PRIMING OF NONVERBAL INFORMATION AND THE NATURE OF IMPLICIT MEMORY

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I. Introduction

Implicit memory refers to the unintentional retrieval of information that was acquired during a specific episode on tests that do not require conscious recollection of that episode (Graf & Schacter, 1985; Schacter, 1987). Systematic investigation of implicit memory represents a relatively new research direction in cognitive psychology and neuropsychology. Psychological studies have been traditonally concerned with explicit memory—intentional, conscious recollection of recent events—as expressed on standard recall and recognition tests. During the past several years, however, there has been a virtual explosion of research concerning various kinds of implicit memory, stimulated largely by studies that have shown that implicit memory can be dissociated sharply from explicit remembering. The dissociations have been produced both by a variety of experimental manipulations in normal subjects and by demonstrations that amnesic patients show intact implicit memory despite impaired explicit memory (for review, see Richardson-Klavehn & Bjork, 1988; Schacter, 1987; Shimamura, 1986).

Various forms of learning and retention can be grouped under the general descriptive heading of "implicit memory," including such phenomena as skill learning and conditioning (see Schacter, 1987). Perhaps the most intensively studied type of implicit memory, however, is known as repetition or direct *priming* (e.g., Cofer, 1967; Tulving & Schacter, 1990). Priming refers to a facilitation in performance that is attributable to prior study of a particular set of target items; priming need not and frequently does not involve any conscious recollection of the targets or the study episode in which they were encountered. The target items in priming experiments are typically familiar words, pseudowords, paired associates, and other verbal materials. The heavy emphasis on verbal information in priming studies may be partly attributable to the historical links between research on priming phenomena and concern with issues of lexical representation and access (e.g., Kirsner & Smith, 1974; Morton, 1979; Scarborough, Gerard, & Cortese, 1979; see Schacter, 1987); it may also be partly attributable to the attention devoted to priming recently by "mainstream" memory researchers, who have traditionally used words and word pairs as target items in explicit memory experiments (e.g. Tulving, 1983).

Although priming research has focused on verbal information, it has not done so exclusively: A number of studies have documented and explored priming of nonverbal information. We think that such studies are important for at least four reasons. First, the preoccupation with words and similar verbal items that characterizes a good deal of past and present priming research will likely produce a rather narrow view of the properties and features of implicit memory. Therefore, at this relatively early stage of research it is desirable and perhaps necessary to establish a broad data base in order to delineate critical characteristics of relevant phenomena. A second and related point is that a narrow empirical focus may also be theoretically misleading. Models of priming and implicit memory that are based exclusively on studies of verbal materials could well be led astray by an undue reliance on phenomena that reflect idiosyncratic properties of verbal information. Third, just as research on lexical priming has provided links between studies of memory and language (e.g., Kirsner & Dunn, 1985), research on priming of nonverbal information could help to build bridges between studies of memory and perception (e.g, Schacter, Cooper, & Delaney, 1990). Fourth, it seems clear from an evolutionary perspective that memory did not evolve initially to deal with verbal information; memory for nonverbal information must represent an earlier evolutionary achievement than memory for verbal information (e.g., Rozin, 1976). Since there are good reasons to believe that the evolutionary process of natural selection has shaped the architecture of memory systems (Sherry & Schacter, 1987) and that the memory systems involved in priming are relatively primitive both phylogenetically and ontogenetically (Schacter, 1984; Schacter & Moscovitch, 1984; Squire, 1987; Tulving &

Schacter, 1990), a theoretical and empirical concern with priming of nonverbal information seems particularly appropriate.

In this chapter we review existing evidence on priming of nonverbal information, discuss methodological, conceptual, and theoretical issues that arise from this research, and sketch a preliminary framework for conceptualizing relevant phenomena that integrates implicit memory research with recent neuropsychological studies of perceptual disorders that are produced by brain damage.

II. Review of the Experimental Evidence

We now turn our attention to experimental data on priming of various kinds of nonverbal information. It should be noted from the outset that we focus largely on studies of repetition or direct priming that conform to what we will call the *study–test* paradigm. In a prototypical study–test procedure, a set of items is initially presented to subjects, followed by a delay that is usually measured in minutes, days, or weeks; then a test is given in which subjects perform a task that does not make explicit reference to or require conscious recollection of the previously presented items. Priming is typically revealed by faster or more accurate performance on previously studied items than on nonstudied or baseline items. We will pay relatively little attention to studies in which primes and targets are separated by extremely brief delays on the order of milliseconds. Although several such studies using nonverbal information have been reported (e.g., Bharucha & Stoeckig, 1986, 1987; Henderson, Pollatsek, & Rayner, 1987; Humphreys & Quinlan, 1988), this type of priming involves a rather different set of issues, paradigms, and perhaps mechanisms than those that are of principal concern to us (for review, see Farah, 1989).

Our review is divided into three major sections, corresponding to the three types of materials that have been used most often in studies of nonverbal priming: familiar objects, novel objects and patterns, and familiar and unfamiliar faces. After considering relevant studies, we discuss a number of methodological and conceptual issues that emerge from the review.

A. Priming of Familiar Objects

In studies concerned with priming of familiar objects, subjects are typically exposed first to pictures or line drawings that contain two-dimensional representations of familiar three-dimensional objects—either animate (e.g., a dog or cow) or inanimate (e.g., a table or car). In most experiments, priming is later assessed by requiring subjects to identify some sort of perceptually degraded stimulus: either a *nonverbal* item such as an incomplete, fragmented, or briefly presented drawing of an object, or a *verbal* item such as a fragmented or briefly presented word. We consider first studies of the former type and then discuss studies of the latter type, which focus on issues of transfer between pictures and words.

1. Neuropsychological and Developmental Evidence

Although intensive experimental scrutiny of priming and implicit memory phenomena represents a relatively recent development, a number of relevant studies were reported prior to the recent surge of interest. Perhaps the earliest of them were studies by Heilbronner conducted in the first decade of the twentieth century (cited in Milner, Corkin, & Teuber, 1968; Parkin, 1982). Heilbronner used a picture-fragment completion task in which brain-damaged and normal subjects were initially shown a series of fragmented pictures of common objects and were asked to identify each object; if they were unable to identify an object from a particular fragment, a series of less fragmented pictures was presented until identification was achieved. When subjects again attempted to identify picture fragments after a delay, Heilbronner observed significant savings in identifying previously presented fragments on the second test. This procedure, which came to be known as "Heilbronner's method," was used in a study of three Korsakoff amnesics by Schneider (1912, cited in Parkin, 1982; Kinsbourne, 1989). He found that amnesics exhibited significant savings in identifying previously exposed fragmented pictures across retention intervals ranging from 7 days to 4 months—even though the patients apparently claimed that they had never seen the pictures previously. This observation thus constitutes an early example of what we would now refer to as a dissociation between implicit and explicit memory.

There was apparently little attempt to follow up Schneider's intriguing observations, but a number of similar studies of amnesic patients were reported before the "modern era" of research on implicit memory. Williams (1953) required 31 patients with memory disturbances and 20 control subjects to name a graded series of inkblot silhouettes of familiar animals; each successive silhouette approximated more closely the shape of the target animals. Free recall and "prompted recall," where silhouettes were presented again for identification, were tested after delays of 2 hr and 7 days. Although memory-disordered patients performed at near zero levels on the free recall test, they performed relatively well on the prompted recall test, particularly at the 2-hr delay. Note, however, that on the prompted recall test, subjects were given explicit memory instructions to try to remember which previously shown animal was represented by the silhouette (Williams, 1953, p. 15). In addition, no information was presented concerning the severity of memory disorders in the patient group. Therefore, it is not clear whether Williams' results should be attributed to priming or to explicit memory. Talland (1965) described similar results in his classic monograph on Korsakoff's syndrome. He presented 14 Korsakoff patients with pictures of familiar objects that were fragmented to different degrees and presented briefly on a tachistoscope for varying amounts of time. Talland reported that previously exposed pictures were identified more readily on a subsequent test than were a novel set of similar fragmented pictures. However, Talland made no mention of any dissociation between this priming effect and patients' inability to recollect their prior experiences. Instead, he simply noted that "Amnesic patients are evidently able to form and retain for a while memory images, in the sense that other persons do" (p. 170).

Probably the best-known study on priming of familiar objects in amnesic patients was reported by Warrington and Weiskrantz (1968), who used the graded series of fragmented pictures developed by Gollin (1960) together with a procedure similar to the one used by Heilbronner and by Schneider. Each of six amnesic patients was presented on an initial trial with the most incomplete version of an object, followed by increasingly less fragmented instances until identification was achieved. The identical procedure was then repeated on four subsequent trials within the same day; five further trials were given on a second and a third day of testing, respectively. Warrington and Weiskrantz (1968) found that all of the amnesic patients exhibited considerable savings—that is, priming—across trials and days. They argued that their findings show long-term retention of specific objects by amnesic patients, and not some sort of nonspecific practice effect, because no improvements in identification performance were observed when fragments of different objects were presented on successive trials. Significantly, however, the learning or priming exhibited by the amnesic patients, though substantial, was not normal; control subjects showed consistently higher levels of identification performance than did amnesics. Although Warrington and Weiskrantz did not distinguish explicitly between the form of memory tapped by the identification task and the form of memory involved in standard recall and recognition tests, they did point out that ". . . in addition to the rapidity and uniformity in learning this task, patients find it a much less exacting test of memory than more conventional ones. They treat it more as a 'guessing game' than a formal test of memory" (1968, p. 974).

