A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA
313/761-4700 800/521-0600

Order Number 9136070

Specificity of priming in nonverbal tests

Srinivas, Kavitha, Ph.D.

Rice University, 1991

U·M·I
300 N. Zeeb Rd.
Ann Arbor, MI 48106

RICE UNIVERSITY
SPECIFICITY OF PRIMING
IN NONVERBAL TESTS

by

KAVITHA SRINIVAS

A THESIS SUBMITTED
IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE DEGREE

DOCTOR OF PHILOSOPHY

APPROVED, THESIS COMMITTEE

Dr. Henry L. Roediger, III,
Professor of Psychology,
Chair

Dr. James R. Pomerantz,
Professor of Psychology

Dr. Michael J. Watkins,
Professor of Psychology

Dr. Richard E. Grandy
Professor of Philosophy

Houston, Texas

April, 1991

SPECIFICITY OF PRIMING IN NONVERBAL TESTS

Kavitha Srinivas

Abstract

Priming is a measure of memory where the influence of studied events is assessed indirectly by a later disguised test (e.g., the effect of studying windmill on the probability of solving the anagram lindwilm). Priming is typically sensitive to the perceptual aspects of studied items (e.g., little priming might be obtained from studying a picture of windmill). This property suggests that priming reflects perceptual operations involved in the identification of words and objects. An investigation of perceptual priming can therefore provide clues about the perception of words and objects.

In five experiments, perceptual priming was assessed in picture identification tasks by varying the perceptual attributes of study and test objects. Experiment 1 investigated the effects of priming on the identification of briefly presented fragmented pictures as a function of receiving the intact pictures, reading the names of pictures, or generating the names at study. Substantial priming was obtained from pictures compared to words, which showed negligible priming in both conditions. Experiment 2 investigated priming on the fragment naming task as a function of receiving the same fragment, an intact picture, or a different fragment of the same object at study. Same fragments showed the greatest priming; less priming was

obtained from intact versions or different fragments. In Experiments 3 and 4, priming on the identification of briefly presented pictures was examined when study and test objects were different viewing angles of the same object. Same study-test views showed the greatest priming. Priming across different views was greater when subjects studied an unusual view of the object and were tested on a usual view, compared to when subjects studied a usual view and were tested on the unusual view. Experiment 5 indicated that priming across viewing angles of the object was specific to obtaining pictorial information about the object: no priming was observed when subjects studied the names of the test objects. Together, these data support theories of memory and perception that assume that priming primarily involves perceptual operations that are specific to studied events (such as the fragment or view presented at study) rather than reflecting abstract representations of the studied events.

Acknowledgments

I would like to express my gratitude to Dr. Henry L. Roediger, Dr. Michael J. Watkins, Dr. James R. Pomerantz, Dr. Richard Grandy, and Dr. David B. Mitchell for their invaluable guidance and their comments on this dissertation. My special thanks to Dr. Roediger for serving as my academic advisor, friend, and counselor. I would also like to thank Dr. Watkins and Dr. Pomerantz for always making the time to discuss the work reported in this dissertation. I would like to thank Dr. Branch Coslett for providing the materials that helped me build my own set of materials, and Dr. Endel Tulving and Dr. Irving Biederman for useful discussions about the project. Finally, I would like to thank Vasanth and Suparna for serving as my programming consultants, research assistants and friends all rolled in one. It was an unenviable role, and they were perfect.

Table Of Contents

Abstract	II
Acknowledgments	IV
Table of Contents	V
List of Tables and Figures	VII
Introduction	1
Properties of Nonverbal Priming	3
Theories of Priming	9
Specificity in Perceptual Priming	12
Word-Picture Priming	12
Picture-Picture Priming	21
Size	21
Reflection	22
Transfer across different exemplars	23
Transfer across different fragments	25
Transfer across different orientations	33
Transfer across different viewpoints	35
The Present Experiments	38
Experiment 1	39
Pilot Study 1	44
Experiment 2	64
Experiment 3	74
Pilot Study 2	77
Experiment 4	91
Experiment 5	101

	VI
General Discussion	106
Summary of the Results	106
Theoretical Accounts of Priming	109
Footnotes	116
References	117
Appendix A	127
Appendix B	135
Appendix C	139
Appendix D	147

List Of Tables and Figures

Table 1.	Summary of studies investigating priming on picture priming tasks as a function of studying words or pictures.....	16
Figure 1.	The original training figure, and the reduced or supplemented fragments used in Rock's (1975) experiments.....	27
Figure 2.	Complementary fragments with alternate lines and vertices deletions in Biederman and Cooper's (in press) experiments.....	30
Figure 3.	Complementary fragments with alternate object components deletions in Biederman and Cooper's (in press) experiments.....	31
Figure 4.	Recoverable and nonrecoverable fragments of a cup.....	41
Table 2.	Proportion of picture fragments correctly identified as a function of fragment type and display time (in ms) in Pilot Study 1.....	47
Table 3.	Proportion of recoverable and nonrecoverable fragments correctly identified as a function of Study Group, Study Status and Fragment Type in Experiment 1.....	56
Table 4.	Proportion of recoverable and nonrecoverable fragments correctly identified as a function of Study Condition and Fragment Type in Experiment 2.....	67
Table 5.	Differences in z scores for the Usual and Unusual Views selected in Pilot Study 2.....	81
Table 6.	Proportion of objects correctly identified as a function of Study and Test conditions in Experiment 3.....	85
Table 7.	Proportion of objects correctly identified as a function of Study and Test conditions in Experiment 4.....	92

Table 8. Proportion of objects correctly identified as a function of Study and Test conditions in Experiment 5.....	103
---	-----

Introduction

Traditional measures of memory such as free recall, cued recall and recognition require people to recollect a previously studied event or episode. In modern parlance, these tests are believed to tap explicit memory (Schacter, 1987). In recent years, there has been burgeoning interest in a different class of tests that are believed to tap implicit memory. These tests do not require the conscious recollection of a prior study episode; nevertheless, performance on these tests is influenced by the unintentional retrieval of the studied information (Schacter, Delaney, & Merikle, 1990a). The basic paradigm used in implicit memory experiments is as follows. In the study phase, subjects are presented with a set of items (e.g., camera) under intentional or incidental study conditions. At test, subjects are required to perform an ostensibly unrelated task, such as solving word fragments (e.g., c-m--a) with the first response to come to mind. Some of the word fragments can be completed with the previously studied items, others cannot. The extent to which test performance benefits (in terms of accuracy or response time) from prior study is called priming, and this is a measure of implicit memory. Although the term "priming" has been used to describe benefits in several paradigms, the usage of the term in this dissertation is restricted to the case outlined above.

There has been a great deal of research done on implicit memory, but most previous studies have focussed on priming with verbal materials. As Schacter et al. (1990a) pointed out, there are good reasons to extend this work to nonverbal materials. To summarize their arguments briefly: (1) We need a broad database in order to establish the critical properties of implicit memory, because theoretical explanations of implicit memory that are based on data only from verbal materials may be misled by specific properties of verbal stimuli; (2) research on nonverbal materials may serve as a link between the fields of memory and perception, and (3) since priming is believed to be phylogenetically primitive (relative to explicit memory), it may be useful to study the nature of nonverbal priming.

Schacter et al. (1990a) have reviewed the existing research on nonverbal priming effects. The purpose of this Introduction is to delineate the main issues and findings in nonverbal priming research, with special reference to the issue of specificity in nonverbal priming. After this review, some critical issues are explored empirically.

Nonverbal priming has been reported on a wide variety of tasks. To give just a few examples, it has been observed with tasks (a) requiring the naming of pictures (e.g., Carroll, Byrne & Kirsner, 1985), (b) requiring identification of degraded pictures (e.g., Warrington & Weiskrantz, 1968), (c) requiring the identification of

briefly presented pictures (e.g., Warren & Morton, 1982), (d) requiring a decision as to whether or not a given object is "structurally possible" (e.g., Schacter, L. Cooper & Delaney, 1990b) or (e) whether or not a given object is mirror reversed (Tarr & Pinker, 1989), and (f) requiring the identification of an anomalous object in a common scene (Warrington & Weiskrantz, 1978).

Most of these tasks appear to be primarily perceptual in nature; they seem to require the resolution of a perceptually degraded item (e.g., identification of degraded pictures, or briefly presented pictures) or a response to perceptual aspects of a stimulus (e.g., is an object "structurally possible" or not, or mirror-reversed or not). What are the most salient properties of priming in these tests?

Properties of Nonverbal Priming

First, like verbal priming, nonverbal priming appears to be insensitive to subject variables such as age and brain damage. For instance, 3-, 5- and 7-year-old children showed equal amounts of priming on a picture naming test even when explicit memory test performance improved with age (e.g., Parkin & Streete, 1988). Similarly, equivalent priming levels were found on a picture naming task for old and young adults although older subjects were significantly impaired on explicit measures of memory (Mitchell, 1989). Normal levels of nonverbal priming have also been reported in

Korsakoff amnesic patients (e.g., Crovitz, Harvey & McClanahan, 1981; Schneider, 1912, cited in Parkin, 1982; Talland, 1965; Warrington & Weiskrantz, 1968), and in patients with Huntington's disease (Heindel, Salmon & Butters, 1990) although both subject populations showed severe impairment in explicit memory performance.

Interestingly, there appears to be a subject population that is impaired on priming relative to normals and Korsakoff patients. Heindel et al. reported both impaired priming and impaired explicit memory in patients with dementia of the Alzheimer's type. Priming was measured on identification of fragmented pictures. This impairment in priming was observed even when the patients' performance on a simple naming task was equivalent to those of control subjects.

Second, like some types of verbal priming, nonverbal priming appears to last a long time. In an early study, Schneider (1912, cited in Parkin, 1982) found that amnesics showed savings in identifying previously presented fragmented pictures at retention intervals of four months. Using a similar task with normal subjects, Leeper (1935) found that training on a set of fragmented pictures facilitated subsequent identification of the same pictures 3 weeks after the initial study session. More recently, Mitchell and Brown (1988) reported that previously named pictures facilitated later naming of the same pictures, and this priming remained fairly stable across 1 to 6 weeks.

Interestingly, recognition memory for these pictures decreased sharply over the same period.

Third, priming has been reported with a wide variety of familiar and unfamiliar nonverbal stimuli. Priming has been observed with simple line drawing pictures and complex photographic pictures of objects (e.g., MacLeod, 1988), faces (Bruce & Valentine, 1985), novel geometrical shapes (e.g., Kunst-Wilson & Zajonc, 1980), novel dot patterns (Musen & Treisman, 1990), novel objects (e.g., Kroll & Potter, 1984), and novel melodies (Johnson, Kim & Risse, 1985). Although the occurrence of priming with unfamiliar stimuli suggests that priming occurs even when there are "no pre-existing representations" of the primed stimuli, there are some results that do not support this conclusion.

For instance, Young, McWeeny, Hay and Ellis (1986) found no priming for unfamiliar faces on a familiarity decision task (subjects had to categorize faces as belonging to known or unknown people) or on a semantic decision task (subjects had to decide whether the face was a politician's). Similarly, Bentin and Moscovitch (1988) found no evidence for priming with unfamiliar faces on a face decision task (subjects had to discriminate faces from nonfaces). These data suggest that unfamiliar faces do not show priming effects, although the reasons for this puzzling result are not clear.

Another inconsistent result has been cited in the

Schacter et al. (1990a) paper. Kersteen-Tucker (1989; cited in Schacter et al., 1990a) investigated priming effects for novel polygons in a task where subjects had to decide whether each of a series of polygons were symmetrical or asymmetrical. Target polygons were repeated at lags of 0, 1, 4, or 8 intervening items. Facilitation for repeated polygons occurred only when they were symmetrical, but not when they were asymmetrical.

In similar vein, Schacter et al. (1990b) found no priming for novel structurally impossible objects (objects that cannot exist in a three dimensional form) on a task that required subjects to decide whether the target item was a possible object or not. Interestingly, recognition memory for structurally impossible objects was only slightly less accurate than recognition memory for possible objects. It seems puzzling that subjects showed no priming for impossible objects when they could recognize the same objects on a recognition memory test. According to Schacter et al., recognition of impossible objects occurred because it could be based on certain distinctive parts of these objects; priming on the impossible objects did not occur because priming is based on global structural descriptions of these objects. Although this explanation is plausible, it is unclear why priming does not occur with unfamiliar faces or asymmetrical polygons, because global "structural descriptions" of both are feasible.

Fourth, like verbal priming, nonverbal priming does not appear to be affected by manipulations of elaborative processing at study. For instance, Carroll et al., (1985) instructed subjects either to search for a cross in the target picture ("shallow" encoding condition) or to classify the picture as animate or inanimate ("deep" encoding condition). Half the subjects were then given a recognition test, and the other half, a naming test. While the recognition data showed an effect of orienting task (deeper encoding leading to better recognition), naming showed the effects of stimulus repetition, but no effects of orienting task. Carroll et. al replicated this result with a group of 7-year-old subjects using a task that required identification of briefly presented pictures.

Schacter et al.'s (1990b) data support the same conclusion. When subjects were asked to decide whether an object was structurally possible, they showed equal priming following elaborative orienting tasks ("think of something similar to this drawing") and "shallow" orienting tasks ("does this drawing face left or right?"). Recognition memory showed the usual benefit following elaborative encoding.

Similarly, Musen (1989) investigated the effects of varying orienting tasks at study on priming for novel line patterns. The patterns were created by randomly connecting dots in a 3 X 3 matrix. Orienting task was manipulated at

study by having subjects write down verbal descriptions of the line patterns, "generate" line patterns using rules provided by the experimenter, or count the number of horizontal and vertical lines in the pattern. Priming was measured on a task that required subjects to identify these briefly presented line patterns. The data suggested no effects of orienting task on the identification of these line patterns. However, better recognition memory was found when subjects wrote down verbal descriptions of the stimuli. Together, these results suggest that nonverbal priming, at least in the tests studied, shows no effects of elaborative encoding.

Fifth, priming appears to be sensitive to the structural properties of studied objects. This was alluded to earlier when it was pointed out that "impossible" objects did not show any priming on object decision tasks (Schacter et al., 1990a, 1990b). In the same experiments, priming was also found for possible objects only when subjects were forced to pay attention to the global structure of the objects at study, indicating that priming occurred only when a structural description of the object could be constructed (or had been constructed) at study.

Finally, priming appears to be very specific to the perceptual aspects of the studied material. Since this is the central issue in this thesis, a more elaborate review will be attempted here. Before the review, the questions of

why specificity in priming is theoretically important, and what is to be gained by studying this property, are discussed briefly.

Theories of Priming

Three properties discussed in the earlier section are particularly important in understanding the nature of nonverbal priming: a) priming is not affected by elaborative or meaningful processing of the studied material, b) priming is sensitive to the structural properties of the studied material, and c) priming is sensitive to a match in perceptual features between studied and tested material. These findings have led many theorists to suggest that priming reflects the perceptual operations involved in the perception of words and objects (e.g., Biederman & Cooper, 1990; Jacoby, 1983; Kolers & Roediger, 1984; Roediger & Blaxton, 1987; Schacter, 1990; Tulving & Schacter, 1990). Although this premise is a common starting point for most theories, they also differ in important ways.

According to the procedural account, perceptual priming reflects the perceptual operations or procedures involved in the perception of objects and words (Jacoby, Baker, & Brooks, 1989; Kolers & Roediger, 1984; Roediger, Weldon, & Challis, 1989). These operations are assumed to be specific to the precise operations performed at study (e.g., priming on a task requiring the identification of geometrically transformed text is specific to the orientation of the

studied text, as well as to the exact text that was presented at study). In other words, by a procedural account, a single episodic representation integrating perceptual as well as meaning-based information is created whenever words or objects are perceived. Perceptual priming is assumed to tap the perceptual aspects of this representation while explicit measures of memory (such as recall or recognition) are assumed to tap the conceptual or meaning-based aspects of the representation (Roediger, et al. 1989)¹.

On the other hand, by the multiple memory systems account, priming is assumed to be mediated by a set of representations that are different from those mediating performance on explicit measures of memory (Schacter, 1990; Tulving & Schacter, 1990). The representations mediating priming are assumed to be abstract structural descriptions of objects and words that do not faithfully represent all perceptual aspects of studied items.

Interestingly, the same assumptions about integrated versus abstract representations differentiate different theories of object recognition. According to one class of theories of object recognition, information about size, orientation, location or shape of the object is integrated into a single representation whenever an object is perceived. By this account, recognition of a new image of the same object at a different size, position or orientation

is achieved through the transformation of new input image so that it corresponds to existing representations (Lowe, 1987; Tarr & Pinker, 1989; Ullman, 1989). A second class of theories of object recognition assume that objects are represented in a single abstract form that is coded independently of the size, position or orientation of the perceived object (e.g., Biederman & Cooper, 1990; Marr & Nishihara, 1978; Sutherland, 1968).