Milner *et al.* (1968) used the Gollin figures and a procedure similar to the one described by Warrington and Weiskrantz in a study of the densely amnesic patient H.M. (Scoville & Milner, 1957). In their experiment, a 1-hr delay intervened between initial presentation of the fragmented pictures and the second presentation or test. Milner *et al.* reported a 48% reduction in H.M's identification errors from initial presentation to test. This facilitation or priming effect was observed even though H.M. ". . . did not remember having taken the test before" (1968, p. 230). Consistent with the data of Warrington and Weiskrantz, however, the priming effect observed in H.M. was not normal; a group of 10 matched control subjects showed a 77% reduction in error rate under identical experimental conditions. Milner *et al.* argued that normal subjects showed a larger facilitation because they made use of "verbal [explicit] memory" (1968, p. 231) abilities not available to H.M. in order to retrieve object names and thereby supplement identification performance.

Priming of familiar objects has been observed in amnesic patients with a number of procedures other than the fragmented-pictures task. Warrington and Weiskrantz (1978) reported a study using the McGill Anomalies Test, in which a picture of an otherwise common scene contains a familiar object in an inappropriate place. Warrington and Weiskrantz (1978) recorded the time it took for amnesic patients to detect the anomalous object and found that they did so more quickly on their second attempt than on their first (see also Baddeley, 1982). Meudell and Mayes (1981) reported a similar finding with a task that involved finding a hidden object in a cartoon. They further found that amnesic patients did not discriminate between previously presented and new cartoon pictures when tested with an explicit recognition test. Crovitz, Harvey, and McClanahan (1981) presented eight amnesic patients of mixed etiologies with two pictures containing hidden figures (e.g., a cow) that are typically not perceived immediately on initial viewing (Carmichael, 1951; Dallenbach, 1951) and noted the time required to perceive the figures. Twenty-four hr later, two old and two new hidden figures were presented and patients again attempted to spot them. Crovitz *et al.* found that patients perceived the old figures much more quickly on the second presentation than on the first, and more quickly than new figures, even though several patients expressed no explicit recollection for the initial presentation of the figures. These results thus demonstrate a relatively long lasting item-specific priming effect. However, Crovitz *et al.* did not include a control group in their study, so it is difficult to know whether amnesic patients exhibited normal priming on this task.

Perhaps the most important finding from these neuropsychological studies is that priming of familiar objects can be observed even when recall and recognition are reduced or absent, thereby indicating that such priming cannot be based solely on explicit memory processes. On the other hand, in most of the published studies, priming effects in amnesic patients are smaller than those observed in control subjects; we shall return to this point later.

Relevant evidence has also been provided by studies in which priming of familiar objects has been observed in young children and older adults whose performance on explicit memory tests is impaired. The first developmental study concerning what we would now call priming of familiar objects was reported by Gollin (1960) in an article that described the fragmented pictures that have come to be known as the Gollin figures. Gollin exposed a series of increasingly complete fragments of familiar objects to 4- to 5-yr-old children and adults and noted how much information was required to achieve identification of the object. He then re-presented old fragments together with new picture fragments than had not been presented previously. Gollin found that both children and adults required less information to identify old than new fragments, the magnitude of this savings or priming effect appeared to increase as a function of the similarity between study and test fragments, and there was even savings in identifying new or nonpresented fragments. These results suggest that children acquired general skill at the fragment completion task as well as specific information about individual objects. However, no explicit memory tests were used, so it is difficult to know whether the observed item-specific effects were attributable to priming or explicit remembering (see also Gollin, 1961, 1962, 1965, 1966).

Parkin and Streete (1988) used the fragmented-pictures paradigm to investigate priming and explicit memory in 3-, 5-, and 7-yr-old children as well as adults. Pictures were initially presented in their most incomplete form, followed by presentation of progressively more complete fragments until identification was achieved. Old and new picture fragments were then presented after retention intervals of 1 hr and 2 weeks. Results indicated that younger children initially required more trials to achieve identification than did older children and adults. To avoid potential confoundings attributable to this baseline difference, Parkin and Streete evaluated priming by expressing savings in identification performance on the second presentation of a fragment as a proportion of identification performance on the first presentation. This proportional analysis revealed significant priming in all subject groups and, most importantly, no effect of age on the magnitude of priming. Results also indicated that the priming effect was attributable to the acquisition of item-specific information and not to the acquisition of general skill: Exposure to fragmented pictures did not facilitate subsequent identification of new pictures. In contrast to the priming results, there was a large effect of age on a yes/no recognition test, with levels of explicit memory increasing steadily from the 3-yr-olds to the adults. The magnitude of priming declined between the 1 hr-to-2 week retention interval in all subject groups (though not as much as recognition), but each age group still showed considerable priming even at the long delay.

Carroll, Byrne, and Kirsner (1985) investigated priming in 5-, 7-, and 10-yr-old children with a paradigm in which subjects studied common objects in various conditions and then named pictures of old and new objects. Priming on this task is indicated by faster naming of old than new objects. Although older children were somewhat faster overall than were younger children to name both old and new pictures, all age groups showed a priming effect of comparable magnitude. In contrast, recognition accuracy increased systematically as a function of increasing age. These data are thus consistent with Parkin and Streete's results insofar as they show a developmental dissociation between implicit and explicit memory. Note, however, that Carroll *et al.* (1985) assessed priming with a *latency* measure and explicit memory with an *accuracy* measure. It is possible that priming would have shown a developmental trend comparable to that observed on the recognition task if it, too, had been assessed with an accuracy measure.

A dissociation between priming and explicit memory for familiar objects has also been observed in research on elderly adults. Mitchell (1989) examined the performance of old and young subjects on a picture-naming task in which old and new items were intermixed in a single long list. Target pictures were named on an initial presentation and then were named again after lags consisting of 5, 25, or 50 intervening items. Mitchell observed a robust facilitation of naming latency in young and old subjects at all lags, although there was some decrease in facilitation as lag increased. Most importantly, the magnitude of this priming effect was equivalent in the young and old subjects, even though older subjects were impaired significantly on explicit tests of memory. The elderly recalled fewer picture names than did the young and also performed less accurately on a yes/no recognition test for the prior occurrence of the pictures. As in the Carroll *et al.* (1985) study, however, the apparent implicit/explicit dissociation could also be interpreted as a dissociation between accuracy and latency measures.

Despite some interpretive problems, the foregoing studies of young children and elderly adults extend the neuropsychological evidence by showing robust priming of nonverbal information in subject groups characterized by impaired performance on explicit memory tests. This pattern of dissociation is, in turn, generally consistent with the larger literature on priming of words and other familiar verbal items in amnesic and elderly subjects who show deficits on explicit tests (see Schacter, 1987; Shimamura, 1986).

2. *Evidence from Normal Young Adults*

The studies discussed in the preceding section were concerned mainly with priming in memory-impaired populations. Nevertheless, they also demonstrated priming of familiar objects in normal adults who acted as control subjects. An early study that can be interpreted as demonstrating object priming in normal subjects was reported by Leeper (1935), who found that exposure to fragmented pictures of objects facilitated subsequent perception of the objects even after a retention interval of approximately 3 weeks. More recently, several studies have provided evidence on the separability of priming and explicit memory that complements the evidence discussed in the previous section by showing that object priming and explicit memory can be dissociated experimentally in normal young adults.

Carroll *et al.* (1985, Experiment 1) examined the effects of two types of study processing on subsequent picture-naming latency and recognition performance in college students: a deep or elaborative encoding task in which subjects judged whether target objects are animate or inanimate, and a shallow encoding task in which they attempted to find a small inked-in cross that had been drawn on the contour of some of the objects. As expected, recognition memory was more accurate following deep than shallow encoding. Despite this difference in explicit remembering, however, picture-naming latencies were facilitated equally following the two encoding tasks. As noted earlier, however, interpretation of results from this study is not entirely straightforward, because recognition was assessed with an accuracy measure and priming was assessed with a latency measure. It is conceivable that if priming had been assessed with an accuracy measure, the levels-of-processing manipulation would have influenced the magnitude of priming, just as it influenced recognition accuracy; alternatively, if recognition had been assessed with a latency measure, it might have been insensitive to the levels-of-processing manipulation, as was observed for priming. Moreover, in other experiments with children Carroll *et al.* (1985, Experiments 3 & 4) observed a levels-of-processing effect on naming latency; however, the effect was not observed when baseline differences among experimental conditions were removed. This inconsistent pattern of results highlights the need to treat Carroll *et al.*'s data with interpretive caution.

Mitchell and Brown (1988) also compared picture-naming latencies and recognition accuracy in an experiment with college students. Subjects named pictures of familiar objects in an initial session; the pictures were then re-presented for naming (intermixed with new pictures) after retention intervals ranging from 1 to 6 weeks. Explicit memory was assessed with a standard yes/no recognition test. Mitchell and Brown observed that initial naming of a picture facilitated subsequent naming performance by about 70 msec at all retention intervals. Recognition memory, by contrast, declined significantly across delays. Mitchell and Brown also observed that the magnitude of the priming effect was independent of whether or not subjects made accurate recognition judgments. This finding thus extends previous reports of stochastic independence between word priming and explicit memory (e.g., Hayman & Tulving, 1989; Jacoby & Witherspoon, 1982; Tulving, Schacter, & Stark, 1982). However, this study is also characterized by the questionable comparison of accuracy and latency measures discussed earlier.

A recent experiment in our laboratory has provided evidence of dissociation between implicit and explicit memory for familiar objects under conditions in which similar measures were used to assess both types of memory (Schacter & Merikle, in preparation). This study, like the experiments by Carroll *et al.* (1985), examined the effects of a levels-of-processing manipulation on priming and explicit memory. Subjects were exposed to line drawings of familiar objects and performed either a *semantic* orienting task, in which they generated functions for the depicted object, or a *structural* orienting task, in which they counted the number of vertices in each object. Priming was assessed by presenting perceptual fragments of studied and nonstudied objects. Fragments were selected that preserved minima of curvature in the object contour, thereby providing useful perceptual information about each object [the fragments and corresponding drawings were selected from various sources by Merikle & Peterson (in preparation)].

In previous studies using fragmented pictures of objects, including those discussed earlier, priming has been assessed by requiring subjects to try to identify each object (e.g., Hirshman, Snodgrass, Mindes, & Feenan, in press; Snodgrass, 1989; Warrington & Weiskrantz, 1968; Weldon & Roediger, 1987). Unfortunately, when subjects are required to identify a fragmented object, they may well attempt to make use of any kind of information that can aid identification, including episodic information that is retrieved through intentional or explicit strategies. Because most studies using fragmented pictures employ procedures akin to the ascending method of limits, where subjects are given exposure to several fragments and are allowed a considerable amount of time to try to identify them, it seems quite likely that standard picture-fragment paradigms encourage the use of explicit memory strategies. The fact that amnesic patients do not show entirely normal priming in the picture-fragment completion task is consistent with the idea that this task typically involves an explicit memory component.

We attempted to overcome these problems and reduce the contribution of explicit memory to fragment completion performance by altering fragment completion instructions so that subjects were told to respond quickly to each perceptual fragment with *the first object that comes to mind* (see also Heindel, Salmon, & Butters, in press) and were also told that there was no correct/incorrect response on the task. A separate group of subjects was given the same perceptual fragments together with explicit memory instructions to try to remember the correct object from the study list. Results revealed that the magnitude of priming was virtually identical following the semantic and structural orienting tasks. By contrast, explicit memory performance was significantly higher following the semantic task than following the structural task. Because the same cues (i.e., perceptual fragments) were used on the implicit and explicit tasks, and performance on both tasks was assessed with the same accuracy measure, we can be confident that this pattern of results reflects a dissociation between priming and explicit memory.

An experiment by Jacoby, Baker, and Brooks (1989) provides evidence for a somewhat different type of dissociation. Subjects were exposed to pictures of common objects in two different ways: (1) pictures were fully exposed on a computer monitor for 7 sec and subjects were required to name them; (2) pictures were "clarified" by a procedure in which random noise dots were gradually replaced by dots from a target picture until subjects could name the depicted object, at which point the fully clarified picture remained on the screen for 7 sec. Memory for the pictured objects was tested explicitly with a free recall test in which subjects were instructed to remember the names of presented objects. Priming was assessed with an identification test that incorporated the clarification procedure; old and new pictures were clarified until subjects could name them, and the amount of clarification required for identification was measured. Jacoby *et al.* reasoned that the extra processing of visual detail in the clarification study condition would benefit identification performance but not free recall of the object name. Moreover, since the additional processing time in the clarification condition yielded a longer retention interval than in the full-exposure condition, there was reason to predict lower free recall performance in the former condition than in the latter. Results were consistent with these expectations: Free recall performance was higher in the full-exposure study condition than in the clarification study condition, whereas the opposite pattern of results was observed on the clarification test—there was more priming in the clarification study condition than in the full-exposure study condition.

The dissociations observed in the foregoing experiments, together with the neuropsychological and developmental evidence, suggest that different mechanisms are involved in priming and explicit memory for familiar objects. A number of studies have provided information about the properties of the representations and processes that support priming. Lachman and Lachman (1980), for example, examined the extent to which priming on a picture-naming task is based on encoding the *visual* properties of objects, as opposed to encoding or activating the lexical information represented by the object's name. To investigate the issue, they examined performance on a yes/no recognition test that included previously studied objects as well as new objects. The actual purpose of the recognition test was to induce subjects to encode the visual properties of objects without requiring overt production of object names; that is, Lachman and Lachman assumed that making a yes/no judgment about the prior occurrence of an object would not entail overt naming of the object. The critical items in the experiment were thus the new or lure objects that had not been presented previously. These lure objects were subsequently presented with a set of entirely new objects on a picture-naming task. Lachman and Lachman found that subjects named the objects that had appeared previously as lures on the recognition test faster than the entirely new objects, thus suggesting that object priming can occur even when subjects do not name the objects at the time of encoding. Unfortunately, no systematic evidence was presented to show that subjects did not in some manner activate the object's name during the recognition test. Nevertheless, these data do show that priming of picture naming need not involve prior *overt* naming of objects during an encoding task. On the other hand, Lachman and Lachman also found that the magnitude of the priming effect on naming latency depended on properties of the object name: Objects that elicited the same name from virtually all subjects appeared to produce less priming than objects that elicited several different names. In addition, some priming of picture naming was observed following processing of the picture name alone, but not nearly as much as was observed following presentation of the picture itself.

A related series of experiments has investigated questions concerning the *specificity* of priming effects with familiar objects: Is the phenomenon based on the activation of some sort of generic or abstract code that represents an object's prototypical features, or does priming reflect specific characteristics of the particular object encoded by the subject on a study trial? Two types of evidence are relevant to this question. First, as noted earlier, in a developmental study Gollin (1960) found that initial "training" on a fragmented version of a picture produced greater subsequent savings (priming) in identifying that fragment than did initial training by exposure to the entire picture. More recently, Snodgrass and Feenan (1989) have replicated and extended these findings with adults and have also shown that priming is greater when the same picture fragment is presented for identification at study and test than when different fragments are used, although there was still significant priming in the different-fragment condition. These kinds of results suggest that priming is based at least in part on a representation of the specific features of objects presented for study, and not solely on an abstract or generic object code. However, explicit memory processes may have played some role in the observed specificity effects. As noted earlier, when training procedures like those in the Gollin and the Snodgrass and Feenan studies are used, explicit memory likely contributes to savings on the identification test (Snodgrass, 1989; Snodgrass & Feenan, 1989). The results of Jacoby *et al.* (1989) with the clarification procedure at least partly address this issue, because they observed specificity effects on an identification test—maximal priming when objects were identified via the clarification technique at both study and test—even though free recall was lower when pictures were studied by "clarification" than with full exposure. Accordingly, it seems unlikely that those explicit memory processes that underlie *free recall of an object's name* contributed to the specificity effect on priming. However, this study provides only partial and equivocal evidence that the specificity effect is attributable to priming and not to explicit memory. It is quite possible that if Jacoby *et al.* had assessed explicit remembering with a recognition test in which subjects were given the same nominal cues as on the identification test, together with intentional retrieval instructions, specificity effects might well have been observed.

A somewhat different type of specificity effect was reported in an early study by Bartram (1974) in which subjects named photographs of familiar objects across blocks of trials. Following the initial naming of an object, there were four critical experimental conditions: (1) the same object was presented again in the same view as on initial presentation; (2) the same object was presented again, but photographed from a different view than on initial presentation; (3) a physically different object with the same name as the target was presented (e.g., photographs of two different cups were named at study and test); and (4) a photograph of a physically different object with a different name was presented. Relative to the baseline level of performance in Condition 4, naming latencies were significantly faster in each of the first three conditions, thereby indicating the presence of priming. Most importantly, however, the largest priming effect was observed for identical objects, less priming occurred for the same object from a different view, and the least amount of priming was found for different objects with the same name (see also Bartram, 1976).