In short, assumptions about integrated versus abstract representations differentiate both theories of memory and object recognition. These assumptions are also critical in differentiating the theories empirically. By the integrated representations account, greatest priming should occur when perceptual aspects of the item presented the second time are identical to the perceptual aspects of the first item. Much less priming should occur when the perceptual aspects of the second item are different from the perceptual aspects of the first item. By the abstract representations account, priming should not be affected if the perceptual aspects of the item presented a second time are different from the perceptual aspects of the item presented the first time, at least for certain perceptual aspects (such as size, location, and orientation). An investigation of the perceptual dimensions to which priming is sensitive is therefore crucial to an understanding of memory and perception.

The preceding discussion is an over-simplification of the different theories of memory and perception; theories that share the same assumptions about the nature of perceptual representations differ in other important ways. However, this distinction provides a broad framework within which the issue of specificity in perceptual priming is investigated in this dissertation.

Specificity in Perceptual Priming

In this section, evidence for specificity on picture priming tasks is reviewed in two separate parts. The first deals with priming between stimuli that are very different on the perceptual dimension (priming from words to pictures), and the second deals with priming between stimuli that are similar on the broad perceptual dimension (priming from pictures to other pictures), but differ in specific visual features.

Word-Picture Priming

A common finding on verbal perceptual priming tests (such as those requiring the completion of fragmented words or identification of brief presentations of words) is that priming is sensitive to the perceptual form in which the study item was presented at test. Maximal transfer is obtained when the study and test items match on perceptual features than when they do not (e.g., Roediger & Weldon, 1987; Srinivas & Roediger, 1990; Winnick & Daniel, 1970). Thus, in the verbal domain, when study and test items share

the same form (words as opposed to pictures), the same modality (auditory or visual), or the same typography, greater priming is observed than when they do not (see Roediger & Blaxton, 1987 for a review). The amount of priming obtained when study and test modes do not match appears to be a function of perceptual similarity between study and test items. For example, greater priming is observed when study and test words are in different typography than when they are in different modality. This conclusion appears to be true (in general) for nonverbal stimuli as well. The following paragraphs review this research; priming data for the described experiments appears in Table 1 on pages 16 and 17.

Durso and Johnson (1979) studied the effects of presenting a word or a pictorial representation of the same concept upon subsequent naming or categorization ("Is it natural or manmade?") of pictures or words. Repeated items were separated by 25 or 50 items. On both tasks, the greatest facilitation in terms of faster naming time occurred when study and test stimuli shared the same form of presentation (word-word or picture-picture) relative to when form was varied between study and test (word-picture or picture-word). In the case when the form was varied between study and test, words facilitated subsequent processing of pictures but pictures did not facilitate the subsequent processing of words. Similarly, Lachman and Lachman (1980)

reported that studying words had facilitating effects on a subsequent picture naming task, although not as much as study of the pictures themselves.

However, Warren and Morton (1982) found little evidence for transfer from words to pictures on a different task. They presented subjects with a mixed list of pictures and words, followed by a test phase where subjects were required to identify briefly presented pictures by the ascending method of limits. Priming was measured in terms of the decrease in exposure duration needed to identify the pictures. Warren and Morton (1982) found significant facilitation effects on the tachistoscopic recognition task from prior exposure to pictures, but no facilitation from exposure to words.

Using the same paradigm, Bruce and Valentine (1985) investigated priming in the identification of briefly presented celebrity faces as a function of the mode of presentation at study (faces or names of celebrities). The results indicated significant facilitation from studying the faces of celebrities, and a smaller but significant effect from studying names of the celebrities. Since these results differed from the findings of Warren and Morton (1982), Bruce and Valentine attempted a replication of their findings with a slightly different task. Now, priming was measured by the time taken by subjects to decide whether the faces (which were presented supra-threshold) were familiar

to them. With the new task, Bruce and Valentine (1985) found that the small crossmodal priming effect they had observed (names to faces) disappeared. Ellis, Young, Flude and Hay (1987) have replicated the latter result with the same familiarity task.

Kroll and Potter (1984) presented subjects with a mixed sequence of words, pseudo-words, and pictures of objects and nonobjects. Subjects were asked to decide whether the objects and words were real or not. Some of the pictures and words were repeated in the same mode of presentation as the first occurrence (picture-picture or word-word), and some were repeated in another mode (picture-word or word-picture). The lag between repeated items was 3 or 10 items. Kroll & Potter (1984) found significant facilitation effects when the mode of presentation was the same between the first and second occurrence for both pictures and words. When the mode of presentation was different, a small priming effect was found for words preceded by pictures, but no effect was found for pictures preceded by words.

Table 1

Summary of studies investigating priming on picture priming tasks as a function of studying words or pictures.

Investigators	Design	Task	Word- Picture	Picture- Picture
Durso & Johnson (1979)	within- subject	Naming Categorizing	105 ms 18 ms	170 ms 38 ms
Lachman & Lachman (1980)	between- subject	Naming	0.8 word/sec	2.0* word/sec
Warren & Morton (1982)	within- subject	Tachistoscopic identification	0.3 ms	8.1 ms
Kroll & Potter (1984)	within- subject	Reality Decision	10 ms	30 ms
Bruce & Valentine (1985), Exp 1	within- subject	Tachistoscopic identification	5.3 ms	14.9 ms
Bruce & Valentine (1985), Exp 2	within- subject	Face familiarity	32 ms	139 ms
Biederman (1987)	between- subject	Fragment identification	0%	15%

Table 1

Summary of studies investigating priming on picture priming tasks as a function of studying words or pictures (contd.)

Investigators	Design	Task	Word- Picture	Picture- Picture
Weldon & Roediger (1987)	within-subject	Fragment Completion	3%	17%
Ellis, Young Flude & Hay (1987)	within-subject	Face familiarity	-5 ms	71 ms
Brown, Neblett Jones & Mitchell (in press), Exp 2	within-subject	Picture naming	23 ms	151.5 ms
Brown et al. Exp 1	between-subject	Picture naming	112 ms	111.5 ms

* Priming is reported as a reciprocal of reaction time to name the object.

Weldon & Roediger (1987) also reported greater priming from studying pictures than words on a task requiring identification of fragmented pictures. However, compared to nonstudied items, words showed small (but nonsignificant) priming effects on the picture fragment identification task. On the other hand, Biederman's (1987) data suggested little or no transfer from studying words on a tachistoscopic identification task with fragmented pictures. Significant priming was observed from studying pictures on the same picture fragment identification task.

A broad conclusion that may be drawn from a review of these studies is that nonverbal priming tests (like verbal priming tests) show specificity in priming effects; i.e., they show greater priming effects when study and test forms match than when they do not. The evidence for transfer across different forms (e.g., words to pictures) seems to be inconsistent, and even when present, is smaller.

Two recent studies, however, argue against this conclusion on different fronts. Brown, Neblett, Jones, and Mitchell (in press) found that this specificity in priming does not occur when study modes are manipulated between-subjects on picture naming and word naming tasks, but it does occur when study modes are manipulated within-subjects. Brown et al. (in press) argued that previous findings of specificity in priming between pictures and words are

products of within-subject designs. They claim that in within-subject designs, subjects' attention is specifically drawn to the perceptual aspects of the prime, and hence, specificity is observed on a later task. In between-subject designs, subjects do not attend to the perceptual aspects of the studied items. Instead, they simply respond at a lexical level to both word and picture stimuli, and this subsequently facilitates a later naming response for pictures and words.

At this point, it is unclear whether the Brown et al. findings extend to other picture priming tasks or even to the same task. For instance, greater priming was found from studying pictures relative to studying words on a picture naming task (Lachman & Lachman, 1980) and a picture fragment identification task (Biederman, 1987) even when study conditions were manipulated between-subjects. In fact, in Biederman's (1987) experiment, studying words did not result in any benefit in performance on the picture fragment task relative to the nonstudied baseline. These results contradict the conclusions of Brown et al. (in press), but obviously need replication.

A second line of argument against the conclusion of specificity in nonverbal priming has been taken by Hirshman, Snodgrass, Mindes and Feenan (1990). In several experiments, Hirshman et al. reported that reading words at

study did not facilitate performance on the picture fragment identification task, but generating words from sentences did (e.g., New York City's nickname is the big a_____). This result was observed even when the study manipulations in question (generate vs. read) were varied between-subjects. In the light of these findings, Hirshman et al. suggest that most previous studies investigating word-picture transfer on picture priming tasks have not shown transfer because they required subjects to simply read the words at study. In order to find transfer between words and pictures, presumably one has to process the word meaningfully. This result is more troubling than the Brown et al. results because it suggests that priming is sensitive to both perceptual and conceptual aspects of studied items, a conclusion that is not consistent with the claim that priming is reflecting the operations of a presemantic perceptual system. However, Hirshman et al. never compared priming from generating words at study relative to priming from pictures at study. This comparison is obviously crucial for a further evaluation of this result; perhaps enhanced priming from generated words is still greater relative to that from pictures.

To summarize the literature on priming from words to pictures, most studies indicate that performance on picture priming tests is greatly facilitated when primed by stimuli

in the same perceptual form (pictures) than those in a different perceptual form (words). However, two recent studies suggest that this perceptual specificity in priming is specific to a particular experimental design (Brown et al., in press) and to a specific study condition (Hirshman, et al., 1990). Experiment 1 in this dissertation will examine these claims. However, the evidence for specificity in picture-picture will first be reviewed.

Picture-Picture Priming

In this section, the evidence for specificity in picture-picture priming when study and test stimuli vary on a variety of perceptual dimensions is reviewed. How is priming between pictures affected, for instance, when study and test items are of a different size, different left-right orientation, different exemplars of the same object (two different drawings of a clown), different fragments of the same picture, the same object in different orientations (along the same plane), or different viewpoints of the same object rotated in depth? These issues are discussed separately.

Size. Biederman and E. Cooper (1990) explored the issue of whether varying the size of the distal stimulus between study and test affects the amount of priming observed on a picture naming task. They found that naming times on the picture naming task did not vary as a function

of whether the test stimulus was the same size as the studied stimulus, or a different size. On the other hand, recognition memory for the same pictures was sensitive to the size differences between study and test. Recognition performance on the studied objects was best when the same size was maintained between study and test relative to when size was changed between study and test.

L. Cooper, Schacter, Ballesteros and Moore (1990) also found no effects of varying size between studied and tested objects in priming on an object decision task. Conversely, recognition memory for the same objects was affected by a change in size between study and test. Recognition memory for items studied in the same size was better than items presented in different sizes at test. These results indicate that nonverbal priming is not sensitive to the size of a given object over intermediate ranges, although this dimension does affect recognition memory, even for other pictorial materials such as faces (Kolers, Duchnicky, & Sundstroem, 1985). Interestingly, changes in size of the stimulus between study and test has no effect on recognition for verbal materials (Kolers et al., 1985).

Reflection. The term reflection refers to the left-right orientation of the object. When subjects are primed with a particular left-right orientation of the object, and then tested on a picture naming task with the same objects

in the same orientation or in a mirror-image reflection no differences are observed (Biederman & E. Cooper, in press). Similar results have been reported by L. Cooper et al. (1990) on a task that required subjects to decide whether a given object was structurally possible or impossible (the object decision task). Studying the object in one left-right orientation transferred almost as well as studying a mirror image reflection of the object. However, a small effect of switching left-right orientation between study and test objects was also observed. These results suggest that priming is not particularly sensitive to the left-right orientation of the object. Recognition performance was once again facilitated by maintaining the same orientation between study and test objects.

Transfer across different exemplars. Some of the studies already discussed in the Word-Picture priming section are relevant here. Warren and Morton (1982), for instance, tested subjects on a picture identification task when the tested pictures were identical to the ones they had studied (identical condition) or were different exemplars of the same objects (same name-different picture condition). They found the greatest transfer in the identical condition, less transfer in the different exemplars condition, and no transfer when just the names of the pictures were presented at study. Warren and Morton (1982) argued that priming in

the different picture condition could not be mediated by the amount of featural overlap between the studied and tested picture, because a post hoc analysis showed no correlation between the size of the priming effect obtained in their different picture condition and the rated similarity between study and test presentations. Bruce and Valentine (1985) also reported post hoc analyses of priming from a face familiarity decision task that supported the conclusion that the size of the priming effect was not correlated with the rated similarity between study and test items. However, neither of the two studies explicitly manipulated the similarity of the "different" pictures to the studied pictures.

When Ellis, Young, Flude and Hay (1987) manipulated the degree of similarity between photographs of faces presented at study or test, they came to a different conclusion. They measured priming on a face familiarity task as a function of three study conditions. In the identical condition, a photograph that was identical to the tested photograph was presented; in the similar condition, a photograph that was rated by observers to be similar to the tested item was presented; and in the dissimilar condition, a photograph rated by observers to be relatively dissimilar to the tested item was presented. The results indicated the greatest benefit in response time when studied photographs were

identical to the test photographs, slightly less facilitation when studied photographs were similar to the test photographs, and the least (although still significant) facilitation when studied photographs were dissimilar from the test photographs. Ellis et al. concluded from these experiments that priming is dependent on the degree of visual similarity between the studied and tested exemplars. The greater the degree of similarity between studied and tested exemplars, the greater the priming.

Transfer across different fragments. In some studies, differential priming has been observed when different fragmented versions of the same picture are presented between study and test. For instance, Gollin (1960) found that initial "training" on a fragmented version of a picture produced greater savings in later identification of the fragment than did exposure to the intact picture. Similarly, Jacoby, Baker and Brooks (1989) found that experience with degraded pictures produced greater transfer in the identification of fragmented pictures than did exposure to intact pictures. Snodgrass and Feenan (1990) have also replicated these findings. They found that priming was greater when the same picture fragment was used at study and test than when different fragments were used, although significant priming occurred even in the different fragment condition.

What mediates priming between different fragments of the same object? Rock (1975) reported an interesting experiment that suggested that priming between different fragments is a function of visual similarity between the fragments. In Rock's (1975) experiment subjects were trained on a fragmented figure (see the top of Figure 1), and then tested on the same figure fragmented differently. In one version, subjects saw a figure more degraded than the original version so that parts of each fragment were eliminated (see bottom left of Figure 1). However, this version was still similar to the studied fragmented figure. In the second version (bottom right), the studied figure was supplemented so that it was a better representation of the object than was the studied figure. However, this second version was not as similar to the studied figure as was the first version because component fragments in the studied figure were joined together, or otherwise no longer retained their identities.

When subjects were "trained" on the original figure, and then tested on the reduced or supplemented fragmented versions, they showed better performance in the reduced version compared to the supplemented version.

Figure 1

The original training figure, and the reduced or supplemented fragments used in Rock's (1975) experiments.

Original Training Figure

Reduced Fragment

Supplemented Fragment

This finding is impressive because a control experiment indicated better identification performance on the supplemented figures compared to the reduced figures when they were not biased by training on the fragments.

These data suggest that a) priming is greatest when the same fragment is presented both at study and test, and b) priming between different fragments is a function of visual similarity between the fragments. Two recent studies suggest other conclusions. The first suggests that the nature of the fragment presented at study also determines the amount of priming that will be observed. Snodgrass and Feenan (1990) compared performance on a fragment completion task as a function of studying three fragment types that varied in the amount of contour that was deleted from them. In one condition, subjects studied fragments that were very difficult to resolve perceptually (Level 1-- most difficult fragments). In the second condition, subjects studied fragments that were easier to resolve perceptually (Level 4--medium difficulty fragments). In the third condition, subjects studied fragments that were almost intact and required little effortful perceptual processing (Level 7--almost complete fragments). Subjects tried to identify the fragments in the study phase. If they failed to identify the fragments, they were given the names of the fragments.

At test, subjects were asked to identify the difficult

fragments (Level 1 fragments). Across several experiments, priming on completing the most difficult fragments (Level 1 fragments) was facilitated most by training on the medium difficulty fragments (Level 4 fragments) relative to the difficult fragments (Level 1 fragments), or the almost intact fragments (Level 7 fragments). These data suggested that completion of the Level 1 fragments was facilitated best not by training on the same level of perceptual difficulty (Level 1 fragments), but by a level that was easier (Level 4 fragments) but not too easy (Level 7 fragments). Snodgrass and Feenan (1990) explained this result by suggesting that the medium difficulty fragments (Level 4) allowed subjects to experience "perceptual closure" on the fragments while the difficult or almost intact fragments did not. Hence, studying the medium difficulty fragments produced greater priming than studying fragments that were of the same level of difficulty as the tested fragments. However, they provided no a priori method to determine the fragments that would be most effective for perceptual closure, nor did they provide an explanation of why fragments that are almost complete do not lend themselves to perceptual closure.