Warren and Morton (1982) reported a similar pattern of results in a study in which subjects initially named either pictures of objects or their verbal labels (e.g., a picture of a clown or the word *clown*). Subjects were then given brief tachistoscopic exposures to pictures and were required to identify them. Some pictures were identical to those named initially, some depicted different objects with the same name (e.g., a picture of a different clown than had been studied), and some had not been previously studied. In their first experiment, Warren and Morton observed significant priming of identical pictures together with a nonsignificant trend for priming of same-name pictures. They argued that the failure to observe significant priming of same-name objects was attributable to the use of explicit memory strategies. According to Warren and Morton (1982, p. 122), if some subjects used an explicit retrieval strategy of attempting to "match" the test picture with a previously studied picture, they would be less likely to find an acceptable match when same-name (but different-object) pictures were exposed. In a second experiment, they attempted to reduce the contribution of explicit memory to picture-identification performance by increasing the length of the study list and testing only a small proportion of the study list items. The obtained pattern of results was quite similar to those observed in the first experiment, except that now the priming effect in the same-name condition was statistically significant. In addition, there was greater priming in the identical condition than in the same-name condition, thus providing some evidence for specificity. Finally, Warren and Morton also observed in both experiments that naming a picture's verbal label at the time of study produced *no* priming on subsequent identification performance, a finding that we shall elaborate on in the next section of the article. Consistent with the results of Warren and Morton, Jacoby *et al.* (1989) found evidence for priming in both identical and same-name conditions with their picture-clarification procedure but also reported more priming in the former condition than in the latter.

The foregoing studies thus suggest that at least some of the priming effect observed on identification and naming tasks is attributable to an encoded representation of the specific object presented at the time of study (more priming in identical than in same-name condition); however, these studies also suggest that priming may be based in part on the activation of a more abstract object representation (significant priming in the same-name condition). Nevertheless, interpretation of these results is not entirely straightforward, because the contribution of explicit memory processes has not been sufficiently scrutinized. It is possible that the observed specificity effects are attributable to explicit memory processes, perhaps because priming in a same-name condition is reduced by subjects' use of intentional retrieval strategies, as suggested by Warren and Morton.

A recent study in our laboratory addresses this issue directly (Schacter & Bowers, in preparation). Subjects were shown pictures of familiar objects and performed either a semantic orienting task (function generation) or a structural orienting task (vertex counting), as in the previously described study by Schacter and Merikle (in preparation). After a delay of several minutes, subjects in both groups were given a priming task in which pictures of objects were exposed for 50 msec (preceded and followed by a pattern mask) and subjects attempted to identify them. The tested objects were (1) *identical* to a previously studied object, (2) different exemplars of the object that had the *same name,* or (3) *new* objects that had not been previously studied. After the identification test, subjects were shown the same pictures and were asked to make yes/no recognition judgments about whether they had seen an object of the kind depicted by the picture on the initial study list (i.e., "yes" responses were correct for both identical and same-name objects).

The experiment yielded three important results. First, recognition memory performance for both identical and same-name objects was significantly higher in the semantic encoding condition than in the structural encoding condition. Second, the magnitude of priming for identical objects did not differ in the semantic and structural conditions: Identification accuracy increased from about 70% for new objects to about 85% for identical objects in both encoding conditions. Thus, the levels-of-processing manipulation produced an implicit/explicit dissociation on the object-identification task, just as it did on the object-completion task used by Schacter and Merikle (in preparation). Third, and perhaps most important, there was *no* priming of same-name objects in the structural condition, together with a marginally significant trend for priming of same-name objects in the semantic condition. The failure to observe any priming of same-name objects following structural encoding is particularly important: If, as suggested by Warren and Morton (1982), explicit memory somehow inhibits priming in a same-name condition, then more priming of same-name objects should have been observed following structural encoding than following semantic encoding, because explicit memory was lower in the former than in the latter condition. However, an opposite pattern of results was observed. Contrary to Warren and Morton, then, our data suggest that facilitation of identification performance for same-name objects may be *attributable to*—rather than *inhibited by*—explicit memory processes and that "genuine" structurally based priming is restricted to identical objects. Of course, it will be necessary to replicate these findings before firm theoretical conclusions can be drawn.

Suggestive evidence concerning the specific type of structural information involved in object priming is provided by Biederman and Cooper (1989b). In an initial experiment, subjects named contour-deleted objects from brief presentations during the first block of trials. On the second block, three types of objects were named: some were *identical* to those named on the first trial (i.e., same object, same contour deletion), some were *complements* of the object named on the first trial (i.e., same object, composed of edges and vertices that were deleted on the initial trial), and some were different objects with the *same name*. Biederman and Cooper observed some priming (faster and more accurate naming) for same-name objects, which they attributed to nonvisual factors (e.g., name or concept priming). More importantly, they observed significantly greater priming for identical and complementary objects, with no difference between these two conditions. The latter finding indicates that priming is not based on some sort of "literal" representation of object features, because objects in the identical and complementary conditions were composed of entirely different contours yet showed equivalent priming. By contrast, in a second experiment Biederman and Cooper constructed complementary objects by deleting alternate convex components or geons (Biederman, 1987) and found significantly less priming in the complementary condition than in the identical condition. Indeed, there was no more priming in the complementary condition than in the same-name condition.

Biederman and Cooper's results suggest that object priming may depend critically on the encoding of structural components of objects. However, two points about their study should be noted. First, they did not include an explicit memory test in either experiment, so we do not know whether and to what extent explicit memory processes contributed to the observed pattern of results. Second, they presented no evidence to support their assumption that priming in the same-name condition is based exclusively on nonvisual information. As noted earlier, Warren and Morton have argued that priming in this condition reflects priming of an abstract, but visual, representation of an object. However, the Schacter and Bowers finding discussed earlier that there is no priming in a same-name condition following a structural encoding task does provide some support for Biederman and Cooper's claim.

In a related study, Biederman and Cooper (1989a) found that priming in their paradigm was unaffected by changes in retinal location (i.e., hemifield of presentation) and left/right orientation of an object between first and second naming trials, even though subjects possessed relatively good explicit memory for location and orientation information. Although these results suggest that object priming is based on an orientation-free representation, Jolicouer (1985) has reported effects of orientation change on priming of naming latencies. In an initial experiment, Jolicouer showed that the time to name drawings of familiar objects increases linearly as the objects are rotated increasingly further from upright. More importantly for the present purposes, Jolicouer showed in two additional experiments that this effect of orientation decreases with practice at naming rotated objects. The effect of practice was item specific, in the sense that repeated naming of rotated objects did not reduce the effect of orientation on novel objects; the effect was observed only for rotated objects that were previously named.

Jolicouer and Milliken (1989) have extended these results to show that initial naming of objects in various rotations reduces subsequent effects of orientation on naming times of previously presented objects relative to a condition in which objects are initially only in upright form. To the extent that the "practice" effects observed by Jolicouer can be taken as expressions of priming, these data suggest that information about the orientation of familiar objects plays a role in priming of naming latencies. Although this conclusion may appear inconsistent with Biederman and Cooper's (1989a) findings, these investigators examined effects of left/right orientation changes, whereas Jolicouer has focused on changes from upright orientation. It should also be noted that information about orientation appears to play an important role in explicit memory performance (Rock & DiVita, 1987; Rock, DiVita, & Barbeito, 1981), so detailed comparisons of the effects of orientation change on priming and explicit memory are clearly necessary in order to understand more fully the role of orientation information in implicit and explicit memory for familiar objects.

3. *Picture/Word Transfer*

A number of studies concerned with priming of nonverbal information have examined transfer of priming between pictures of familiar objects and the corresponding object names. Perhaps the earliest such study was reported by Winnick and Daniel (1970). In their experiment, subjects were exposed to pictures of familiar objects or to words corresponding to the pictured objects. Priming was assessed with a word-identification test and explicit memory was assessed with a free recall test. Winnick and Daniel observed a striking dissociation between these two memory tests: Free recall was higher following study of a picture than study of the corresponding word, but priming effects on the word-identification test were greater following study of the word than study of the picture. Indeed, there was only a slight priming effect in the pictorial study condition.

Although Winnick and Daniel's findings were largely overlooked in subsequent years (see Roediger & Weldon, 1987; Schacter, 1987), they were confirmed and extended by two studies that appeared nearly a decade later. Scarborough *et al.* (1979) required subjects to name concrete words or corresponding pictures and then examined performance on a lexical decision test in which words from the two study conditions (as well as new words and nonwords) were presented, and subjects decided as quickly as possible whether each letter string constituted a word or a nonword. Prior study of a word produced significant facilitation of lexical decision latency, but prior study of pictures produced no priming. In contrast, a subsequent experiment showed that recognition memory was higher for previously studied pictures than words, thus providing a dissociation similar to that observed by Winnick and Daniel. Consistent with the results of Scarborough *et al.*, Durso and Johnson (1979) found that initial naming of a picture produced no priming of naming latency when subjects subsequently named the corresponding word, although considerable priming was observed when the same picture was named again. However, Durso and Johnson also reported an asymmetry in priming: Initial naming of a word facilitated subsequent naming of the pictorial equivalent, although priming was not as robust as in a word–word condition. Durso and Johnson found a similar pattern of results with a task that involved repeated categorization of words and pictures. Consistent with these results, it was noted earlier that Lachman and Lachman (1980) found that study of words produced significant, albeit reduced, priming on a subsequent picture-naming task relative to study of their pictorial equivalents. Warren and Morton (1982), however, found that studying words produced no priming on a subsequent test of picture identification from brief tachistoscopic exposures.