Figure 2

Complementary fragments with alternate lines and vertices deletions in Biederman and Cooper's (in press) experiments.

Intact Version

Complementary fragments with alternate lines and vertices deletions.

Figure 3

Complementary fragments with alternate object components
deletions in Biederman and Cooper's (in press) experiments.

Intact version

Complementary fragments with alternate object component
deletions.

The second study suggests that priming is not necessarily specific to the fragment presented at study. In Biederman and E. Cooper's (in press) experiments, priming was either specific to the fragment presented at study, or not specific to the fragment presented at study depending on the method used to construct the fragments. One set of fragments was created by deleting alternate lines and vertices in the picture (see Figure 2 for an example). A second set of fragments was created by deleting alternate convex components (or object parts) in the picture (see Figure 3).

Priming was measured on a task requiring the identification of these briefly presented fragmented pictures. At test, subjects were presented with a fragment identical to the fragment presented at study (identical condition), a complement of the studied fragmented image (complementary condition) or with a fragmented different exemplar of the same object (e.g., a fragmented version of an upright piano). The results indicated as much priming in the complementary condition as in the identical condition on fragments constructed by the deletion of alternate lines and vertices (Figure 2). These data indicate that priming on these types of fragments was not specific to the exact perceptual form of the studied fragments. However, much less transfer was found on the complementary condition

relative to the identical condition on fragments constructed by the deletion of alternate convex components (Figure 3). These data indicate that priming is specific to the perceptual form of the studied fragment on these types of fragments.

According to Biederman and Cooper (in press), these results suggest that priming is mediated by an abstract representation that encodes common object parts between study and test objects. When alternate lines or vertices are deleted, study and test fragments still share common parts or components. Hence equivalent priming is found from the identical and complementary conditions. When whole components of the object are deleted, study and test fragments do not share any common parts or components. Hence, specificity in priming from one fragment to another is observed.

Transfer across different orientations. Specificity in picture-picture transfer has also been reported when study and test patterns differ in orientation along the picture plane. For instance, Jolicoeur (1985) had subjects name line drawings of objects that were rotated 0 to 120 degrees from the upright position in the study phase. In this phase, he observed large effects of disorientation so that naming times increased as the objects were rotated further from the upright position. However, this disorientation

effect decreased significantly over subsequent blocks of trials. The decrease in the disorientation effect was specific to objects seen in the prior blocks. Objects that were not seen in the previous blocks still showed large effects of disorientation on naming even in later blocks. Therefore, the decrease in the disorientation effect could not be attributed merely to a general skill, but was specific to the studied objects.

In an extension of this work, Jolicoeur and Milliken (1989) investigated whether the reduced disorientation effect with practice would be obtained when objects were viewed only in the upright position. The context in which the upright views of objects were studied was varied so that subjects studied them in the context of upright objects only, or in the context of disoriented objects. Subjects were then transferred to a condition where subjects had to name disoriented versions of the upright objects. The results were striking: transfer to other orientations of the object did not occur when the upright objects were studied in the context of other upright objects, but substantial transfer to other orientations occurred when upright objects were studied in the context of other rotated objects. These results suggest that specificity in transfer across different orientations is a function of the orienting task at study. Subjects do not invariably extract orientation-

invariant attributes of the object. However, these attributes can be used, and some encoding contexts encourage subjects to use these attributes even if it is not the usual mode of processing.

Transfer across different viewpoints. The effects of varying rotation of objects in depth between study and test have been relatively puzzling and inconsistent (see Appendix C for examples of objects rotated in depth). Bartram (1974) studied the effects of practice and stimulus variability on picture naming latencies. Pictures were repeated so that over 8 blocks of practice trials, the same picture appeared in every block to represent a given object (identical condition), different views of the same object appeared in every block (different view condition), or different exemplars from the same object class appeared in every block (different exemplar condition). Bartram (1974) found greatest effects of practice in the identical condition, smaller practice effects in the different view condition, and smallest practice effects in the different exemplar condition (although these were still significant). Also, naming latencies were more variable in the different view and the different exemplar condition relative to the identical condition. These data indicate that although transfer does occur from one viewpoint of the object to another, it is not as great as transfer in the identical

condition. Similar findings have been reported by Bartram (1976) in a matching task where subjects had to decide whether two simultaneously presented pictures of objects had the same name. Subjects were fastest at matching the pictures when they were identical, slower when the pictures were different viewpoints of the same object, and slowest when the pictures were different examples of the same object.

Interestingly, Bartram (1974) also reported that practice on the identical pictures condition transferred as well to the different viewpoint condition as did practice on different viewpoint condition itself. This implies that, unlike results in the Jolicoeur and Milliken (1989) experiments, subjects were not influenced by the nature of the orienting task; as much priming was shown from training on different viewpoints than training on a single viewpoint. Finally, practice on the identical and different viewpoint conditions did not transfer to the different exemplar condition, indicating that priming was specific to the studied objects.

These data suggest that although priming on picture naming tasks is greatest when the identical form is used at study and test, considerable facilitation is observed when the objects presented at study and test vary in viewpoint. In fact, Biederman (1987) reported that in four experiments

with colored slides, Biederman and Lloyd (1985) "failed to observe any effect of variation in viewing angle". Priming was apparently not affected by changes in viewpoint between study and test. The details of these experiments are not available, so it is hard to reconcile the results.

To summarize the literature on picture-picture priming, variation in perceptual dimensions between study and test pictures have yielded mixed results. Priming does not appear to be affected by changes on perceptual dimensions such as size or left-right orientation between study and test objects, but it is affected by changes in orientation along the plane between study and test objects. Changes in viewing angle or in the fragments between study and test appear to affect priming on some occasions, but not on others. Finally, reliable priming has always been reported from other exemplars of the tested object, although it is not always found to be correlated with visual similarity between the exemplars.

The Present Experiments

It is clear from the previous review that priming is specific to the perceptual aspects of studied items on some occasions (e.g., when form of presentation is manipulated within-subjects), and is not at all specific on others (e.g., when size, reflection, or viewpoint is varied between study and test). The present experiments were designed to explore whether it would be possible from theory to determine precisely when priming would be specific to the studied stimulus, and when it would not. Most of the predictions were generated from the theories of priming and object recognition that were outlined earlier, under the assumption that picture priming reflects the operations involved in the perception of objects. Specifically, the two main issues that were outlined earlier were investigated in five experiments. Priming between different perceptual forms at study and at test (words to pictures) was one of the issues, and priming between different fragments or different viewpoints of objects at study and test was the other. Experiment 1 was designed to investigate issues related to priming across different perceptual forms.

Experiment 1

Experiment 1 explored three specific issues about priming between words and pictures. The first issue was Hirshman et al.'s (1990) suggestion that the appropriate study condition for obtaining word-picture transfer involves the generation of words at study. Recall that Hirshman et al. demonstrated greater priming effects from words on a picture priming task when the words had been generated from sentence frames relative to when they had simply been read in isolation. However, they did not include pictures as a study condition in their experiments to investigate specificity in priming between words and pictures. In other words, if subjects were required to study pictures, or generate words in the training phase, and were then transferred to a picture fragment completion task, would studied pictures still show greater priming than words generated at study? Similarly, would generated words produce greater priming than words read out of context?

The second point was related to the methodological issue raised by Brown et al. (in press) in their studies with picture naming. They suggested that specificity in picture naming, and by extension in all priming tasks, occurs only when within-subject designs are used, and these effects disappear when between-subjects designs are used. The present study was also designed to investigate whether this finding would generalize to other nonverbal priming

tasks, such as a picture fragment completion test.

The third (and more central) issue that this experiment was designed to address was whether one could manipulate the amount of word to picture transfer on picture fragment tests by manipulating the type of fragments presented at test. The rationale for this manipulation was derived from Biederman's (1987) recognition-by-components theory of object recognition, which is discussed below.

According to Biederman's (1987) theory, certain contours in the image are critical for recognition of objects when contextual inference is not possible (as in most studies of picture fragment completion). By the theory, the recognition of any object begins by parsing the object into different components (or parts) at its concavities. If the contours of the object are deleted at regions of concavity so that when the contours are extended through collinearity or curvilinearity, misleading components are retrieved, perceptual recognition should be difficult. These degraded objects that give rise to misleading components are called "nonrecoverable" objects (see Figure 4). On the other hand, if the correct components are retrieved through the processes of collinearity or curvilinearity, recognition of the objects should be possible even when deletion occurs at the vertices of the object, such degraded objects are called "recoverable" objects.

Figure 4

Recoverable and nonrecoverable fragments of a cup. The example provided was in this dissertation, but a similar example has been provided by Biederman (1987).

Intact version

Recoverable Fragment

Nonrecoverable Fragment

Figure 4 shows the recoverable and nonrecoverable versions of a cup as an example. In the nonrecoverable version, the curve of the handle of the cup is drawn so that it is continuous with the curve of the cylinder forming the back rim of the cup so that a misleading component is created when the contours are filled in. On the other hand, in the recoverable version, filling in leads to retrieval of the correct components of the object. Of course, as Biederman (1987) pointed out, it is difficult to remove contours supporting all the components of the object so that objects are recoverable or nonrecoverable only in a relative sense.

Biederman (1987) also provided data supporting the recoverable/nonrecoverable distinction. He found that identification performance for the two fragment types differed widely as a function of different display times (100, 200, 750 or 5000 ms). For the recoverable objects, identifications rates rose from 40% at 100 ms to almost 100% at 5 s. For nonrecoverable objects identification rates rose from 10% at 100 ms to about 20% at 200 ms. Any further increase in display time beyond 200 ms had absolutely no effect on identification rates for nonrecoverable fragments. Therefore, recoverable and nonrecoverable fragments may be operationally defined as those fragments that can be identified with increasing accuracy as a function of increases in exposure time (recoverable), or those that

cannot (nonrecoverable). Biederman (1987) also found that previous exposure to intact versions of these pictures primed both recoverable and nonrecoverable versions of the pictures (by about 15%), but exposure to their names did not.

Experiment 1 was designed to investigate an alternative explanation to the Hirshman et al. (1990) results described earlier. Hirshman et al. found substantial priming from generated words on a picture priming task, and explained this result by claiming that conceptual processing of words is necessary for priming to be observed from words on pictures. While this could be one explanation, it could also be possible that Hirshman et al.'s use of a slightly different variant of the typical picture fragment completion task influenced the pattern of data they observed. In their task, pictures were clarified slowly on the screen by illuminating increasing proportions of pixels within every 16 X 16 pixel block of the complete picture. This algorithm that was used for the fragmentation might have inadvertently resulted mostly in the creation of what Biederman (1987) terms "recoverable" fragments (In fact, some of the fragments shown as examples in Hirshman et al.'s experiments do appear to be recoverable). If this hypothesis is correct, priming from generated words may have been obtained in the Hirshman et al. data because they used recoverable fragments. Would priming from generated words be obtained

only on recoverable fragments, or would it also generalize to nonrecoverable fragments? This was the third issue addressed in Experiment 1.

In order to address the three issues, priming from studied words, generated words, or studied pictures to recoverable and nonrecoverable versions of picture fragments was investigated in Experiment 1. The first step, however, was to develop a set of recoverable and nonrecoverable materials.

Pilot Study 1

A pilot study was conducted to develop a set of materials with recoverable and nonrecoverable fragments for each picture. Items were then tested for their recoverability or nonrecoverability using the method specified by Biederman (1987). The method involved plotting the identification rates for the recoverable and nonrecoverable fragments over different display times (100, 200 and 750 ms). Identification rates for the recoverable fragments were expected to increase greatly as a function of increased display times while identification rates for the nonrecoverable fragments should change at a much slower rate.

This method was also used to select display times for the recoverable and nonrecoverable fragments so that the identification rates in the nonstudied condition would be approximately equal. This was done to enable easy

comparison of priming scores across recoverable and nonrecoverable fragments.

Method

Subjects. Twenty-four Rice undergraduates participated in this experiment for a course requirement.

Materials. Forty-eight line drawings were selected from the Snodgrass and Vanderwart (1980) norms so that each drawing had more than one part. They had been scanned for use on an Apple Macintosh computer. The drawings were converted to IBM-PC PCX files. The drawings were then edited using the PC-Paintbrush program on the IBM. In Biederman's (1987) experiments, recoverable fragments were easier to identify than nonrecoverable fragments even at the shortest exposure durations (100 ms). Since one aim in this experiment was to equate the identification rates of recoverable and nonrecoverable fragments, the recoverable fragments were made much more difficult to identify in these experiments. This was done by deleting more contour and vertices in the recoverable fragments. Biederman (1987) has shown that neither of these two variables affects the recoverability of the fragments.

Recoverable fragments were created by deleting sections of the line drawings while preserving the outline of the object. Nonrecoverable fragments were created by deleting parts of the object represented in the line drawing. Often, the contours of the object were deleted so that when the

contours were extended through collinearity or curvilinearity, misleading components would be retrieved. A sample of the recoverable and nonrecoverable fragments that were constructed is provided in Appendix A.

Design. A 2 (Type of Fragment: Recoverable or Nonrecoverable) X 3 (Display Time: 100, 200 or 750 ms) within-subject design was used. Forty-eight items were randomly distributed into six blocks of eight items each. Each block was assigned to each of the six conditions across six lists. The items were presented in a different random order for each subject. The dependent measure was the proportion of fragments correctly identified.

Procedure. Subjects were tested in groups of 1-4. The task required the subjects to identify brief presentations of fragmented line drawings on the computer screen. Subjects were shown an example of a simple line drawing that had been deleted, and they were told that they would have to identify line drawings similar to these that would be briefly presented on the computer screen. Subjects were told that the experimenter was interested in how people mentally completed these fragmented pictures in order to identify them. Subjects were warned that this was a difficult task, but they could adopt a guessing strategy in solving the problem. Each trial began with a warning signal for 2 s.

Table 2

Proportion of picture fragments correctly identified as a function of fragment type and display time (in ms) in Pilot Study 1.

	Display Times (in ms)			
	100	200	750	(5000)
Fragment Type				
Recoverable	0.35	0.44	0.61	(0.77)
Nonrecoverable	0.19	0.31	0.30	(0.31)

The fragment then appeared in the center of the computer screen for a short period (either 100, 200 or 750 ms), and was then replaced by a mask. The mask was always the same across trials, and consisted of a pattern of two white concentric circles against a black background. Following the mask, subjects were asked to write down their responses on a sheet of paper. Subjects initiated the next trial by hitting a key.

Results and Discussion

Table 2 shows the mean proportion of fragments correctly identified as a function of fragment type (recoverable or nonrecoverable fragments), and display time (100, 200 or 750 ms). The 5 s data will be discussed below. For the recoverable fragments, the mean proportion of fragments correctly identified increased from 0.35 to 0.61 as a function of an increase in display time from 100 to 750 ms. For nonrecoverable fragments, performance increased from 0.19 to 0.31 as a function of increased display time from 100 to 200 ms. However, a further increase in display time from 200 to 750 ms did not result in an increase in the proportion of nonrecoverable fragments correctly identified (0.31 to 0.30). This pattern of data is very similar to that obtained in Biederman's (1987) experiments.

All the results reported as being reliable in this experiment, as well as in other experiments in this dissertation, exceeded the .01 level of confidence unless

otherwise specified. Repeated measures analysis of variance indicated reliable main effects of Fragment Type ($F(1, 23) = 31.85$, $MSe = 0.03$) and Display Time ($F(2, 46) = 13.46$, $MSe = 0.02$). The interaction between Fragment Type and Display Time was also reliable ($F(2, 46) = 4.41$, $MSe = 0.02$, $p < .02$), indicating that the effect of increasing display times on recoverable fragments was different from the effect of increasing display times for the nonrecoverable fragments.

A second group of 10 subjects was tested on the recoverable and nonrecoverable fragments when the display time was 5000 ms for both types of fragments. Results showed that recoverable fragments were identified correctly 77% of the time, while nonrecoverable fragments were identified correctly only 31% of the time. While these data were similar to Biederman's results, identification rates for these recoverable fragments at 5 s were much lower than those reported by Biederman (almost 100%). This difference might reflect the fact that more contour was removed on these recoverable fragments than on those in Biederman's experiments. The important point is these fragments would be defined as recoverable by the operational definition.