The foregoing experiments suggest that there is little if any priming from pictures to words on a variety of tests. Some picture–word priming has been documented, however, in subsequent studies. Kroll and Potter (1984) required subjects to make "reality" decisions concerning whether letter strings represented real words or nonwords and whether line drawings represented real objects or nonobjects. Large repetition priming effects on decision latencies were observed in word–word and picture–picture conditions. Significant, albeit substantially reduced, priming was found from pictures to words. In contrast to previous studies, however, no priming was found from words to pictures. Kirsner, Milech, and Stumpfel (1986) examined priming on a tachistoscopic word-identification test following a study task in which subjects classified words on their pictorial equivalents as living or man-made. Significant priming was found in both the word–word and the picture–word conditions, although the former condition yielded more priming than did the latter. When a study task was used that required subjects to judge the real-world size of words or pictorial equivalents, similar amounts of priming were found on a subsequent word-identification test. However, Kirsner *et al.* also showed that the "intramodal" component of priming (i.e., word–word transfer) could be dissociated from the "intermodal" component (i.e., picture–word transfer), inasmuch as a word frequency manipulation affected the intermodal but not intramodal type of priming. Kirsner *et al.* also showed that studying pictures yielded higher levels of explicit memory on a yes/no word-recognition test than did studying words, in contrast to the priming data.

Weldon and Roediger (1987) examined the effects of studying words or their pictorial equivalents on two subsequent tests: word-fragment completion and free recall. They observed a striking crossover interaction between the two tests similar to the pattern first reported by Winnick and Daniel; free recall performance was higher for pictures than for words, whereas there was greater priming on the fragment completion test for words than for pictures. Weldon and Roediger found that studying pictures produced some priming on the fragment completion test, but the effects were quite small. Conversely, additional experiments showed that studying pictures of objects produced large priming effects on a picture-fragment completion test.

Hirshman *et al.* (in press) reported several experiments that used a study task in which subjects studied target words by generating a sentence that contained each word. Priming was assessed with a picture-fragment completion task using the ascending method of limits procedure described earlier (e.g., Gollin, 1960; Snodgrass, 1989). Hirshman *et al.* observed significant word–picture priming in this experiment and two similar ones, and on the basis of these results argued for a conceptual component to priming. Several features of this study, however, limit the force of this conclusion. First, Hirshman *et al.* did not use a picture–picture condition, so we do not know whether the word–picture priming effects that they observed were smaller than picture–picture priming effects, as has been observed previously. Second, and perhaps more importantly, it was noted earlier that when priming on a picture-fragment completion task is assessed with the ascending method of limits, as was done in the Hirshman *et al.* study, explicit retrieval processes likely play a major role in task performance. Thus, the word–picture transfer reported by these investigators may be entirely or largely attributable to explicit retrieval. Hirshman *et al.* attempted to deal with this possibility by comparing performance on the picture-fragment completion task and a free recall task (in which subjects recalled target words). They found little correlation between free recall and picture completion performance and thus argued that word–picture priming is not attributable to explicit memory. Unfortunately, this line of reasoning is not compelling, because the same outcome might have been observed even if subjects had in fact treated the picture completion test as an explicit cued recall test; that is, free recall of words and explicit cued recall of pictures may not be strongly correlated. As discussed elsewhere in this article, to evaluate the possible contribution of explicit memory to a priming effect on an allegedly implicit task, it is necessary to use the same nominal cues on the two tasks and vary only task instructions (see discussion on pp. 110–112). Comparisons of the kind made in the Hirshman *et al.* study do not speak directly to the role of explicit memory processes, so their data must be treated with interpretive caution.

Despite the variability and occasional inconsistencies among the foregoing studies, it seems safe to conclude that there is generally a good deal less priming from pictures to words and words to pictures than from words to words or pictures to pictures. Whether or not *no* intermodal priming is found, or *reduced* levels of intermodal priming are observed compared to an intramodal condition, varies across experiments and likely depends on tasks and materials in ways that are not yet well understood. Nevertheless, the generally reliable finding that priming is reduced in intermodal conditions indicates that the physical form of a stimulus plays a large role in priming. Moreover, the finding that studying familiar pictures enhances recall and recognition of corresponding words, while producing little or no priming on word identification, fragment completion, and lexical decision tests, indicates that form-based information plays a different role in priming than in explicit memory. Note, however, that the crucial importance of form information is observed only for *repetition* or *direct* priming; studies of *semantic* or *associative* priming have consistently provided evidence of extensive and even complete transfer between pictures and words (e.g., Vanderwart, 1984). We shall return to this point later when considering theoretical interpretations of nonverbal priming.

B. Priming of Novel Objects and Patterns

Although the studies considered in previous sections include a wide variety of tasks, experimental procedures, and subject populations, in all experiments either the study or the test materials consisted of photographs, pictures, or line drawings of common objects. These materials are thus familiar to subjects before the initial study presentation in the sense that the objects that they depict are represented in long-term memory prior to the experiment. The fact that most studies on priming of nonverbal information have used familiar materials with preexisting memory representations has a number of theoretical implications that will be discussed shortly. Nevertheless, there have been some, albeit relatively few, studies that have examined priming of novel or unfamiliar nonverbal information.

One set of relevant findings is provided by studies of the "mere exposure" effect (Zajonc, 1980) on preference judgments. In an experiment by Kunst-Wilson and Zajonc (1980), subjects were exposed for 1 msec to line drawings of novel shapes (irregularly shaped octagons). They were then given two types of forced-choice tests: (1) a recognition test in which an old and a new octagon were presented and subjects indicated which shape had been presented previously; and (2) a preference test in which an old and a new octagon were presented and subjects indicated which shape they liked better. Since the latter task does not require conscious recollection of the study exposure, it can be viewed as an implicit memory test that may be influenced by priming. Although subjects did not perform significantly higher than chance on the recognition test, they showed a reliable preference for the previously exposed octagon. Seamon, Brody, and Kauff (1983) reported that exposure effects on preference judgments were larger when target shapes were initially exposed in the right than in the left visual field, whereas a left-visual-field advantage was observed for recognition. Johnson, Kim, and Risse (1985) found normal exposure effects on preferences for novel melodies in amnesic patients who were impaired on a recognition test, thereby providing further evidence for a dissociation between preference judgments and explicit memory.

Mandler, Nakamura, and Van Zandt (1987) questioned whether the effects observed in the foregoing studies reflect a fundamental difference between cognition (indexed by recognition memory) and affect (indexed by preference judgments), as had been argued by Zajonc (1980). As in the Kunst-Wilson and Zajonc and Seamon *et al.* studies, Mandler *et al.* gave subjects brief (2 msec) exposures to unfamiliar shapes and then tested recognition and preference judgments for old and new shapes in two different subject groups. In addition, however, Mandler *et al.* also required two other subject groups to judge which of two test stimuli (one old and one new) seemed *brighter* or which of the two seemed *darker*. Consistent with previous results, they observed a reliable preference for old shapes under conditions in which recognition memory did not differ from chance. More importantly, Mandler *et al.* also found that subjects showed a similar tendency to judge previously exposed shapes as either brighter or darker than new shapes in the appropriate conditions. These results suggest that the dissociation between preference and recognition judgments observed in previous studies is not based on a fundamental split between cognition and affect, but rather reflects a nonspecific priming effect that can be expressed in a variety of judgments independently of explicit memory.

A number of studies have examined priming of novel nonverbal information using implicit tests that are in some respects similar to the identification, completion, and lexical decision tasks that have been used extensively in the verbal domain. Two recent experiments have focused on priming of dot patterns. In a neuropsychological study of the severely amnesic patient H. M. (Gabrieli, Milberg, Keane, & Corkin, in press), the target materials were spatial arrangements of five dots from a 3 × 3 matrix that were connected by four lines to form a specific pattern. After exposing a series of such patterns to H.M. and a group of control subjects, priming was assessed with a "dot-completion" test in which unconnected five-dot arrangements were presented and subjects were asked to draw any figure that connected the dots with straight lines. There were a number of possible completions for each figure, and the question of principal interest was whether subjects would tend to connect the dots to form previously studied figures. Results indicated robust and similar levels of priming in H.M. and control subjects; dot patterns on the completion test were connected to form previously studied figures at significantly higher than baseline levels. Moreover, a dissociation between priming and explicit memory was observed: H.M. showed intact pattern priming despite his severe impairment on a recognition test in which subjects were asked to remember explicitly which patterns had been presented previously.

Musen and Treisman (1990) also examined priming of novel dot patterns with a different implicit test. In their study, college students were shown 50 dot patterns similar to those used by Gabrieli *et al.*, consisting of five dots from a 3 × 3 matrix that were connected by four lines. Priming was assessed after delays of 1 hr, 3 hr, or 7 days with a perceptual identification test in which old and new dot patterns were presented briefly, and subjects tried to copy the correct pattern on an empty 3 × 3 grid. Exposure time on the identification test was calibrated so that baseline accuracy in copying patterns without any study exposure was about 40–45% correct. Musen and Treisman observed significant priming effects in their experiment—subjects copied significantly more old than new patterns—and the magnitude of priming was largely unaffected by length of retention interval. Explicit recognition of the patterns, by contrast, declined across the delay. In addition, recognition and priming exhibited stochastic independence (e.g., Tulving *et al.*, 1982); the probability of recognizing a particular pattern was uncorrelated with the probability of producing that pattern from a brief exposure.