An analysis by items was also conducted to compare performance on recoverable and nonrecoverable fragments. To increase the number of observations per cell, performance for the two fragment types was collapsed across the display times (100, 200, 750 and 5000 ms). The analysis indicated

that performance on the two types of fragments was reliably different by items ($F(1, 47) = 38.00, MSe = 0.01$).

Together, these results suggest that the recoverable/nonrecoverable distinction is a psychologically valid one, and the materials developed for this project capture it. Recoverable fragments can be identified by "filling in" processes that take time. Increased display time thus increases the "recoverability" of these fragments. Nonrecoverable fragments on the other hand, do not appear to benefit as much from increases in display time because "filling in" processes presumably lead to the recovery of incorrect components or parts. The next step was to determine whether studying pictures, words or generated words would differentially affect priming on these two types of fragments.

To recapitulate, Experiment 1 was an attempt to explore specificity in priming when isolated words, generated words and pictures were studied in a first phase, and transfer was measured on a picture priming task. Experiment 1 was designed to address three questions: a) Is priming sensitive to the perceptual form of the studied items even when subjects see only one form at study? In other words, is specificity in priming only a product of within-subject designs? To answer this question, study conditions (Pictures, Words or Generated Words) were manipulated between-subjects. According to Brown et al. (in press),

equivalent priming from pictures and words is predicted under these conditions. b) Does priming across different perceptual forms (pictures and words) depend on the type of processing performed on study items? To answer this question, priming on pictures was measured as a function of studying both isolated words, and words that were generated to a sentence context. According to Hirshman et al. (1990), the conceptual processing of words in the generated condition should result in greater priming from generated words on picture priming tests. c) If priming does occur across different perceptual forms (e.g., pictures and words), does it depend on the degree to which the test item permits perceptual recovery? To answer this question, priming was measured from pictures, words and generated words on recoverable and nonrecoverable fragments. Experiment 1 was thus designed to replicate and extend the findings of Brown et al. (in press), Hirshman et al. (1990), and Biederman (1987).

Method

Subjects. Ninety-six Rice undergraduates took part in this experiment in partial fulfillment of a course requirement.

Materials. The 48 items from the pilot study were used in this experiment. Intact versions of the pictures were used in the Picture study condition. For the Word and Generated Words conditions, the names for the pictures were

taken from the Snodgrass and Vanderwart (1980) norms. Sentence frames were constructed to specify uniquely each study word. These sentence frames, along with the first letter of the word, were the cues used in the generation task (e.g., This animal builds cobwebs. s_____). The set of words and their corresponding sentence frames is provided in Appendix B.

The test fragments (recoverable and nonrecoverable) were the fragments constructed and tested in pilot study (a sample is provided in Appendix A).

Design. A 3 (Study Group: Pictures, Words, Generated Words -- between-subjects) X 2 (Study Status: Studied or Nonstudied -- within-subjects) X 2 (Fragment Type: Recoverable or Nonrecoverable -- within-subjects) mixed design was used. Forty-eight items were divided into four blocks of 12 items each. Each subject studied two such blocks (24 items) -- one block was later tested as recoverable fragments, the other was tested as nonrecoverable fragments. The other two blocks (24 items) served as the nonstudied baseline. Again, one block of the nonstudied items was later tested as recoverable fragments, and the other block was tested as nonrecoverable fragments. For each study condition (Pictures, Words, and Generated Words), four study lists were created by rotating the four blocks of items through the four study/test conditions. Thus, each item appeared in each condition equally often.

Separate study lists were created for the Pictures, Words, and Generated Words conditions resulting in 12 lists. Each subject was presented with the study and test items in a different random order that was determined for that subject. The dependent measure was the proportion of fragments correctly identified.

Procedure. Thirty-two subjects were assigned to each of the three study conditions (Pictures, Words or Generated Words). In the study phase, subjects were presented with pictures, words or sentence frames to generate the words for 10 s on the computer screen. Subjects were informed that the items that they would see on the computer screen were materials they would help develop for a future experiment. Subjects were instructed to rate the picture, the word or the word they generated to the sentence frame on a scale from 1 to 7 for pleasantness of meaning. In each case, they were asked to rate the concept represented by the picture, word, or generated word, and not the surface features of the items (e.g., what the word sounded like). Subjects responded by circling the appropriate number on a rating scale provided to them. In the Generated Words condition, if subjects failed to generate the item, they were asked to respond with a question mark. Each trial began with a warning signal for 2 seconds, followed by the presentation of the studied item. The entire study session lasted 10 minutes.

Subjects were then engaged in a 10 minute distractor task where they wrote down the names of states in the U.S., along with their capitals. Following the distractor phase, subjects were introduced to the picture fragment identification task. The priming task involved the identification of briefly presented picture fragments. Brief exposure was chosen because performance on recoverable fragments would be at ceiling if a conventional picture fragment completion test was used (i.e., display times at 5 s or more). Display times for the recoverable and nonrecoverable fragments were selected so that performance would be roughly comparable for the nonstudied recoverable and nonrecoverable fragments. This was done to facilitate comparison of study conditions across the different fragment types. Since the results of the pilot study suggested that performance on recoverable fragments at 100 ms was roughly equivalent to performance on nonrecoverable fragments at 200 ms, these different display times were chosen for the two types of fragments.

In the test phase, subjects were introduced to a task that they were told involved "perception". Subjects were instructed that their task was to identify brief presentations of line drawings that were fragmented or incomplete. They were told that the task was a difficult one to perform, but they were to adopt a guessing strategy in solving the fragments. Each trial began with a warning

signal (for 2 s), followed by a brief presentation of the target item (100 ms for recoverable fragments, 200 ms for nonrecoverable fragments). This was in turn followed by the mask (for 500 ms) that was used in the pilot study. The mask was an abstract pattern of circles. Following the presentation of the mask, an instruction to write down the correct response was displayed on the computer. Subjects wrote down their responses on a sheet, and then pressed a key to initiate the next trial. Subjects were not informed that this was a memory test, and they were not told about the different types of fragments used.

At the end of the test phase, subjects in the generated word conditions were presented once again with the sentence frames, and were asked to write down the words they had generated the first time. This was done to ensure that subjects had generated the correct words in the earlier study phase.

Results and Discussion

Table 3 shows the proportion of fragments correctly identified as a function of study condition in Experiment 1. In the Generated Words condition, the proportion correct for each condition was conditionalized on successful generation of the word at study. Subjects generated the items at study successfully 98% of the time.

Table 3

Proportion of recoverable and nonrecoverable fragments correctly identified as a function of Study Group, Study Status and Fragment Type in Experiment 1.

Study Group	Study Status		
	Studied		Nonstudied
	Recoverable Fragments	Nonrecoverable Fragments	Recoverable Fragments Nonrecoverable Fragments
Pictures	0.66	0.59	0.37 0.33
Words	0.43	0.27	0.38 0.23
Generated Words	0.40	0.29	0.37 0.27
Priming Scores			
Study Group	Fragment Type		
	Recoverable Fragments	Nonrecoverable Fragments	
Pictures	0.29	0.26	
Words	0.05	0.04	
Generated Words	0.03	0.02	

The results indicated that studying pictures in the study phase produced substantial priming for both recoverable (.29) and nonrecoverable (.26) fragments. However, words showed smaller priming effects on both recoverable (.05) and nonrecoverable (.04) fragments. Priming on generated words was also relatively small (.03 for recoverable, and .02 for nonrecoverable fragments).

Repeated measures ANOVA indicated reliable main effects of Study Group ($F(2, 93) = 22.70, MSe = .05$) indicating that the three groups of subjects who studied either pictures, words or generated words differed reliably in performance. Performance on studied items was also reliably better than performance on nonstudied items, as evidenced by the main effect of Study Status ($F(1, 93) = 65.09, MSe = .02$). However, there was an interaction so that the advantage for studied items differed across groups ($F(2, 93) = 32.83, MSe = .02$). Finally, despite efforts to equate performance on recoverable and nonrecoverable fragments on the nonstudied baseline, there was a main effect of Fragment Type ($F(1, 93) = 61.95, MSe = .02$), and an interaction so that performance on recoverable and nonrecoverable fragments differed across groups ($F(2, 93) = 4.64, MSe = .02$). No other effects approached significance.

Individual t tests were performed to examine specific comparisons. As expected, priming for studied pictures was reliable on both recoverable ($t(31) = 11.52$) and

nonrecoverable fragments ($t(31) = 5.85$). Priming from read words was not reliable for either recoverable ($t(31) = 1.48$, $p > .10$) or nonrecoverable fragments ($t(31) = 1.23$, $p > .10$). Similarly, priming from generated words was not reliable for either recoverable ($t(31) = 1.07$, $p > .10$) or nonrecoverable fragments ($t < 1$). Since the means indicated a small (about 3.5%) priming effect for words and generated words, an analysis was conducted by collapsing across recoverable and nonrecoverable fragments, and across generated and read words. Comparison of studied versus nonstudied conditions in such an analysis (with 1536 observations in each condition) revealed a reliable priming effect ($F(1, 63) = 4.40$, $p < .04$, $MSe = 0.007$) for words.

Surprisingly, studying pictures resulted in equivalent priming for recoverable and nonrecoverable fragments. The difference in priming from pictures to recoverable fragments was not reliably different than priming from pictures to nonrecoverable fragments ($t < 1$).

Three important findings emerged from Experiment 1. First, priming from pictures was robust while priming from words was relatively small, even when a between-subjects design was used. Second, priming from generated words was not reliably different from the baseline. In fact, the numerical advantage from generating words was smaller than the advantage from studying words. Third, little or no priming occurred from words and generated words for both

recoverable and nonrecoverable fragments. Equivalent priming was observed from pictures on both recoverable and nonrecoverable fragments. Each of these issues is discussed separately.

The finding that pictures serve as effective primes on a later picture priming task while words do not is consistent with a large body of findings in the literature. The data are discrepant with the findings of Brown et al. (1990), and Hirshman et al. (1990) because little priming was observed for either the Word or the Generated Word conditions even when a between-subjects design was used. Of course, Brown et al. used picture naming whereas the task used in this experiment was picture fragment completion from brief displays. However, even if one were to appeal to task differences between the paradigms to account for the discrepancies, the present data suggest that varying levels of perceptual difficulty (or the level to which the task permits perceptual recovery) does not account for the differences in results, because type of fragment (recoverable or nonrecoverable) had no effect on priming from pictures, words or generated words. Other findings also discount such an explanation. Lachman & Lachman (1980), and Biederman (personal communication) have found little or no priming from words on picture naming tasks. At the present time, it is hard to resolve the issue. The dominant pattern in the literature appears to be little

priming from words relative to substantial priming from pictures on picture priming tasks, in either within or between-subjects designs.

A second result in Experiment 1 was that little priming was obtained for either recoverable or nonrecoverable fragments from generating words at study. Hirshman et al. (1990) suggested that inducing meaningful processing of the word through generation results in priming on pictures. There is little evidence in Experiment 1 to support this hypothesis.

The third finding in Experiment 1 was that priming did not differ across fragment types. Equivalent priming was observed from pictures on both recoverable and nonrecoverable fragments when their nonstudied base rates were equated at test. If priming is a function of common object parts between study and test (Biederman and Cooper, in press), then the match between studied and tested object parts should be greater in the pictures-to-recoverable fragments condition than in the pictures-to-nonrecoverable fragments condition. In the case of recoverable fragments, all the studied parts could be reconstructed at test. In the case of the nonrecoverable fragments, the parts were deleted or the contours were deleted to form misleading parts. Therefore, the match between studied and tested items (in terms of parts) should have resulted in greater priming in the pictures-to-recoverable fragments condition

when compared to the pictures-to-nonrecoverable fragments condition. However, no such advantage was observed. Because the pilot study validated the type of fragments, these results are quite problematic for Biederman's recognition-by-components theory.

Experiment 2 was designed to address this issue. One possible explanation for the equivalent priming results of recoverable and nonrecoverable fragments in Experiment 1 is that priming from intact pictures tends to override any differences between recoverable and nonrecoverable fragments. That is, having studied the intact versions of the pictures with all the parts tends to avert the formation of misleading components in the nonrecoverable case. What would happen if subjects studied incomplete pictures in the study phase, and were then tested on the same or different incomplete versions at test?

Experiment 2 was conceptually similar to the Biederman and Cooper (in press) and Snodgrass and Feenan's experiments. In Biederman and Cooper's study, subjects were primed with one fragment, and then tested with either the identical fragment or its complement (see Figures 2 and 3). Priming on the identical fragment condition was the same as priming on the complementary fragment condition when alternate lines and vertices were deleted (Figure 2). These fragments are similar to the recoverable fragments in Experiment 1. It could also be argued that they afforded

"perceptual closure". However, priming on the identical fragment condition was much greater than priming on the complementary fragment when alternate components were deleted (Figure 3). These fragments are similar to the nonrecoverable fragments in Experiment 1. It could be argued that these fragments do not allow perceptual closure. While Biederman & Cooper (in press) examined priming among different versions of recoverable fragments (Figure 2) and among different versions of nonrecoverable fragments (Figure 3), Experiment 2 explored transfer across the two fragment types.

In Experiment 2, subjects studied intact pictures, recoverable fragments or nonrecoverable fragments in the study phase, along with names of objects. At test, subjects were transferred to recoverable or to nonrecoverable fragments. If priming is mediated by a representation that codes the object parts of the studied object, studying intact pictures and recoverable fragments should yield the same representations because they presumably allow access to the same components. On the other hand, nonrecoverable fragments should yield a different representation because they presumably do not allow access to the same components that intact pictures or recoverable fragments share. Thus, by Biederman's recognition-by-components theory, equivalent priming should occur from studying pictures and recoverable fragments on recoverable and nonrecoverable fragments at

test. On the other hand, studying nonrecoverable fragments should result in little priming on the recoverable fragments, and much greater priming on the same nonrecoverable fragments at test. Experiment 2 tested these predictions.

Experiment 2

Method

Subjects. Thirty-two Rice undergraduates took part in this experiment in partial fulfillment of a course requirement.

Materials. The same 48 pictures (with their corresponding recoverable and nonrecoverable fragments) used in Experiment 1 were used in this experiment.

Design. A 4 (Study Condition: Intact Pictures, Recoverable Fragments, Nonrecoverable Fragments or Nonstudied) X 2 (Test Condition: Recoverable or Nonrecoverable Fragments) within-subjects design was used in this experiment. Forty-eight items were blocked into eight sets of six items each, and each set was rotated across the eight conditions to form eight counterbalanced study and test lists. Items in each study/test list were presented in a random order that was separately determined for each subject. The dependent measure was the number of fragments correctly identified at test.

Procedure. Subjects were tested in small groups of between 2-4. In the study phase, subjects were instructed that they had to help prepare some materials for a future experiment. Subjects were told that they would be presented with fragmented line drawings each for 10 s on the computer screen. Beside each line drawing would be the word corresponding to the line drawing. The subjects' task was

to rate the line drawing for how difficult/easy it was to mentally complete the line drawing on a scale from 1 (difficult) to 5 (easy). Subjects were also told that they would occasionally be presented with the intact version of the line drawing in order to help them rate the incomplete line drawings relative to the complete ones. They were told that the intact versions would be rated as 5 on the scale. Subjects were then presented with the pictures on the computer. Each trial was preceded by a warning signal for 2 s. The target picture or fragment then appeared for 10 s during which time subjects rated the picture on a sheet of paper. The entire study phase lasted about 10 minutes. Following the study phase, subjects were engaged in the same distractor task as in Experiment 1 for about 10 minutes. This was followed by the test phase. Subjects were told that they would see incomplete line drawings similar to the ones they had studied, but they were told that this time, they should identify (name) the drawings. Subjects were informed that the incomplete line drawing would be briefly presented on the screen, and their task was to try to identify the line drawing. Subjects were asked to adopt a guessing strategy to solve the fragments.

At test, recoverable fragments were presented for 100 ms and nonrecoverable fragments were presented for 200 ms in an attempt to equate the base rates for these two types of fragments. The procedure in the test phase was identical to

that in Experiment 1. Each trial began with a warning signal for 2 s, followed by a brief (100 or 200 ms) presentation of the fragment which was then masked by a pattern for 500 ms. The mask was once again the abstract pattern of circles that was presented in Experiment 1. The mask was followed by a prompt to the subject to enter the item. Subjects entered their responses on the keyboard, and then hit the "Enter" key to go on to the next item.

Results and Discussion

Table 4 shows the proportion of fragments correctly identified as a function of study condition and test fragment type in Experiment 2. Priming scores and the size of the priming effect (effect size indicator r from Rosenthal & Rosnow, 1991) are also provided in the Table. Effect size measure r was estimated from t values. The measure r is simply a correlation between membership in a particular category (e.g., primed or unprimed) and the dependent measure (e.g., proportion of fragments correctly identified). The results show reliable priming effects for all study conditions relative to the nonstudied baseline on both recoverable and nonrecoverable fragments.

Table 4

Proportion of recoverable and nonrecoverable fragments correctly identified as a function of Study Condition and Fragment Type in Experiment 2.

Study Condition	Fragment Type					
	Recoverable Fragments			Nonrecoverable Fragments		
	Prop. Correct	Priming	Effect Size(r)	Prop. Correct	Priming	Effect Size(r)
Pictures	.65	0.25	0.60	.61	0.35	0.80
Recoverable Fragments	.84	0.44	0.86	.58	0.32	0.73
Nonrecoverable Fragments	.65	0.25	0.62	.84	0.58	0.95
Nonstudied	.40			.26		

The primary result in Experiment 2 was that priming was greatest when identical fragments were repeated between study and test (.44 in the recoverable-recoverable case and .58 in the nonrecoverable-nonrecoverable case). In conditions where study and test formats were different, priming did not appear to be affected by the particular type of study format. Thus, for example, priming from intact pictures (.25) was equivalent to the priming obtained from studying nonrecoverable fragments (.25) when the test items were recoverable fragments. Similarly, priming from intact pictures (.35) was equivalent to the priming obtained from recoverable fragments (.32) on nonrecoverable fragments.

Repeated measures ANOVA indicated reliable main effects of Study Condition ($F(3, 93) = 65.30$, $MSe = .04$), and Fragment Type ($F(1, 31) = 6.49$, $MSe = .04$). The interaction between the two factors was also reliable ($F(3, 93) = 14.62$, $MSe = .04$). Individual t tests indicated reliable priming for recoverable fragments from having studied intact pictures ($t(31) = 4.21$), recoverable fragments ($t(31) = 9.40$), and from studying nonrecoverable fragments ($t(31) = 4.39$). Similarly, reliable priming was obtained for nonrecoverable fragments from studying intact pictures ($t(31) = 7.51$), recoverable fragments ($t(31) = 5.99$), and nonrecoverable fragments ($t(31) = 14.00$). Performance was reliably better on the recoverable fragments when recoverable fragments had been studied in the study phase,

relative to when intact pictures ($t(31) = 4.86$) or nonrecoverable fragments ($t(31) = 4.41$) had been studied. Similarly, performance was better on the nonrecoverable fragments when nonrecoverable fragments had been studied relative to when intact pictures ($t(31) = 5.71$) or recoverable fragments ($t(31) = 5.89$) were studied. No other differences were reliable.

Several interesting results emerged from Experiment 2. First, greater priming was found when the same fragment was repeated between study and test than when intact pictures were presented at study, or when different fragments were presented at study and test. This result suggests that priming is highly specific to the perceptual features of the studied item, a conclusion that is in agreement with Gardiner, Dawson and Sutton's (1989) findings with word fragment completion. Gardiner et al. (1989) found substantial priming on the word fragment completion test when the same fragment was repeated between study and test. When a different fragment of the same word was presented at test, priming dropped to levels where the word was primed by its intact version. Similar results indicating hyperspecificity in priming have been reported by Hayman and Tulving (1989).

The present data are consistent with theories of memory that have emphasized that priming reflects the perceptual aspects of an episodic representation (e.g., Jacoby, 1983;

Kolers & Roediger, 1984) rather than abstract representations of studied items. By these accounts, greatest priming would be predicted when the same fragments are repeated between study and test compared to when different fragments are presented between study and test, even when the two fragments share the same abstract representation.

However, these results are not consistent with the notion that priming reflects the activation of an abstract representation, especially with Biederman's (1987) recognition-by-components theory. The data contradict the predictions derived from the theory on three grounds. First, according to Biederman's theory, priming in the pictures-recoverable fragments condition should have been greater than priming in the pictures-nonrecoverable fragments condition because intact pictures share more common components with recoverable than with nonrecoverable fragments. However, the data indicate equivalent priming from pictures on both recoverable and nonrecoverable fragments. Second, according to Biederman's theory, intact pictures should have produced the greatest priming on both recoverable and nonrecoverable fragments, because intact pictures presumably allow access to all the components on the test fragments. Instead, the data indicated a consistent superiority for studied fragments when the test fragment was exactly the same. Intact pictures or different

fragments produced much less priming. Finally, according to Biederman's theory, studying recoverable fragments should have been roughly equivalent to studying intact pictures, because recoverable fragments allow virtually the same access to the components as intact pictures do (assuming they are 100% recoverable). Even if recoverable fragments were not completely recoverable, they should have allowed access to more components than nonrecoverable fragments. The least amount of priming should have been obtained from studying nonrecoverable fragments. Instead, the data indicate that recoverable fragments, nonrecoverable fragments, and intact pictures produce equivalent amounts of priming on fragments that are different from studied ones. This outcome suggests that subjects are able to recover the correct components with nonrecoverable fragments when given the names of the objects at study. Because the results of Experiment 1 demonstrate that simply giving the names of the objects is not sufficient to produce substantial priming in this paradigm, giving the fragments along with the names appears to make recoverable and nonrecoverable equally recoverable.

The current data are also inconsistent with Snodgrass et al.'s perceptual closure principle of picture fragment completion. According to the perceptual closure principle, stimuli that afford perceptual closure (in this case, recoverable fragments) should show the greatest amount of

priming on a picture fragment completion test. The data indicate instead that both stimuli that afford perceptual closure (recoverable fragments) and those that do not (nonrecoverable fragments) produce priming equivalent to those obtained with intact pictures on cases where a different fragment was presented at test. Of course, one might argue that nonrecoverable fragments permit perceptual closure when provided with the names of the objects, but as pointed out earlier, there appears to be no operational definition to specify perceptual closure.

To recapitulate the main results of Experiment 2, a) priming is greatest when the same fragment is presented at study (with its name) and is repeated at test, b) both recoverable and nonrecoverable fragments function as effectively as intact pictures in priming fragments that are not identical to the studied fragments. This second outcome suggests that the distinction between recoverable and nonrecoverable stimuli is valid only when the stimuli are processed with no prior experience. Any prior experience, either with intact pictures of the fragments, or with words along with the fragments, tends to make both fragment types equivalent in identification difficulty.

So far, the results of Experiments 1 and 2 support the notion that priming is sensitive to the perceptual form of the studied stimulus, a finding that is consistent with integrated, episodic explanations of priming. Experiment 3

was designed to investigate whether the same type of specificity would be observed when priming was measured across viewpoints in depth.

Experiment 3

There are good empirical reasons to believe that priming is not specific to a particular studied viewpoint (e.g., Bartram, 1974; Biederman, 1987). These data suggest that (at least with familiar objects) priming is mediated by an object code or representation that is not sensitive to viewpoint. Alternatively, as both Bartram (1974) and Biederman (1987) point out, their studies did not control for the degree of visual similarity between different viewpoints of the object, and this similarity could be mediating transfer across viewpoints of the object. Further, it is also possible that the object naming task used in their experiments was not perceptually difficult, so transfer occurred across different views of the object. Presumably, if the task measuring the recognition of objects is made more difficult, it may be possible to observe differential priming effects.

Experiment 3 was designed to test these possibilities by minimizing the visual similarity in viewpoints presented at study and at test by presenting "usual" and "unusual" views of the target objects. Usual views of the object are typical viewing angles in which most people see or imagine the objects. It is also the view of the object that is most effective for recognition (Palmer, Rosch, & Chase, 1981). Unusual views of the object are views where the saliency of the object's distinctive feature is reduced (Humphreys &

Riddoch, 1984), or where the principal axis of the object is foreshortened. Unusual views are not as effective as usual views in triggering perceptual recognition. Typically, the visual overlap between usual and unusual views of the objects is minimal, which accounts for why the two views differ in their effectiveness for recognition (see Appendix C for examples of usual and unusual views).

The priming task chosen for these experiments was a slightly modified version of the task used in Experiments 1 and 2. The task required the identification of briefly presented intact pictures. Previous studies (as well as the current experiments) have shown the task to be sensitive to perceptual changes between studied and tested items. It was hypothesized that this task may prove more useful in exploring specificity in priming across viewpoints than a picture naming task with unlimited exposure, because of the greater difficulty involved in performing the task.

In Experiment 3, the effect of changing viewpoint between study and test was investigated by having subjects study either the usual or the unusual view of the object at study, and then transferring them either to the same view at test, or to a different view at test. Thus, priming was measured in four study-test conditions -- usual to usual, unusual to unusual, usual to unusual and unusual to usual viewpoints.

Based on the findings in Experiments 1 and 2, it was

predicted that priming would be specific to the viewpoint presented at study, i.e., priming in the study-test conditions of usual-usual and unusual-unusual should be much greater than priming in the usual-unusual or unusual-usual conditions. On the other hand, if what mediates priming is an abstract representation that codes across size, orientation, location, or viewpoint (e.g., Marr and Nishihara, 1978), priming should generalize across different viewpoints just as Bartram (1974) and Biederman (1987) had found. In other words, equivalent priming should be observed in the usual-usual, usual-unusual, unusual-unusual, and unusual-usual conditions.

However, merely positing that an abstract object representation mediates priming does not necessarily imply that priming must generalize across all viewing angles of the object. According to Biederman's recognition-by-components (1987) theory, this abstract representation is specified in terms of the components or parts of the object. Therefore, by his theory, priming will generalize across different study and test viewpoints only when the study and test viewpoints share the same set of object parts in the same relations. Data from Gerhardstein and Biederman's experiments (cited in Biederman, Hilton, & Hummel, 1991) suggest that this is indeed the case. What happens when priming is measured across viewpoints that do not share many components (for example, between usual and unusual views)?

In this case, recognition-by-components theory would predict that priming between viewpoints that share common parts (e.g., the usual-usual or unusual-unusual conditions) should be much greater than priming in conditions that do not share common components (e.g., the unusual-usual or the usual-unusual views).

A third theory of object representation is that objects are represented in their canonical or usual viewing angles (Palmer, Rosch and Chase, 1981), and new views of objects are rotated or aligned to this stored representation before they can be recognized (Tarr & Pinker, 1989; Ullman, 1989). By this model, unusual views of the object would have to be transformed into usual views in order to be recognized, but usual views do not have to undergo any such transformation. If priming is mediated by this type of representation, an asymmetry should be observed in priming across different viewpoints. More priming should be observed from the unusual to usual viewpoints than from the usual to unusual viewpoints of objects. These different predictions were tested in Experiment 3.

Pilot Study 2

The purpose of this pilot study was to obtain a set of usual and unusual views of objects that could be used to test the predictions outlined above. In order to obtain an empirical validation for the "usual" or "unusual" views for objects, an object identification task was used in the pilot

study.

Method

Subjects. Fifty-six Rice undergraduates participated in this experiment in partial fulfillment of a course requirement.

Materials. Fifty-five objects were selected for the experiment -- some of them were real, and some were models of real objects. The objects were selected according to three primary criteria. First, the objects selected had to have more than one unusual view. Some objects, such as basketballs, do not have any unusual view, while others, such as coins, have only one unusual view (an edge-on view of a coin). Second, objects were chosen so that they would be familiar to all subjects. Third, most of the objects chosen were roughly bilaterally symmetrical so that traversing 180 degrees about the object would cover most views of the object.

Each object was photographed from 4 different viewpoints (front, side, back, and top). If the object appeared to be impossible to identify from a given viewpoint (e.g., a pencil viewed with just the pointed tip visible), more information was added by changing the visual angle slightly. The purpose of this exercise was to allow unusual view to still be recognizable, and not just be nonsensical to the subject. Each viewpoint of the object was photographed against a white background so that the object

appeared to float in the photograph. This was done to eliminate any background cues that might cue viewing angle. The objects were also photographed with artificial lights to eliminate any spurious shadows in the photograph.

Black and white photographs of the objects were then scanned onto an Apple Macintosh computer. The image files were then converted to IBM TIFF files to allow the manipulation of 16 levels of gray. Appendix C contains some examples of these images.

Design. Four lists were created for presentation to the subjects. Each view of each of the 55 objects occurred only once in a list. Across the four lists, each object appeared in each view equally often. Response time to identify the objects was the dependent measure.

Procedure. Subjects were tested in small groups (2-4). The task required the identification of the pictures that were presented on the computer screen. Subjects were required to hit a key as soon as they recognized the object. Once they hit the key, they were required to type in the name of the object. Each object stayed on the screen for a maximum of 10 s or until such time the subject identified the object. The objects were presented in a random order that was determined for each subject. Response times were collected to press the key to the nearest millisecond using a software timer.

Results

The mean response time for each individual subject was calculated by collapsing across all objects in the list that the subject had correctly identified. The subjects' response times when he/she incorrectly identified (or failed to identify) objects were not included in the calculation of the mean. The response time for each object the subject had identified was then converted to a z-score using this mean and standard deviation. For each object at each view, the data were collapsed across 14 subjects to obtain a mean z-score. These z-scores were then used to compare the four views of each object to determine the most effective ("usual") and the most ineffective ("unusual") view for each object. Objects were selected depending on two criteria: a) they had at least two views with reliably different z-scores, b) they were identified by at least 11 out of 14 subjects (see column N in Table 5). On the basis of these results, 42 out of 55 objects were selected for use in Experiment 3. Table 5 provides a list of the 42 selected objects, as well as the z-scores and the number of subjects who could identify the objects for the selected usual and unusual views.

Table 5

Differences in z scores for the Usual and Unusual Views
selected in Pilot Study 2.

Object Name	Usual View	N	Unusual View	N	t
1. cow	-0.117	14	0.894	12	3.05
2. wrench	-0.525	14	0.399	13	3.11
3. hairdryer	-0.323	14	0.036	12	1.83
4. kangaroo	-0.507	14	0.398	14	5.72
5. chair	-0.566	14	-0.321	13	2.01
6. screwdriver	-0.486	13	1.800	11	6.93
7. truck	-0.364	14	0.293	14	3.31
8. pencil	-0.271	13	0.141	14	1.95
9. hammer	-0.567	14	-0.346	14	1.99
10. hairbrush	-0.542	14	1.008	14	5.11
11. lock	-0.619	14	0.161	14	6.20
12. screw	-0.521	14	0.043	14	4.00
13. table	-0.356	14	0.782	11	3.59
14. ring	-0.357	13	0.746	11	2.43
15. pan	-0.354	14	0.127	12	2.08
16. lightbulb	-0.480	14	-0.145	14	5.36
17. cassette	-0.471	14	0.171	13	2.28
18. plug	-0.107	14	2.546	12	4.50
19. knife	-0.299	14	0.066	14	1.87
20. racket	-0.558	14	-0.014	14	2.21
21. goat	-0.438	12	-0.066	12	3.34
22. car	-0.021	14	-0.157	14	0.44
23. fork	-0.570	14	0.148	13	2.68
24. paintbrush	-0.449	14	-0.112	14	3.34
25. airplane	-0.575	14	-0.303	14	1.95
26. shark	-0.439	14	0.021	14	3.10
27. shoe	-0.481	14	-0.271	14	2.10
28. horse	-0.574	14	-0.037	14	2.94
29. clock	-0.383	14	-0.105	14	3.47
30. gun	-0.586	14	0.539	12	3.64
31. comb	-0.186	14	0.867	13	3.08
32. camera	-0.477	14	0.159	14	2.04
33. scissors	-0.592	14	-0.368	14	2.55
34. glasses	-0.552	14	-0.343	14	3.15
35. guitar	-0.541	14	0.067	14	2.41
36. hanger	-0.613	14	-0.366	14	2.55
37. key	-0.507	14	-0.002	14	2.35
38. cup	-0.485	14	0.276	14	2.75
39. watch	-0.354	14	0.009	12	1.73
40. spoon	-0.541	14	-0.220	14	1.98
41. helicopter	-0.451	14	0.008	14	3.21
42. fan	-0.390	14	0.607	13	2.88

As the Table indicates, most views that were selected to be "usual" views for the objects were more easily identified than views that were selected to be "unusual". The t values for most objects were reliable (or approached significance). In one case, however (for the object car), the t values between what was deemed a usual view was not reliably different from the unusual view. Despite this, this object was included for counterbalancing purposes.

Experiment 3 was an attempt to test the predictions outlined earlier regarding priming across different viewpoints of the same object when the different viewpoints were not visually similar.

Method

Subjects. Forty-eight Rice undergraduates took part in this experiment in partial fulfillment of a course requirement.