Several other recent studies have examined priming of novel two-dimensional and three-dimensional shapes and objects. As noted earlier, Kroll and Potter (1984) examined priming with an object decision task in which subjects decided whether drawings of either familiar, real-world objects or constructed nonobjects did or did not exist in the world. Both objects and nonobjects were repeated after lags of three or ten intervening items in a continuous sequence during which subjects made object decisions. Kroll and Potter found that subjects were faster to make such decisions about nonobjects on the second presentation of a drawing than on the first; similar effects were observed for familiar objects. Thus, priming was observed in this experiment for both novel items with no preexisting memory representations and familiar items that have preexisting representations.

A rather different type of object decision task was used in a series of experiments by Schacter *et al.* (1990). The materials in these experiments were two-dimensional drawings of novel, unfamiliar three-dimensional objects. Although none of the target objects actually exist in the real world, half of the drawings depict structurally *possible* objects whose surfaces and edges are connected in such a way that they could exist in three-dimensional form. The other half of the drawings, in contrast, represent *impossible* objects that contain surface, edge, or contour violations that would make it impossible for them to exist in three-dimensional form (e.g., Penrose & Penrose, 1958). To assess priming of these objects, Schacter *et al.* devised an object decision test in which subjects were given brief (100 msec) exposures to possible and impossible objects and were required to decide whether each object was structurally possible or impossible; half of the test objects had been studied several minutes earlier and half were new. The main question was whether priming of novel objects would be observed—that is, whether study of possible and impossible objects increased the accuracy of subsequent object decisions. Explicit memory was assessed with a standard yes/no recognition test.

In an initial experiment, priming on the object decision task was found following a study task that was intended to induce subjects to encode information about the global three-dimensional structure of the objects (indicating whether each object faced primarily to the left or right). By contrast, no priming was observed following a study task that required encoding the local features of target objects (indicating whether each object had more horizontal or vertical lines). The magnitude of priming in the left/right condition was about the same whether or not the object decision task was preceded by a recognition task on which all critical objects were exposed; that is, mere exposure to an object on the recognition task did not produce priming on the object decision task. Priming also showed stochastic independence from recognition memory. Significantly, priming was found only for the structurally possible objects; no priming of structurally impossible objects was observed in this study or in subsequent experiments. However, recognition memory for impossible objects was only slightly less accurate than was recognition of possible objects.

The results of this experiment were interpreted as suggesting that priming on the object decision test depends on prior encoding of a global three-dimensional *structural description* (Marr, 1982; Marr & Nishihara, 1978) of target objects. By this view, the failure to find priming of impossible objects indicates that it is difficult to form a global structural description of such objects. In a subsequent experiment, the left/right encoding task was compared to an *elaborative* encoding task in which subjects had to think of a familiar object from the real world that each target object reminded them of most. As expected, this encoding task yielded higher levels of explicit memory performance on the recognition test than did left/right encoding; the elaborative task required subjects to relate target objects to preexisting semantic knowledge of objects, thus producing a distinctive and hence highly memorable episodic memory representation (e.g., Jacoby & Craik, 1979). The striking result, however, was that *no* priming was observed following the elaborative task, whereas the left/right task again produced substantial priming. One potential reason for the failure to observe priming following elaborative encoding was that subjects often produced two-dimensional elaborations of the objects and did not encode them as three-dimensional structures. In a third experiment, an attempt was made to induce subjects to achieve three-dimensional elaborations by requiring them to indicate whether each object reminded them most of a type of furniture, a household object, or part of a building. Significant priming was observed following this task; however, these priming effects were no greater than those observed following the left/right task, even though the three-dimensional elaboration task produced higher recognition performance than did the left/right task.

As noted above, the fact that priming was observed for possible but not impossible objects suggests that subjects are unable to form global structural descriptions of impossible objects. Schacter *et al.* noted, however, that a number of alternative interpretations of this finding could not be excluded. For example, the target objects for these experiments were selected initially on the basis of a pilot study in which subjects were given unlimited time to classify them as possible or impossible; only those objects that yielded high levels of intersubject agreement were included in the target set. However, whereas there was 97% agreement about the possible objects, there was less agreement (87%) concerning the impossible objects. It is thus possible that priming of impossible objects could be observed if a set of objects were used that yielded close to 100% agreement with unlimited viewing time. In more recent studies (Schacter, Cooper, Delaney, Peterson, & Tharan, in preparation), a new set of impossible objects that conformed to this criterion was used, and a number of other procedural changes were made to increase the likelihood of observing priming for structurally impossible objects. Nevertheless, these experiments, like the earlier studies, have yielded no evidence for priming of impossible objects—even after four repetitions of the left/right encoding task. Interestingly, four vs. one study list repetitions had no effect on priming of possible objects—similar amounts of priming were observed in both study conditions—even though explicit memory for possible and impossible objects was significantly higher following four than following one study list repetition. Thus, the overall pattern of data suggests that subjects can encode local features and parts of impossible objects that are sufficent to support reasonably high levels of recognition memory, but do not and perhaps cannot form global descriptions of impossible objects that are needed to support priming on the object decision test.

A recent study by Kersteen-Tucker (1989) has yielded a pattern of results that in some respects parallels the one observed in the foregoing experiments. Kersteen-Tucker examined priming of novel, unfamiliar polygons in a continuous-response procedure in which subjects decided whether each of a series of polygons was symmetrical or nonsymmetrical; half of the targets were symmetrical and half were not. Target polygons were repeated after lags of zero, one, four, or eight intervening items. The dependent measure was latency to make the symmetry judgment, and priming was indicated by faster response latencies to repeated than to nonrepreated polygons. Kersteen-Tucker observed a significant priming effect at all lags for symmetrical polygons, although the magnitude of the effect declined across lags. By contrast, no priming was observed for nonsymmetrical polygons, even at the zero lag. Thus, just as possible but not impossible objects showed priming on the object decision task, symmetrical but not nonsymmetrical shapes showed priming on the symmetry judgment task. However, explicit memory for the shapes was not investigated in Kersteen-Tucker's experiment.

C. Priming of Familiar and Unfamiliar Faces

There have been only a few studies concerned with priming of faces, but they have yielded several suggestive experimental facts. Bruce and Valentine (1985) reported two experiments that were motivated by Warren and Morton's work on priming of familiar objects. In their first experiment, subjects were initially presented with either pictures of familiar faces (e.g., politicians, entertainers) or the corresponding printed names. In the former condition, subjects were required to name the face; in the latter they read aloud the printed name. Priming was assessed after a 20-min filled delay with a task in which subjects were given brief exposures to faces and attempted to name them. The duration of presentation was manipulated using the ascending method of limits: Presentation of a particular face began at 10 msec and was increased by 10 msec/exposure until subjects identified the face twice in succession. Priming was assessed by comparing subjects' naming thresholds in four different conditions defined by the prior history of the faces: (1) neither the face nor name of the face had been presented in the naming phase of the experiment *(baseline);* (2) the name but not the face had been presented *(name);* (3) the same face had been presented *(same);* and (4) a different view of the face had been presented during naming *(different).* Bruce and Valentine found that, relative to baseline, comparable levels of priming were observed in the name and different conditions, while significantly greater priming was found in the same condition. These results were thus similar to the analogous picture priming data of Warren and Morton (1982), except that no priming was found in the name condition of the Warren and Morton study. Bruce and Valentine noted, however, that they might have observed priming in the name condition because a naming response was required on their test. To investigate this issue, they performed a second experiment in which priming was assessed with a familiarity test that did not require naming: Subjects had to indicate as quickly as possible whether the face was familiar to them, and the dependent variable was latency to make the familiarity judgment. Using the same four study conditions as in the first experiment, Bruce and Valentine reported significant priming in the different condition, even greater priming in the same condition, and, most importantly, no priming in the name condition. These results suggest that the priming observed in the name condition in Experiment 1 was likely attributable to a facilitation of name production.

Similar results were reported in subsequent study by Young, McWeeny, Hay, and Ellis (1986, Experiment 4). Subjects in their experiment were initially exposed to either the faces or the names of politicians and unfamiliar people. When exposed to faces, subjects made either a *familiarity decision* (i.e., Is this face familiar?) or a *semantic decision* (i.e., Is this face a politician?). When exposed to names, they made a *name-familiarity decision* (i.e., Is this name familiar?). Priming was assessed with the semantic decision task; latency to make the semantic decision was the dependent variable. Young *et al.* found significant and comparable amounts of priming for familiar faces following both the familiarity and the semantic decision tasks; no priming of unfamiliar faces was observed following either task. In addition, no priming for either familiar or unfamiliar faces was observed following the name-familiarity judgment. Thus, as in the Bruce and Valentine study, when a face-judgment test does not require a naming response, prior exposure to a name does not produce priming.