Materials. The materials consisted of two views (usual and unusual) for each of the 42 objects normed in the pilot study.

Design. A 3 (Study conditions: Usual View, Unusual View, Nonstudied) X 2 (Test conditions: Usual View or Unusual View) within-subjects design was used in this experiment. Six sets of 7 items each were rotated across the study and test conditions so that each item appeared equally often in each of the study-test conditions. Presentation of study and test items was determined

separately for each subject. At test, subjects were required to identify brief presentations of the objects. The proportion of objects correctly identified was the dependent measure.

Procedure. Subjects were tested in small groups of 1-3. In the study phase, subjects were instructed that they would see scanned black and white photographs of common objects that would appear on the computer screen for a period of 2 s. Following the presentation of the picture, they would be asked to identify the picture by typing the name into the computer. Subjects were told that the experimenter was interested in ensuring that these objects could be easily identified in a future experiment. After they had typed in the name, subjects were provided with the correct name, regardless of the response the subject had typed in. Subjects were told to pay attention to the feedback in case they misidentified the pictures. At the end of the study phase, subjects were engaged in a 5-minute distractor phase that required subjects to write down the names of all the countries in the world that they could recall.

In the test phase, subjects were told that they would see black and white photographs similar to those they had studied before, but this would be a new set of objects. They were also told that the task of identifying the objects would be much more difficult, because each object would be

presented very briefly on the screen, and then an irrelevant picture would be presented that they had to ignore.

Subjects were asked to identify by name brief presentations of the first objects on the computer. They were instructed to ignore the mask, and the nature of the mask was described to them. Each trial was initiated by the subject by pressing the Enter key. The object was then briefly presented (for 50 ms), and was followed by a mask (for 500 ms). The mask was created by cutting up sections of the target objects, and pasting them together haphazardly. The mask remained the same across all trials. Following the mask, subjects were prompted to type in their responses, and then hit the Enter key to initiate a new trial. Subjects were presented with 62 items at test (10 practice items, 42 target items, and 10 fillers). They were told that 10 practice trials preceded the actual test, but there was no break between the end of the practice trials, and the beginning of the test trials.

Table 6

Proportion of objects correctly identified as a function of Study and Test conditions in Experiment 3.

Study Condition	Test Condition				
	Usual Views		Unusual Views		
	Prop. Correct	Priming Effect Size (r)	Prop. Correct	Priming Effect Size (r)	Effect Size (r)
Same View	0.71	0.14	0.32	0.18	.66
Different View	0.66	0.09	0.21	0.07	.39
Difference	0.05	0.05	0.11	0.11	.41
Nonstudied	0.57		0.14		

Results and Discussion

On the average, subjects failed to correctly identify 7% of the unusual views and less than 1% (.002) of the usual views in the study phase. Since subjects were told the correct response after they attempted to identify the object, the results reported here were not conditionalized on whether subjects could correctly identify the unusual views in the study phase. However, a separate analysis indicated no changes in the pattern of data reported here as a result of conditionalizing performance at test on correct identification at study.

Table 6 shows the proportion of objects correctly identified in Experiment 3 for the usual and unusual views of objects when either same or different views (usual or unusual) were presented at study. Priming scores and effect sizes for each priming effect are also reported. The effect sizes reported in the table were obtained by first calculating effect size by items and by subjects, and then combining them (Rosenthal & Rosnow, 1991).

The data indicate that when usual views were primed with usual views in the study phase, a 14% priming effect was observed. When usual views were primed with unusual views in the study phase, a smaller 9% priming effect was obtained. When unusual views were primed with unusual views in the study phase, an 18% priming effect was obtained. When unusual views were primed with usual views, a smaller

7% priming effect was obtained. The results suggested in general, greater priming when study and test viewpoints matched relative to when they did not.

In order to test whether performance on the identification task was affected by the change in viewpoint between study and test, a repeated measures ANOVA was conducted using two factors -- View at Test (Usual or Unusual) and Studied View (Same View as at test or Different View). The nonstudied baselines were dropped from the analysis because the same baseline performance would be subtracted from the Same View or Different View conditions in each of the test conditions. The main effect of View at Test was reliable both by subjects and by items ($F(1, 47) = 263.53$, $MSe = .03$ by subjects, and $F(1, 41) = 120.17$, $MSe = .06$ by items) indicating that performance on the unusual views differed from performance on the usual views at test. Given the results of the pilot study, this was not a surprising finding. The effect of whether the studied item was in the same view as the tested item or in a different view was also reliable ($F(1, 47) = 8.61$, $MSe = .03$ by subjects, $F(1, 41) = 13.49$, $MSe = .02$ by items). The interaction between the two factors failed to reach significance either by subjects or by items ($F(1, 47) = 1.29$, $MSe = .03$ by subjects, and $F(1, 41) = 1.04$, $MSe = .03$ by items) suggesting that the effects of same or different viewpoint between study and test did not differ as a

function of whether the views were usual or unusual.

Individual t tests were conducted to examine these specific comparisons. Priming effects were reliable for all the studied conditions: Usual-Usual ($t(47) = 4.11$ by subjects, $t(41) = 3.71$ by items), Unusual-Usual ($t(47) = 2.34$ by subjects, $t(41) = 2.82$ by items), Unusual-Unusual ($t(47) = 5.04$ by subjects, $t(41) = 5.79$ by items), and Usual-Unusual ($t(47) = 2.53$ by subjects, $t(41) = 3.13$ by items). The difference between same study-test views versus different study-test views was reliable for the unusual views at test ($t(47) = 2.57$ by subjects, $t(41) = 3.39$ by items) indicating that priming for the unusual views was greatest when the same views were presented at study rather than different views. This pattern was not found, however, with the usual views. Although the same viewpoint conditions showed a numerical advantage over the switched viewpoint conditions (a 5% effect), the difference between Usual-Usual versus Unusual-Usual views was not reliable by subjects or by items ($t(47) = 1.73$, $p < .09$ by subjects, and $t(41) = 1.39$, $p > .10$ by items). This was not surprising given that the size of the effect was small (.23) relative to other effects reported in this experiment. In order to detect an effect of this size, a much greater sample size (100-125) would be needed (Cohen, 1977).

An important finding that emerged from this experiment was that there was an effect of switching viewpoint of the

object between study and test when the subjects were tested on the identification of briefly presented objects. For instance, performance on the Unusual-Unusual condition was reliably better than performance on the Usual-Unusual condition. However, it was unclear from these data whether this result generalized to the conditions when subjects viewed usual angles at test. For the usual views, the difference in priming due to switching viewpoint between study and test appeared to be a much smaller effect. Because the results for the usual views were not as clear cut as the results for the unusual views, a replication of this experiment was attempted in Experiment 4 with the same materials, a different set of subjects, and slightly different procedures.

A potential problem in interpreting the results of Experiment 3 was that the nonstudied base rates were very different for the usual and unusual views (.57 for usual and .14 for unusual views). It could be that the pattern of data obtained for the usual and unusual views was slightly different because usual views were easier to identify than unusual views. Experiment 4 evaluated this possibility by equating baseline performance on usual and unusual views by varying display times for the usual and unusual views. From a pilot study with 12 subjects, it was determined that nonstudied base rates on usual and unusual views of objects were about 30% when usual views were displayed for 34 ms,

and when unusual views were displayed for 84 ms. Thus, in this experiment, nonstudied base rates on usual and unusual views were equated by presenting usual views at 34 ms and unusual views at 84 ms.

Experiment 4

Method

Subjects. Forty-eight Rice undergraduates took part in this experiment in part fulfillment of a course requirement.

Materials. The same 42 items from Experiment 3 with their usual and unusual views were used in this experiment.

Design. The design was identical to Experiment 3.

Procedure. The procedure was the same as in Experiment 3, except that usual and unusual views were presented for 34 and 84 ms at test, respectively.

Results and Discussion

In the study phase, subjects failed to correctly identify 10% of the unusual views of objects and less than 1% (.001) of usual views of objects. Once again, priming from the unusual views was not conditionalized upon correct identification. A separate analysis indicated no changes in the pattern of data reported here as a result of conditionalizing performance at test on correct identification at study.

Table 7 shows the proportion of objects correctly identified in Experiment 4 as a function of the views presented at study and test. Once again, priming scores and effect size indicators are reported for all the differences of interest. Again, effect size was calculated by first determining the size of the effect both by subjects and by items, and then combining the two.

Table 7

Proportion of objects correctly identified as a function of Study and Test conditions in Experiment 4.

Study Condition	Test Condition				
	Usual Views		Unusual Views		
	Prop. Correct	Priming Effect Size (r)	Prop. Correct	Priming Effect Size (r)	Effect Size (r)
Same View	0.47	0.15	0.42	0.15	.53
Different View	0.44	0.12	0.19	0.12	.45
Difference	0.03	0.03	0.23	0.03	.18
Nonstudied	0.32		0.29		

As the table shows, the nonstudied base rate for the usual views at test (.32) was about equal to the base rate for the unusual views (.29), indicating that usual and unusual views were equally difficult for subjects to identify. For the usual views, a 15% priming effect was obtained as a function having studied the same usual views at study, and a roughly equivalent 12% effect was obtained as a function of having studied an unusual view. For the unusual views, a 42% priming effect was obtained when the same unusual views were presented in the study phase, but a smaller 19% effect was obtained when usual views were presented in the study phase.

Once again, nonstudied base rates were dropped from the analysis, and a repeated measures ANOVA was conducted with the two factors of View at Test (Usual or Unusual) and Studied View (Same as test view, or Different from test view). The results indicated reliable main effects of View at Test ($F(1, 47) = 18.51$, $MSe = .06$ by subjects, $F(1, 41) = 8.38$, $MSe = .10$ by items), and Studied View ($F(1, 47) = 28.01$, $MSe = .03$ by subjects, $F(1, 41) = 34.42$, $MSe = .02$ by items). The more important result was that the interaction between the two was also reliable ($F(1, 47) = 16.00$, $MSe = .03$ by subjects, and $F(1, 41) = 14.16$, $MSe = .03$ by items), indicating that the effect of switching viewpoint between study and test differed reliably for usual and unusual views.

Individual t tests indicated reliable priming effects for all study conditions: Usual-Usual ($t(47) = 4.07$ by subject, $t(41) = 4.23$ by items), Unusual-Usual ($t(47) = 3.27$ by subject, $t(41) = 3.58$), Unusual-Unusual ($t(47) = 9.90$ by subjects, $t(41) = 11.87$ by items), Usual-Unusual ($t(47) = 4.08$ by subjects, $t(41) = 5.76$ by items).

The results for the unusual views paralleled those found in Experiment 3. Performance on the unusual views differed as a function of study condition: when the study condition was also that of an unusual view, performance was reliably superior relative to when the study condition was a usual view ($t(47) = 5.55$ by subjects, $t(41) = 6.34$ by items). These data suggest specificity in priming across viewpoints of pictures, so that priming for the same views of objects (Unusual at study, Unusual at test) is much better than priming across viewpoints (Usual at study, Unusual at test). Once again, the results for the usual views failed to show the effects of specificity. Performance on the usual views did not differ reliably as a function of having studied the same usual view or a different unusual view ($t(47) = 1.35$, by subjects, $t(41) = 1.13$ by items). Again, this result was not surprising given that the size of the effect was small (.18) relative to the other effects reported in this experiment.

The results of Experiment 4 were remarkably similar to the results of Experiment 3, except that priming effects for

the unusual views on both the same and the different viewpoint study conditions were much larger in Experiment 4. This might be due to lower base rate identification performance for the unusual views in Experiment 3 (.14) relative to Experiment 4 (.29). However, similar changes in base rate for usual views between Experiment 3 (.57) and Experiment 4 (.32) resulted in virtually no difference in priming effects. This suggests the interesting possibility that priming does not change as a function of changes in base rate over intermediate ranges, but it is influenced by changes in base rates at the extremes.

The most important finding that emerged from Experiments 3 and 4 was that asymmetric patterns of priming were observed when study and test objects differed in viewing angle. When subjects studied usual or unusual views, and were later tested on unusual views, a large effect of switching viewpoint between study and test was observed on priming (effect size ranging from .41 to .66). When subjects studied usual or unusual views, and were later tested with usual views, priming showed a relatively small effect of switching viewpoint between study and test (effect size ranging from .18 to .23). Across the two experiments, the size of the effect indicated that a much larger sample size (100-125) would be required to observe the difference in priming between the same and different viewpoints for usual views. In fact, when the data were analyzed by

collapsing across the two experiments, the effect of switching viewpoints for usual views approached significance ($t(95) = 1.99$, $p < .05$ by subjects, $t(81) = 1.79$, $p < .10$ by items). Even so, only 22 out of 42 items showed reduced priming for the usual views when study and test views were different, 9 items showed no difference, and 11 items showed a reversal (see Appendix D). On the other hand, the effect of switching views for unusual views was more consistent across items: 32 out of 42 items showed reduced priming when study and test views were different, 7 items showed no difference, and 3 items showed a reversal.

These data suggest that when subjects identified the unusual views of objects in the study phase, they also reconstructed a usual view of the object, which would explain why studying an unusual view primed identification of a usual view almost as much as studying the same usual view. This finding is even more impressive when one considers that there are typically multiple viewpoints that are canonical or usual views of a given object (Palmer, Rosch, & Chase, 1981; Tarr & Pinker, 1989). The fact that as much priming was observed in these experiments from the unusual view to an arbitrarily selected usual view makes the result a surprising one. The present data support the notion that unusual views of objects are recognized by a transformation to more usual or canonical views (Tarr & Pinker, 1989; Ullman, 1989).

However, some component of priming appears to be driven by processing of common features or parts as well, because priming was obtained when usual views of objects were studied, and unusual views were presented at test.

(Presumably, recognition of a usual view of an object does not require the reconstruction of all the unusual views of the object.) This provides support for the idea that priming is sensitive to common parts, or distinctive features that are present in both study and test objects (e.g., Biederman, 1987). However, priming does not appear to be driven by common features or parts alone, because asymmetric patterns of priming that were obtained depending on whether usual or unusual views were presented at test. The advantage for preserving the same viewpoint between study and test was much greater for unusual views at test than for usual views even though the match between the different views in each case was identical. Thus, neither set of theories (Biederman, 1987, or Tarr & Pinker, 1989) can account for all the findings in this experiment. Only a combination of the two approaches can account for the data. This alternative is discussed in the General Discussion.

A curious finding in Experiment 4 was that priming for the unusual views was much greater than priming for the usual views when they were repeated at test (Usual-Usual and Unusual-Unusual), suggesting that unfamiliar materials show a larger priming effect than familiar material. A similar

result has been reported by Watkins and Peynircioglu (1983) with a word fragment completion task. In their second experiment, the effects of changing the language of presentation between studied and tested words were examined with Turkish-English bilingual subjects. The dominant language for these subjects was Turkish. Watkins and Peynircioglu (1983) found that priming on a word fragment completion task was restricted to the language of presentation at study. Words that were presented in English primed fragment completion if the fragments were also presented in English, and words presented in Turkish primed fragment completion if the fragment was also presented in Turkish. Little priming was observed when the words were presented in Turkish, and the tested fragment was its English equivalent, or vice versa. Interestingly, more priming was observed in the English-English conditions (.24) relative to the Turkish-Turkish conditions (.08), suggesting that familiar materials (in this case, Turkish) show less priming than unfamiliar ones. Similarly, it has been reported that low-frequency words show greater priming than high-frequency words on word fragment completion (MacLeod, 1989), word identification tasks (Jacoby & Hayman, 1987) and lexical decision tasks (Scarborough, Cortese, & Scarborough, 1977). Although there is no clear theoretical interpretation of these results, it suggests a strange inconsistency. If priming is mediated by representations

involved in the perception of objects and words (Tulving and Schacter, 1990; Biederman & Cooper, in press), why is such a large advantage obtained for items that are difficult to perceive? Presumably, we do not use these low frequency, unfamiliar words or difficult views of objects in the recognition of new words or objects (or they would not be low frequency words or objects). So the question remains as to why priming is greatest for these less frequent materials. Importantly, Experiment 4 shows that the difference exists even when base rates are experimentally equated, which has not been shown in previous investigations. In fact, when the base rates were not equated (as in Experiment 3), no such advantage was obtained for unusual views. The effect size for priming in the Unusual-Unusual condition was about the same as priming in the Usual-Usual condition (.66 versus .50).

A potential problem with Experiments 3 and 4 was that subjects were asked to identify the objects by their names in the study phase. While this procedure was necessary to ensure that unusual views had indeed been recognized, providing subjects with the names of the objects may have produced some priming on the later picture identification test. The results of Experiment 1 suggest that words produce little priming on picture priming tasks, but to ensure that changes in the task (from picture fragment identification to the identification of intact pictures), or

the materials (from line drawings to photographs) did not change the basic conclusions drawn in Experiment 1, a further experiment was carried out. In Experiment 5, the effect of studying words on later priming of usual and unusual views of pictures was assessed. In order to enable comparison of priming from words relative to priming from pictures, pictures were also included in the study phase. However, in this experiment, the viewpoint of the picture shown at study was never the same as the viewpoint of the picture shown at test. This was done so that both in the case of words, as well as in the case of pictures, study and test items did not share a physical match. If equivalent priming was observed from pictures and words in this experiment, it could be argued that priming in the cases when viewpoint was switched between study and test was a function having studied the name of the item, and not a function of having accessed three-dimensional information about the object.

Experiment 5

Method

Subjects. Fifty-four Rice undergraduates participated in this experiment in partial fulfillment of a course requirement.

Materials. The same 42 items used in Experiments 4 and 5 were used in this experiment.

Design. A 3 (Study Condition: Word, Different View, Nonstudied) X 2 (Test Condition: Usual and Unusual View) within-subject design was used in the experiment. The assignment of items to the conditions and the counterbalancing was identical to Experiment 4.

Procedure. Subjects received either words or pictures to identify in the study phase. They were told that they had to assist in the development of materials for a future experiment. In each case, they had to identify the picture or word that appeared on the screen (for 2 s). They were told that the words were in an unusual graphics font, and the purpose of the experiment was to ensure that everybody could identify them. Subjects were also informed that they had to identify black and white photographs of objects to ensure that everybody in the future experiment could identify them. As soon as the picture or word disappeared, subjects were asked to type in the name of the studied object or word into the computer. After the subjects had entered the names, the computer always provided them the

name of the correct item, regardless of the correctness of the response. This feedback was provided for both words and pictures. Subjects were asked to pay attention to the feedback. Following this task, subjects once again participated in a distractor task that required them to name all the names of countries in the world for 10 minutes. The procedures followed in the test phase that followed were identical to those in Experiments 3 and 4. The display times for usual and unusual views were fixed at 34 ms and 84 ms respectively (as in Experiment 4).

Results and Discussion

Table 8 shows the proportion of objects correctly identified in Experiment 5 as a function of subjects' having studied words, or objects from a different viewpoint from the one presented at test, and then tested on usual or unusual views of objects. The data indicated equivalent base rates on the usual (.39) and the unusual views (.38). Priming was obtained from studying a usual view to an unusual view (13%), and from studying an unusual view to a usual view (9%). However, studying words yielded little or no priming effects, both for usual views (0%) and unusual views (2%).

Table 8

Proportion of objects correctly identified as a function of Study and Test condition in Experiment 5.

Study Condition	Test Condition			
	Usual Views		Unusual Views	
	Prop. Correct	Priming	Prop. Correct	Priming
Picture-Different View	0.48	0.09	0.51	0.13
Word	0.39	0	0.40	0.02
Nonstudied	0.39		0.38	

As before, a repeated measures ANOVA with Study Condition (Words or Pictures) and Test View (Usual or Unusual) revealed only the main effect of Study Condition ($F(1, 53) = 18.27$, $MSe = .03$ by subjects, $F(1, 41) = 17.69$, $MSe = .02$ by items). No other effects were reliable either by subjects or by items ($F_s < 1$).

Individual t tests revealed reliable priming effects for the Usual-Unusual condition ($t(53) = 3.36$ by subjects, $t(41) = 3.55$ by items) and the Unusual-Usual condition ($t(53) = 1.96$, $p < .05$ by subjects, $t(41) = 2.71$ by items), replicating the results of Experiments 3 and 4. However, priming from words on both usual and unusual views was not reliable ($t_s < 1$). The differences between the Word-Usual and Unusual-Usual conditions was reliable ($t(53) = 3.30$ by subjects, $t(41) = 3.51$ by items). Similarly, the differences between the Word-Unusual and the Usual-Unusual conditions was also reliable ($t(53) = 2.63$ by subjects, $t(41) = 2.80$ by items).

The results are consistent with the findings of Experiment 1 with a different task, a different design (within-subjects) and a more natural set of materials; words show little priming on picture priming tasks. As in Experiment 1, priming from words did not depend on the perceptual difficulty of the test items. Little priming resulted from studying words on both usual and unusual views of objects. These data indicate that the priming observed

across viewpoints of objects in Experiments 3 and 4 was not due to the subjects' naming the concepts in an earlier study phase. Priming was produced only when specific pictorial information was presented about the object.

General Discussion

A broad issue that has been of primary concern in this dissertation is the question: What mediates priming on perceptual priming tasks? In five experiments, priming was shown to be sensitive to the perceptual features of the studied event so that the greatest priming was obtained when study and test items shared the same perceptual features compared to when they did not. When study and test items did not share perceptual features, the amount of priming that was observed depended on the dimension that was being varied. These findings are discussed in greater detail below.

Summary of the Results

Experiments 1 and 5 indicated that mere exposure to the verbal concepts that are tested in the picture priming task do not mediate priming. Little or no priming was obtained from studying words in either experiment even when the perceptual difficulty of resolving the test item was varied (recoverable versus nonrecoverable fragments, Experiment 1) or when more realistic depictions of objects (such as photographs) were used (Experiment 5). Similarly, conceptual processing of words from generating than in a sentence context yielded little priming effects (Experiment 1). These results indicate that priming is specific to the perceptual form of studied items: substantial priming is found from pictures on picture priming tasks compared to

little priming from words. This pattern appeared in both between-subjects (Experiment 1) and within-subjects (Experiment 5) designs. The next step was to determine exactly what perceptual aspects of studied pictures are preserved in priming. Words and pictures may represent the same concept, but they share virtually no perceptual features. What features of the primed object are critical in producing priming?

Previous studies suggest that priming is not specific to the size, location, or left-right orientation of the studied objects (Cooper et al., 1990, Biederman & Cooper, in press). Experiment 2 explored whether priming is sensitive to the specific contours or lines in the studied pictures by examining priming when same or different fragments of the same picture were presented between study and test. Priming was found to be specific to the studied fragment -- greatest priming occurred when the same fragment was presented between study and test, followed by less priming when intact versions of the pictures or different fragments were presented between study and test. These data indicate that priming is sensitive to the particular contours that were presented at study, although there is a nonspecific component to priming as well (as evidenced in intermediate priming from intact pictures to fragments, or priming from a different fragment of the same object).

Experiments 3 and 4 investigated whether priming is

specific to a given two-dimensional view of the object, or whether it generalizes to other views of the same object. Results indicated greater priming (in general) when study and test objects were in same view relative to when they were different. However, priming was also obtained when different views of the same object were presented between study and test. In both experiments, an asymmetry was observed in priming so that studying a canonical view of an object (the usual view) was not a very effective prime for the identification of an unusual view of the object, while studying an unusual view of the object served as a more effective prime for the identification of a canonical view. In fact, studying an unusual view of the object was almost equivalent to studying a usual view of the object when priming was later tested on a usual view. These data represent, for the first time in these experiments, a case of priming not being specific to the perceptual aspects of studied items.

A broad conclusion from these five experiments is that priming is specific to the perceptual aspects of the studied event, but there appears to be an abstract component to priming as well. This abstract component appears to be specific to pictorial information about the studied object. Thus, considerable priming is obtained between different viewpoints of the same object, or between different fragmented versions of the same object, but little priming

is obtained when object names are used as primes. In the next section, these results are discussed in relation to various theoretical accounts of priming.

Theoretical Accounts of Priming

As discussed earlier, theoretical accounts of priming and object recognition fall into two broad categories depending on the assumptions that they make about the representations mediating priming or perception. One class of theories assumes that every time we perceive an object (or word), a single episodic representation integrating the various perceptual and conceptual aspects of the object is formed (Jacoby, Baker, & Brooks, 1989; Kolers & Perkins, 1975; Kolers & Roediger, 1984). In other words, according to these theories, priming reflects the operations of integrated representations. But how do we perceive new images of the same object on another occasion? According to a subset of this class of theories, when the same object is perceived at a different size, orientation or location on a second occasion, the object is perceived by some type of transformation (such as scaling or mental rotation) to the original representation (Lowe, 1987; Tarr & Pinker, 1989; Ullman, 1989).

A second class of theories assumes that every time we perceive an object, the object is decomposed into basic components that are invariant across changes in certain perceptual dimensions such as size, orientation, location,

and viewpoint in depth (Biederman, 1987; Biederman & E. Cooper, 1990; Marr & Nishihara, 1978; Sutherland, 1968). Objects (and words) are thus assumed to be stored as abstract representations. Priming on object and word priming tasks is assumed to reflect the activation of these abstract structural descriptions (Schacter, 1990; Tulving & Schacter, 1990, L. Cooper et al., 1990). Measures of explicit memory, on the other hand, are assumed to reflect a different set of representations that may be sensitive to certain perceptual features (such as size or orientation) to which the perceptual system is insensitive (Biederman & E. Cooper, in press; L. Cooper et al., 1990). These assumptions lead to a curious paradox. How is it possible for episodic memory to be sensitive to perceptual dimensions to which the perceptual memory seems insensitive? This question is not addressed by these theories of priming.

The findings from these experiments indicating that priming is specific to the perceptual form of the studied item (Experiment 1), the precise contours presented in the study item (Experiment 2), and the particular viewpoint of the studied item (at least with unusual views at test in Experiments 3 and 4) are consistent with the account of priming as reflecting the operations of integrated event-specific representations. It is clear from the present experiments that priming is sensitive to the perceptual aspects of the studied objects, and not merely to their

abstract representations. However, the integrated representation accounts of priming cannot easily predict the conditions under which priming will be observed when study and test objects do not share perceptual features.

One approach to this problem has been to suggest that when study and test objects do not share perceptual features, priming will be a function of the amount of perceptual overlap between study and test objects. Thus, it has been argued in the context of verbal priming that priming between studied and tested words should be greatest for words in the same font, slightly less for words in a different font, and much less for words in a different modality (Roediger & Blaxton, 1987). This explanation of priming in terms of perceptual overlap can account for why changes in size and left-right orientation of pictures do not affect priming. However, it cannot explain one of the findings from this dissertation, viz., the asymmetry that was observed in priming when usual views were primed by unusual views, relative to when unusual views were primed by usual views. Unusual views primed usual views almost as much as did usual views, but usual views primed unusual views much less than unusual views did. The visual similarity between the unusual-usual conditions was identical to that between the usual-unusual conditions, yet priming in the different viewpoint condition was almost equal to priming in the same viewpoint condition for the

usual views, whereas priming in the different viewpoint condition was much smaller than priming in same viewpoint condition for unusual views.

Such asymmetries in priming are not restricted just to this experiment. For instance, Kolers and Perkins (1975) found that training on reading certain types of geometrically transformed text (e.g., inverted text) sometimes resulted in more transfer to reading other geometric transformations of text (e.g., rotated text) than training on the same transformation (rotated text). The transfer was, however, asymmetric; training on rotated text showed very little transfer to reading inverted text. Kolers and Perkins (1975) argued that such asymmetries in transfer occur when the perceptual operations involved in perceiving one type of transformation (say, inverted text) have all the components required to read rotated text, but the operations involved in perceiving rotated text do not include all the components required in the perception of inverted text. While plausible, this account cannot specify a priori the conditions under which transfer will not occur.

A second approach to the problem of explaining transfer across conditions where study and test objects do not share the same perceptual features is provided by theories of object recognition (e.g., Tarr & Pinker, 1989; Lowe, 1987; Ullman, 1989). As opposed to theoretical accounts of priming as a memory phenomenon, accounts of priming as a

phenomenon of perception have focussed on how two images of the same object are recognized as equivalent even when the perceptual features of the object are virtually never the same across images viewed at different times. This class of theories still maintains the assumption that integrated, episodic representations mediate priming. However, they argue that new images of the same objects are recognized by scaling and transforming the new object to match the stored representations. Thus, for instance, if the new image of the object differs from the previous image in its orientation along the plane, this image is transformed into its canonical orientation before it can be recognized. This explanation can account for the asymmetric priming observed in Experiments 3 and 4, because usual views at study would match existing canonical representations so that there would be no need for rotation of the usual view in depth to achieve recognition. However, unusual views at study would have to be transformed to match existing canonical representations in order to be recognized, and hence, substantial transfer should occur from unusual views to usual views.

But how does the perceiver know, before recognition has occurred, the direction in which the object has to be rotated? Ullman (1989) suggests that a small set of distinctive features may serve as cues (or "alignment keys") to signal the direction in which the object must be turned.

These same distinctive features are used in matching the input image to stored representations. This explanation can account for why some priming was found in Experiments 3 and 4 when usual views were presented at study, and unusual views were presented at test. Presumably, usual views are not transformed into unusual views at study to be recognized, nor is there any existing episodic representation of the unusual views to mediate priming. However, because the usual and unusual view of the object share some distinctive features, some priming is obtained.

The preceding discussion suggests that priming reflects the perceptual aspects of an integrated representation that is specific to the studied event rather than the activation of an abstract perceptual representation. However, as pointed out earlier, there are other findings in the literature indicating that priming reflects the operation of abstract representations that are different from those involved in episodic memory tests. In these experiments, priming was not sensitive to the exact size, location, left-right orientation or even viewpoint of study items (Biederman & E. Cooper, in press; Biederman & Gerhardstein, 1990, cited in Biederman, Hilton, & Hummel, 1991; L. Cooper et al., 1990), while the same perceptual aspects appeared to influence recognition memory. At this point, there are not enough data to organize these discrepant results in a coherent manner. For instance, it is not clear whether

insensitivity to the perceptual aspects such as size, left-right orientation, and location, is a property of all priming tasks. Certainly, verbal and nonverbal priming differ in their sensitivity to these perceptual aspects, because priming in words is sensitive to left-right orientation (Kolars & Perkins, 1975) while priming in pictures is not.

The existing data indicate that, in general, there is a component to priming that is event-specific, and another component that is more abstract but object-specific. A similar conclusion has been drawn by Kirsner, Dunn and Standen (1989) in the verbal domain. Kirsner et al., (1989) argue that priming in words has a event-specific component that is specific to the modality and typography of the studied word, and a non-specific component that is specific to the word. Thus, no priming is obtained when different lexical responses are primed between study and test (e.g., dog and chien in bilinguals), but priming is obtained when the same lexical item occurs at study and test even when there is virtually no overlap between their perceptual features (e.g., the same word written in Hindi and Urdu scripts). Further investigation of this abstract component in pictorial and verbal priming is likely to shed light on how perceptual procedures establish equivalences between different forms of the same objects or words.

Footnotes

¹ Priming measures that rely on the conceptual processing of a stimulus (e.g., priming on a task requiring the generation of exemplars to a category name) are assumed to tap conceptual aspects of memory (Blaxton, 1989; Srinivas & Roediger, 1990). Thus, conceptual priming measures are believed to be similar to explicit or conventional memory tests by this theoretical account.

References

- Bartram, D.J. (1974). The role of visual and semantic codes in object naming. Cognitive Psychology, 6, 325-356.
- Bartram, D.J. (1976). Levels of coding in picture-picture comparison tasks. Memory and Cognition, 4, 593-602.
- Biederman, I. (1987). Recognition-by-components: A theory of human image understanding. Psychological Review, 94, 115-147.
- Biederman, I., & Cooper, E.E. (1990). Scale invariance in visual object priming. Unpublished manuscript.
- Biederman, I., & Cooper, E.E. (in press). Priming contour-deleted images: Evidence for intermediate representations in visual object recognition. Cognitive Psychology.
- Biederman, I., & Cooper, E.E. (in press). Evidence for complete translational and reflectional invariance in visual object priming. Perception.
- Biederman, I., Hilton, H.J., & Hummel, J.E. (1991). Pattern goodness and pattern recognition. Chapter to appear in J.R. Pomerantz & G.R. Lockhead (Eds.), The Perception of Structure. Washington D.C.: APA.
- Bentin, S., & Moscovitch, M. (1988). The time course of repetition effects for words and unfamiliar faces. Journal of Experimental Psychology: General, 117, 148-160.
- Brown, A.S., Neblett, D.R., Jones, T.C., & Mitchell, D.B.

(in press). Transfer of processing in repetition priming: Some inappropriate findings. Journal of Experimental Psychology: Learning, Memory, and Cognition.

Bruce, V., & Valentine, T. (1985). Identity priming in the recognition of familiar faces. British Journal of Psychology, 76, 373-383.