The Young *et al.* study also suggests that unfamiliar faces, unlike unfamiliar objects, may not be susceptible to priming. This notion receives some additional support from an investigation by Bentin and Moscovitch (1988). They assessed priming with a *face-decision* task in which the critical stimuli were either pictures of normal but unfamiliar faces or faces with scrambled features ("nonfaces"). Subjects decided whether each configuration formed a normal human face or a nonface on two successive presentations of critical targets that were separated by lags of 0, 4, or 15 intervening items. Priming was observed for both faces and nonfaces only in the zero lag condition. In contrast, on an analogous lexical decision task, familiar words showed priming at all lags whereas nonwords showed priming only at lag zero. In subsequent experiments, Bentin and Moscovitch attempted to increase the "strength" of the memory representation for unfamiliar faces by varying study task and number of repetitions. Nevertheless, they found no priming of unfamiliar faces beyond lag zero on the face-decision task. However, when subjects were given an explicit recognition task, memory for the unfamiliar faces was observed even at the longest lag, thus suggesting that some sort of representation of these faces had been formed.

Both the Young *et al.* and Bentin and Moscovitch studies, then, failed to find priming of unfamiliar faces on two different types of implicit tests (semantic decision and face decision). Some unpublished data suggestive of priming for unfamiliar faces, however, was alluded to briefly in an article by Tulving (1985). In the cited experiment, subjects were initially presented with "shadow drawings" of unfamiliar faces. Priming was then assessed by presenting old and new shadow drawings and asking subjects to indicate whether or not they could "see" a face in the drawing (some drawings did not represent faces); explicit memory was assessed with a yes/no recognition test. Tulving reported that subjects correctly identified more old than new shadow faces and that this priming effect exhibited stochastic independence from recognition memory.

III. Methodological, Conceptual, and Theoretical Issues

The studies that we have reviewed indicate that priming of nonverbal information can be observed across a wide range of tasks and materials. Priming has been observed on fragment completion, picture-identification, picture-naming, object decision, preference, face-naming, semantic decision, and pattern identification/completion tasks; and priming has been demonstrated both for familiar objects and shapes as well as for novel objects and patterns that have no preexisting memory representations. We now turn to some of the major methodological and conceptual issues that arise from this literature. We consider first the possible contributions of explicit memory and naming processes, respectively, to performance in priming paradigms. We then consider alternative accounts of the phenomena that we have reviewed and conclude by outlining a preliminary theoretical framework for conceptualizing priming of nonverbal information.

A. Contributions of Explicit Memory

The studies that have been considered in this chapter all share one critical feature: They have assessed the influence of information acquired during an episode on subsequent performance with implicit memory tests that do not make explicit reference to, or require conscious recollection of, the prior study episode. It is precisely because such tests have been used that we refer to the phenomena of interest as expressions of *priming* and not *remembering*. However, as indicated earlier in the article the fact that a test does not require explicit remembering of a prior episode does not preclude the possibility that subjects will make use of explicit memory processes. For example, we have noted several times that the standard picture-fragment completion task, which has been used in numerous studies of priming, is readily influenced by explicit memory processes (e.g., Snodgrass, 1989).

The possibility that explicit memory processes influence performance on nominally implicit tests raises some tricky interpretive issues. Consider, for example, the finding that amnesic patients show significant, but not normal, priming on the picture-fragment completion task (e.g., Milner *et al.*, 1968; Warrington & Weiskrantz, 1968). The fact that amnesics show *some* priming despite near chance levels of recognition performance indicates that the observed priming cannot be attributed to explicit memory. However, the additional fact that amnesic patients show lower levels of completion performance than do control subjects can be interpreted in two different ways. First, the processes that support object priming in amnesics may be impaired. Second, priming may be intact in amnesics, but normal subjects supplement completion test performance by engaging in explicit retrieval strategies (e.g., Milner *et al.*, 1968). The same sort of interpretive problem arises when an experimental variable has parallel effects on explicit and implicit tests. The parallel pattern of results may on the one hand reflect an important similarity between implicit and explicit memory; on the other hand, it may be attributable to the use of explicit retrieval strategies on a nominally implicit test.

In a general discussion of the issue, Schacter, Bowers, and Booker (1989) put forward a method for dealing with this problem, alluded to earlier in the article, called the *retrieval intentionality criterion*. This criterion consists of three key components: (1) the same nominal cues should be presented to subjects on implicit and explicit tests; (2) only the implicit/explicit nature of test instructions should be varied; and (3) an experimental or subject variable should be identified that produces dissociations between implicit and explicit task performance. Schacter *et al.* argued that when an implicit/explicit dissociation is observed under these conditions, the possibility that subjects use explicit strategies on the implicit test can be ruled out. Adherence to this criterion provides a noncircular means for interpreting parallel effects on implicit and explicit tasks. If parallel effects of experimental variables A and B are observed within the same paradigm that also produces a dissociation between variables C and D, then we can be confident that the observed parallel effects are not attributable to explicit memory processes (see Schacter *et al.*, 1989, for more extensive discussion).

Applying this logic to the research that we have reviewed, only a few studies have produced dissociations in strict conformity with the retrieval intentionality criterion (Gabrielli *et al.*, in press; Kunst-Wilson & Zajonc, 1980; Mandler *et al.*, 1987; Mitchell, 1989; Musen & Treisman, 1990; Parkin & Streete, 1988; Schacter *et al.*, 1990; Schacter & Bowers, in preparation; Schacter & Merikle, in preparation). Several studies have documented similar dissociations under conditions in which the nominal cues differed on implicit and explicit tests (e.g., Hirshman *et al.*, in press; Jacoby *et al.*, 1989; Weldon & Roediger, 1987; Winnick & Daniel, 1970);

as discussed previously, this sort of comparison is not entirely satisfactory. Other investigations have attempted to examine the contribution of explicit memory processes to priming through different types of analyses (e.g., Snodgrass & Feenan, 1989; Warren & Morton, 1982). Unfortunately, however, a large number of studies on priming of nonverbal information have not included explicit memory tests. Therefore, we must remain uncertain about the possible role of explicit remembering in many of the phenomena reviewed earlier. Until appropriate dissociations are produced, interpretive caution should be exercised when attempting to draw theoretical inferences from priming studies about the processes and systems involved in implicit and explicit memory.

B. Facilitation of Naming versus Priming of Nonverbal Information

A second issue with important interpretive implications that has been acknowledged in the literature concerns the role of object naming in priming effects. The question is whether we can safely attribute observed performance facilitations to priming of *nonverbal* information—representations of objects, patterns, faces, and the like—or whether these effects are attributable to overt or covert naming processes. As discussed by several investigators (e.g., Bruce & Valentine, 1985; Lachman & Lachman, 1980), subjects may generate names of familiar objects at the time of study, and facilitated access to object names may produce priming on subsequent tests. And even when unfamiliar objects or patterns are used, it is always possible that subjects code them verbally during study and that priming is attributable to retrieval of verbal codes at test.

One reason why this issue must be considered seriously is that most of the implicit tests that have been used to assess priming of nonverbal information involve a naming response; identification of fragmented or briefly presented pictures and picture naming are the most prominent examples. One type of evidence relevant to this issue is that studying words yields little if any priming on picture completion and identification tests (Warren & Morton, 1982; Weldon & Roediger, 1987) and reduced (relative to pictures) though significant priming on picture-naming tests (Durso & Johnson, 1979; Lachman & Lachman, 1980). These results suggest that simple generation of a verbal label is not a major source of priming on nonverbal tests. On the other hand, naming a word during the study phase has produced some priming in several studies, thereby suggesting that name generation may play some role in priming on picture identification and naming tests. Moreover, even if naming a *word* at the time of study produced no priming, it is still logically possible that priming depends crucially on generating a name for a studied *picture*. Lachman and Lachman (1980) attempted to exclude this possibility by demonstrating that presentation of lure pictures on a yes/no recognition test produced significant facilitation on a subsequent picture-naming test. However, the theoretical significance of this finding depends critically on the validity of the rather uncertain assumption that subjects do not generate an object name when making a recognition decision about a lure item. Bruce and Valentine (1985) found that naming a face produced priming on a subsequent face-naming task but not on a semantic decision task, thereby suggesting that naming processes may play a role on some though not all implicit tests.

Several additional findings call into question the importance of object naming during the study phase for subsequent priming. First, priming is higher when the *same* object is presented at study and test than when a *different* object with the same name is presented (Bartram, 1974; Biederman & Cooper, 1989b; Jacoby *et al.*, 1989; Schacter & Bowers, in preparation; Warren & Morton, 1982). Second, the specific *orientation* of an object at study and test appears to influence priming, at least under some conditions (Bartram, 1974; Jolicouer, 1985; Jolicoeur & Milliken, 1989). These findings suggest that priming depends on specific visual attributes of encoded objects and cannot be explained as a simple consequence of generating an object name at the time of study. However, with the exception of the Schacter and Bowers study, these experiments have not produced implicit/explicit dissociations in conformity with the retrieval intentionality criterion discussed in the preceding section. Until appropriate dissociations are produced in these paradigms, it could be argued that the observed specificity effects reflect the use of explicit memory processes and thus may not speak directly to the role of naming processes in priming.