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

Cohen, J. (1977). Statistical power analysis for the behavioral sciences. NY: Academic Press.

Cooper, L. A., Schacter, D.L., Ballesteros, S., & Moore, C. (1990). Priming of structural representations of three-dimensional objects. Paper presented at the meetings of the Psychonomic Society, New Orleans.

Crovitz, H.F., Harvey, M.T., & McClanahan, S. (1981). Hidden memory: A rapid method for the study of amnesia using perceptual learning. Cortex, 17, 273-278.

Durso, F.T., & Johnson, M.K. (1979). Facilitation in naming and categorizing repeated pictures and words. Journal of Experimental Psychology: Human Learning and Memory, 5, 449-459.

Ellis, A.W., Young, A.W., Flude, B.M., & Hay, D.C. (1987).

- Repetition priming of face recognition. The Quarterly Journal of Experimental Psychology, 39A, 193-210.
- Gardiner, J.M., Dawson, A.J., & Sutton, E.A. (1989). Specificity and generality of enhanced priming effects for self-generated study items. American Journal of Psychology, 102, 295-305.
- Gollin, E.S. (1960). Developmental studies of visual recognition of incomplete objects. Perceptual and Motor Skills, 11, 289-298.
- Hayman, C.A.G., & Tulving, E. (1989). Is priming in fragment completion based on a "traceless" memory system? Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 941-956.
- Heindel, W.C., Salmon, D.P., & Butters, N. (1990). Pictorial priming and cued recall in Alzheimer's and Huntington's disease. Brain and Cognition, 13, 282-295.
- 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. (1984). Routes to object constancy: Implications from neurological impairments of object constancy. Quarterly Journal of Experimental Psychology, 36A, 385-415.
- Jacoby, L.L., Baker, J.G., & Brooks, L.R. (1989). Episodic

- effects on picture identification: Implications for theories of concept learning and theories of memory. Journal of Experimental Psychology: General, 110, 306-340.
- Jacoby, L.L., & Hayman, C.A.G. (1987). Specific visual transfer in word identification. Journal of Experimental Psychology: Learning, Memory and Cognition, 13, 456-463.
- Johnson, M.K., Kim, J.K., & Risse, G. (1985). Do alcoholic Korsakoff's syndrome patients acquire affective reactions? Journal of Experimental Psychology: Learning, Memory and Cognition, 11, 27-36.
- Jolicoeur, P. (1985). The time to name disoriented natural objects. Memory and Cognition, 13, 289-303.
- Jolicoeur, P., & Milliken, B. (1989). Identification of disoriented objects: Effects of context of prior presentation. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 200-210.
- Kolers, P.A., Duchnicky, R.L., & Sundstroem, G. (1985). Size in the visual processing of faces and words. Journal of Experimental Psychology: Human Perception and Performance, 11, 726-751.
- Kolers, P.A., & Perkins, D.N. (1975). Spatial and ordinal components of form perception and literacy. Cognitive Psychology, 7, 228-267.
- Kolers, P.A., & Roediger, H.L. (1984). Procedures of mind.

- Journal of Verbal Learning and Verbal Behavior, 23, 425-449.
- Kroll, J.F., & Potter, M.C. (1984). Recognizing words, pictures, and concepts: A comparison of lexical, object, and reality decisions. Journal of verbal Learning and Verbal Behavior, 23, 39-66.
- Kunst-Wilson, W.R., & Zajonc, R.B. (1980). Affective discrimination of stimuli that cannot be recognized. Science, 120, 557-558.
- Lachman, J.L., & Lachman, R. (1980). Age and the actualization of world knowledge. In L.W. Poon, J.L. Fozard, L.S. Cermak, D. Arenberg, & L.W. Thomson (Eds.), New directions in memory and aging (pp. 285-311).
- Leeper, R. (1935). A study of a neglected portion of the field of learning -- the development of sensory organization. Journal of Genetic Psychology, 46, 41-75.
- Lowe, D.G. (1987). The viewpoint inconsistency constraint. International Journal of Computer Vision, 1, 57-72.
- MacLeod, C.M. (1988). Forgotten but not gone: Savings for pictures and words in long term memory. Journal of Experimental Psychology: Learning, Memory, and Cognition, 14, 195-212.
- MacLeod, C.M. (1989). Word context during initial exposure influences degree of priming in word fragment

- completion. Journal of Experimental Psychology: Learning, Memory, and Cognition, 15, 398-406.
- Marr, D., & Nishihara, H.K. (1978). Representation and recognition of the spatial organization of three-dimensional shapes. Proceedings of the Royal Society (London), B200, 269-294.
- Mitchell, D.B. (1989). How many memory systems? Evidence from aging. Journal of Experimental Psychology: Learning, Memory and Cognition, 15, 41-49.
- 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.
- Musen, G. (1989). Implicit and explicit memory for novel visual patterns. Poster paper presented at the meetings of the Psychonomic Society. Atlanta, GA.
- Musen, G., & Triesman, A. (1990). Implicit and explicit memory for visual patterns. Journal of Experimental Psychology: Learning, Memory, and Cognition, 16, 127-137.
- Palmer, S., Rosch, E., & Chase, P. (1981). Canonical perspective and the perception of objects. In J. Long & A. Baddeley (Eds.), (pp. 135-151). Attention and Performance, IX. Hillsdale, NJ: Lawrence Erlbaum Associates.

- Parkin, A.J. (1982). Residual learning capability in organic amnesia, Cortex, 18, 417-440.
- Parkin, A.J., & Streete, S. (1988). Implicit and explicit memory in young children and adults. British Journal of Psychology, 79, 361-369.
- Pinker, S. (1984). Visual cognition: An introduction. Cognition, 18, 1-63.
- Rock, I. (1975). An introduction to perception. NY: Macmillan. (pp. 350).
- Roediger, H.L., & Blaxton, T.A. (1987). Retrieval modes produce dissociations in memory for surface information. In D. Gorfein & R.R. Hoffman (Eds.), Memory and Learning: The Ebbinghaus Centennial Conference. Hillsdale, NJ: Erlbaum.
- Roediger, H.L., & Weldon, M.S. (1987). Reversing the picture superiority effect. In M.A. McDaniel & M. Pressley (Eds.), Imagery and related mnemonic processes; theories, individual differences, and applications. (pp. 151-174). New York: Springer Verlag.
- Roediger, H.L., Weldon, M.S., & Challis, B.H. (1989). Explaining dissociations between implicit and explicit measures of retention: A processing account. In H.L. Roediger and F.I.M. Craik (Eds.), Varieties of Memory and Consciousness: Essays in Honour of Endel Tulving. Hillsdale, N.J.: Erlbaum.

- Rosenthal, R. & Rosnow, R.L. (1991). Essentials of behavioral research: Methods and data analysis. NY: McGraw-Hill.
- Scarborough, D.L., Cortese, C., & Scarborough, H.S. (1977). Frequency and repetition effects in lexical memory. Journal of Experimental Psychology: Human Perception and Performance, 3, 1-17.
- Schacter, D.L. (1987). Implicit memory: History and current status. Journal of Experimental Psychology: Learning, Memory and Cognition, 13, 501-518.
- Schacter, D.L. (1990). Perceptual representation systems and implicit memory: Towards a resolution of the multiple memory systems debate. In A. Diamond (Ed.), The Development and Neural Bases of Higher Cognitive Functions. NY: Annals of the New York Academy of Sciences.
- Schacter, D.L., Cooper, L.A., & Delaney, S.M. (1990a). Implicit memory for unfamiliar objects depends on access to structural descriptions. Journal of Experimental Psychology: General, 119, 5-24.
- Schacter, D.L., Delaney, S.M., & Merikle, E.P. (1990b). Priming of nonverbal information and the nature of implicit memory. In G.H. Bower (Ed.), The Psychology of Learning and Motivation, 26. New York: Academic Press.
- Snodgrass, J.G., & Feenan, K. (1990). Priming effects in

picture fragment completion: Support for the perceptual closure hypothesis. Journal of Experimental Psychology: General, 119, 276-298.

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.

Srinivas, K., & Roediger, H.L. (1990). Testing the nature of two implicit tests: Dissociations between conceptually-driven and data-driven processes. Journal of Memory and Language, 28, 389-412.

Sutherland, N.S. (1968). Outlines of a theory of visual pattern recognition in animals and man. Proceedings of the Royal Society (London), 171B, 297-317.

Talland, G.A. (1965). Deranged memory. New York: Academic Press.

Tarr, M.J., & Pinker, S. (1989). Mental rotation and orientation-dependence in shape recognition. Cognitive Psychology, 21, 233-282.

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

Ullman, S. (1989). Aligning pictorial descriptions: An approach to object recognition. Cognition, 32, 193-254.

Warren. C., & Morton, J. (1982). The effects of priming on

picture recognition. British Journal of Psychology, 73, 117-129.

Warrington, E.K., & Weiskrantz, L. (1968). New method of testing long-term retention with special reference to amnesic patients. Nature, 217, 972-974.

Warrington, E.K., & Weiskrantz, L. (1978). Further analysis of the prior learning effect in amnesic patients. Neuropsychologia, 16, 169-177.

Watkins, M.J., & Peynircioglu, Z.F. (1983). On the nature of word recall: Evidence for linguistic specificity. Journal of Verbal Learning and Verbal Behavior, 22, 385-394.

Weldon, M.S., & Roediger, H.L. (1987). Altering retrieval demands reverses the picture superiority effect. Memory and Cognition, 15, 269-280.

Winnick, W.A., & Daniel, S.A. (1970). Two kinds of response priming in tachistoscopic recognition. Journal of Experimental Psychology, 84, 74-81.

Young, A.W., McWeeny, K.H., Hay, D.C., & Ellis, A.W. (1986). Access to identity-specific semantic codes from familiar faces. Quarterly Journal of Experimental Psychology, 38-A, 271-295.

Appendix A

The set of pictures along with their recoverable and nonrecoverable fragments used in the pilot study and in Experiment 1.

Recoverable

Nonrecoverable

Recoverable

Nonrecoverable

Recoverable

Nonrecoverable

Recoverable

Nonrecoverable

Recoverable

Nonrecoverable

Recoverable

Nonrecoverable

Recoverable

Nonrecoverable

Recoverable

Nonrecoverable

Appendix B

The set of verbal materials used in Experiment 1. The set of sentence frames used for the generation of target words, and the target words are provided.

1. In Holland, this large device with blades generates electricity from the breeze. w_____ (windmill)
2. You take infants out for walks in a stroller or in this. b_____ (baby carriage)
3. This is a large farm building used to store grain, farm animals, or farm equipment. b_____ (barn)
4. This is a vehicle that has two wheels and is pedalled. b_____ (bicycle)
5. A male garment that is similar to a blouse is called this. s_____ (shirt)
6. Cowboys often wear this type of tall, leather footgear. b_____ (boot)
7. A ribbon or a necktie is often tied in a knot like this. b_____ (bow)
8. A popular food item is peanut butter and jelly on this. b_____ (bread)
9. This is a brightly colored insect that is related to the moth. b_____ (butterfly)
10. For birthdays, people often bake this. c_____ (cake)
11. You often light this in churches. c_____ (candle)
12. This is another name for a divan or a sofa. c_____ (couch)

13. A piece of furniture with a flat top and drawers, used when reading or writing is called this. d_____ (desk)

14. You drink coffee or tea from this. c_____ (cup)

15. In order to enter a house, you need to turn this round handle. d_____ (doorknob)

16. Just as an apple belongs to the category, "Fruit", a rose belongs to this category. f_____ (flower)

17. On Sesame Street, Kermit is this green animal.

f_____ (frog)

18. You use this to correct for poor eyesight. g_____ (glasses)

19. You shoot someone with this instrument. g_____ (gun)

20. When you enter a building, you typically take off your coat and this piece of headgear. h_____ (hat)

21. You remove creases or wrinkles in your clothes with this. i_____ (iron)

22. This is a vessel used to boil water to make tea.

k_____ (kettle)

23. You use this small metal object to start your car.

k_____ (key)

24. This is an aircraft with rotary blades that can land on top of buildings. h_____ (helicopter)

25. This tool is used by firemen to climb up and down.

l_____ (ladder)

26. This decorative object is used for illuminating rooms, and can be placed on the floor or on tables. l_____

(lamp)

27. This source of illumination is sold by the number of watts, e.g., 60 watts. l_____ (lightbulb)

28. The police often use this to make a shrill sound (often to beckon dogs). w_____ (whistle)

29. Burglars often "pick" this device in a door that secures things. l_____ (lock)

30. This keeps your hand warm in winter (like a glove). m_____ (mitten)

31. This is an edible fungus that looks like a toadstool. m_____ (mushroom)

32. This colorful paper toy is used for flying. k_____ (kite)

33. You use this with a bolt or screw to tighten something. n_____ (nail)

34. You serve champagne in a goblet or in this. w_____ (wine glass)

35. The Canadian national symbol is this part of a maple tree. l_____ (leaf)

36. Electrical appliances have this to connect into sockets. p_____ (plug)

37. A woman's purse is also called this. h_____ (handbag)

38. This is also called a phonograph or a gramophone. r_____ (record player)

39. This water craft is propelled by using a cloth or

canvas to catch the breeze. s_____ (sailboat)

40. This is used to cut paper or cloth. s_____
(scissors)

41. This soft bodied animal has a spiral shell, and it
crawls very slowly. s_____ (snail)

42. You put this on before you put on your shoes. s_____
(sock)

43. This animal builds cobwebs. s_____ (spider)

44. This is used to pack one's belongings when one is
travelling. s_____ (suitcase)

45. Alexander Graham Bell invented this. t_____
(telephone)

46. You hold this over you for protection from the rain.
u_____ (umbrella)

47. You wear this on your wrist so you can tell the time.
w_____ (watch)

48. This container with a long tubular spout is something
you use in a garden. w_____ (watering can)

Appendix C

Samples of the four viewing angles of the objects used in Experiments 3 and 4 are provided. For the each of the objects shown, the following views (numbered 1 to 4 from top to bottom) were selected to be usual or unusual based on data from the second pilot study.

Object Name	Usual View	Unusual View
1. wrench	4	3
2. fork	4	1
3. helicopter	2	4
4. car	2	4
5. shoe	4	3
6. hammer	4	2
7. mug	2	4

Appendix D

The combined results of Experiments 3 and 4 are shown by items below. For each item, the difference between the same and different viewpoint conditions when the tested item was a usual view or an unusual view is given in the Table. A positive difference indicates that priming was greater for these items when same views were presented between study and test. A negative difference indicates that priming was better when different views were presented between study and test. Information is also provided about whether the unusual view of the object included the foreshortening on one of its natural axes (F in the table), the occlusion of distinctive parts (P in the table), or a combination of the two.

	Features of the Unusual Views	Diff. Between Same and Different Views	
		Usual	Unusual
1. cow	F + P	-0.12	+0.31
2. wrench	F	+0.12	+0.32
3. hairdryer	P	+0.13	+0.25
4. kangaroo	F + P	+0.19	+0.19
5. chair	P	+0.06	+0.29
6. screwdriver	F	-0.19	+0.19
7. truck	F + P	0	+0.25
8. pencil	F	0	0
9. hammer	P	+0.12	0
10. hairbrush	F + P	-0.06	+0.31
11. lock	F	+0.06	+0.06
12. screw	F	+0.06	+0.29
13. table	F + P	0	+0.31
14. ring	P	+0.25	-0.13
15. pan	F	-0.31	0
16. lightbulb	F	+0.07	+0.38
17. cassette	F	+0.18	+0.13
18. plug	P	+0.36	+0.19
19. knife	F	+0.25	+0.13

20. racket	F			+0.07	+0.19
21. goat	F	+	P	+0.50	+0.07
22. car	F	+	P	0	+0.31
23. fork	F			-0.04	+0.25
24. paintbrush	F			-0.12	-0.04
25. plane	F	+	P	-0.07	0
26. shark	F			+0.18	+0.25
27. shoe	F	+	P	-0.19	+0.36
28. horse	F	+	P	0	+0.06
29. clock	F			+0.13	+0.18
30. gun	F	+	P	-0.06	0
31. comb	F			+0.06	+0.31
32. camera			P	+0.13	0
33. scissors	F			0	0
34. glasses			P	+0.18	+0.19
35. guitar	F	+	P	0	+0.32
36. hanger	F			0	+0.07
37. key	F			0	+0.18
38. cup	F			-0.25	+0.25
39. watch			P	+0.12	+0.31
40. spoon	F			+0.07	+0.12
41. helicopter	F	+	P	+0.06	+0.12
42. fan	F	+	P	-0.13	+0.25