A third kind of evidence is provided by the finding of robust priming for novel objects and patterns that do not have any names, under conditions in which observed implicit/explicit dissociations rule out the possibility that priming is attributable to explicit memory (Gabrielli *et al.*, in press; Kunst-Wilson & Zajonc, 1980; Mandler *et al.*, 1987; Musen & Treisman, 1990; Schacter *et al.*, 1990). Of course, it could be argued that even though novel objects and patterns do not have agreed-upon names, subjects may attempt to code them verbally anyway and that it is this verbal coding that supports priming. Existing evidence, however, casts doubt on this possibility: Priming of novel shapes has been observed under conditions of brief exposure at which subjects do not reliably detect the presence of the shapes (Kunst-Wilson & Zajonc, 1980), and when subjects were *required* to generate verbal labels for unfamiliar objects in the study by Schacter *et al.* (1990, Experiment 2), no priming was observed on a subsequent object decision test. A fourth and related source of evidence is provided by the finding of robust priming on fragment completion (Schacter & Merikle, in preparation) and object identification (Schacter & Bowers, in preparation) tasks following a vertex-counting encoding task in which subjects did not overtly name target objects.

In summary, although the role of naming and verbal labeling in priming of allegedly nonverbal information clearly requires more extensive study, at least two tentative conclusions can be advanced. First, when implicit tests are used that require a naming response, prior naming may contribute to priming. Second, there are good reasons to believe that priming of nonverbal information on implicit tests that do not require a naming response (e.g., object decision, semantic decision, preference, dot-pattern identification, and completion) is independent of prior naming. Accordingly, we suggest that progress in understanding priming of nonverbal information will be facilitated by development of implicit tests that do not require naming responses.

C. Theoretical Accounts

The literature that we have reviewed encompasses a number of theoretical issues and problems that reflect the concerns of the various contributors to it: Some investigators have been concerned primarily with the nature of semantic memory processes; others have attempted to use priming as a tool to investigate the structure of object representations; and still others have focused on the nature of the processes and systems that underlie implicit and explicit memory. Thus, for example, one of the key issues that has motivated a number of studies of picture–word transfer concerns whether pictures and words share a common, amodal representation or whether there are separate, form-based representations for the two types of materials (e.g., Durso & Johnson, 1979; Kirsner *et al.*, 1986; Kroll & Potter, 1984; Lachman & Lachman, 1980). The fact that modest and sometimes negligible amounts of priming are observed between pictures and words supports the idea that separate form-based representations exist. As noted earlier, however, high levels of picture–word transfer in *semantic* priming paradigms suggest the existence of an amodal level of semantic representation that is distinct from modality-specific form-based representations (for discussion, see Kirsner *et al.*, 1986; Riddoch & Humphreys, 1987; Snodgrass, 1984; Vanderwart, 1984). Thus, any attempt to explain repetition priming of nonverbal information in terms of semantic processes is unlikely to succeed.

An early theoretical account of picture priming was offered by Warren and Morton (1982), who argued that priming of familiar objects reflects the temporary activation of a preexisting representation of the object that they called a *pictogen*. A pictogen was held to be an abstract representation of all objects with the same name (e.g., all clocks). Thus, the pictogen is a sort of nonverbal equivalent of the *logogen*, a term coined by Morton (1979) to refer to abstract lexical representations that are presumed to underlie word priming effects. The data that we have reviewed, however, present several problems for the pictogen view: Priming of nonverbal information can last for days and weeks whereas activation of a pictogen was held to decay extremely rapidly; priming has been demonstrated for novel objects and patterns that have no preexisting pictogens; and some priming effects appear to be more specific than would be expected if they were based on activation of an abstract pictogen.Thus, just as logogen theory has serious problems handling the data from verbal priming experiments (e.g., Jacoby, 1983; Richardson-Klavehn & Bjork, 1988; Roediger & Blaxton, 1987; Schacter, 1987, in press), the pictogen view cannot account for all of the data on nonverbal priming.

In contrast to the pictogen view, Weldon and Roediger (1987) and Jacoby *et al.* (1989) have proposed an episodic account of priming that they have applied to nonverbal materials. By their view, implicit memory can be understood by applying principles that have proven useful in understanding explicit memory, such as transfer-appropriate processing and encoding specificity. More specifically, they have argued that performance on such tests as picture identification and completion is primarily *data driven*—that is, guided by physical features of test cues. Consistent with the principle of transfer-appropriate processing (e.g., Roediger & Blaxton, 1987), it is thus argued that priming on these tasks depends on access to episodic representations of specific physical features of target materials. Performance on standard explicit tests of recall and recognition, in contrast, typically depends on subject-initiated, *conceptually driven* processing. This view can thus accommodate the general finding of a large form-based component in object priming, is consistent with observed specificity effects, handles a number of implicit/explicit dissociations, and is not embarrassed by instances of long-lasting priming. One serious problem with this view, however, is that it does not provide an account of preserved priming of either words or nonverbal materials in amnesic patients (for discussion, see Hayman & Tulving, 1989; Schacter, in press).

D. Priming and Perceptual Representation Systems

An alternative approach that incorporates some of the foregoing ideas and extends them into a multiple memory systems framework has been described in detail in several recent papers (Schacter, in press; Schacter *et al.*, 1990; Tulving & Schacter, 1990). The basic idea is that priming on data-driven implicit tests depends on a class of presemantic *perceptual representation systems* that are dedicated to the representation and retrieval of information about the form and structure, but not the meaning, of words and objects. This general notion is motivated by two independent lines of evidence. The first is provided by priming experiments. Several studies of object priming reviewed in this article (e.g., Carroll *et al.*, 1985; Schacter *et al.*, in press; Schacter & Bowers, in preparation; Schacter & Merikle, in preparation), as well as various studies of verbal priming (e.g., Graf & Mandler, 1984; Jacoby & Dallas, 1981; Schacter & McGlynn, 1989), have shown that priming effects are robust following structural encoding tasks and do not require any semantic study processing. In addition, a number of studies have shown that priming is sensitive to changes in structural or surface feature information (e.g., Bartram, 1974; Jacoby *et al.*, 1989; Schacter & Bowers, in preparation; Weldon & Roediger, 1987). Thus, experimental evidence from implicit memory studies indicates that priming on data-driven tests such as completion and identification is a structurally based, presemantic phenomenon.

Second, neuropsychological research on patients with selective deficits of reading and object processing has provided evidence for presemantic perceptual systems. The crucial observations take the form of striking dissociations between impaired access to semantic knowledge of words or objects on the one hand together with relatively intact access to structural knowledge on the other (e.g., Ellis & Young, 1988). In the verbal domain, for example, several studies have demonstrated intact access to visual and orthographic knowledge of words despite impaired acccess to word meaning (e.g., Funnell, 1983; Schwartz, Marin, & Saffran, 1979). These studies, together with converging evidence from neuroimaging research using the technique of positron emission tomography (Petersen, Fox, Posner, Mintum, & Raichle, 1988), point to the existence of a presemantic *visual word-form system* (Warrington Shallice, 1980) that appears to be involved in various verbal priming effects (Schacter, in press).

More directly relevant to the present concerns, other neuropsychological research suggests the existence of a presemantic system that is dedicated to handling information about the form and structure of visual objects. The key evidence comes from studies of patients with various forms of object agnosia, who are typically unable to recognize common objects. A number of studies have shown that such patients perform relatively well on tests that tap *structural* knowledge of objects despite severe impairments on tests that tap *associative* or *functional* knowledge of the same objects (cf. Riddoch & Humphreys, 1987; Sartori & Job, 1988; Warrington, 1982; Warrington & Taylor, 1978). Following Riddoch and Humphreys (1987), we refer to this system as the *structural description system* (Schacter *et al.*, 1990).

In view of the aforementioned evidence that various nonverbal priming effects are observed independently of semantic study processing and are affected by study–test changes in the physical form and structure of target materials, we suggest that the structural description system plays an important role in priming of nonverbal information. Because this system is hypothesized to operate exclusively on the form and structure of objects and does not handle associative, functional, or contextual information about them, we think that it plays a limited role in explicit memory for a previous encounter with an object. Explicit remembering appears to require the involvement of an episodic memory system (Tulving, 1983) that represents various kinds of information about the content of an event and relates them to a spatiotemporal context.

The idea that a presemantic structural description system plays an important role in implicit memory for nonverbal information represents a beginning hypothesis that requires a good deal of further development. For example, the extent to which this system is involved in priming will likely depend on the exact nature of the implicit memory test that is used. Though we think that the structural description system is involved in nonverbal priming when data-driven implicit tests are used, different processes will likely be tapped when conceptually driven tests are used (see Schacter, in press; Tulving & Schacter, 1990). Similarly, more detailed hypotheses are required concerning exactly what types of information the system handles and how they are expressed on implicit memory tests. Despite these and other gaps in the framework, this idea has the virtue of specifying a candidate system that is involved in nonverbal priming and suggesting an underlying structural basis for transfer-appropriate processing models. At the same time, it also provides an explicit link between implicit memory research and neuropsychological studies of reading and object-processing deficits that can help to guide future studies concerned with priming of nonverbal information and the nature of implicit memory.

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