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Considerable progress has been made during the past year toward achieving the project's main goals of elucidating the representations and processes involved in implicit and explicit memory for novel visual objects. Experiments have been completed or initiated that a) clarify the effects of structural and functional encoding manipulations on priming and explicit memory, b) help to specify the nature of the structural representation that underlies priming effects on the object decision task, c) extend findings on priming of novel objects to tests other than possible/impossible object decision, d) elucidate the extent to which implicit memory for novel objects is spared in subject populations with explicit memory deficits, and e) examine conditions under which priming of novel objects may be observed.

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Lynn A. Cooper, Co-investigator

Abstract

Considerable progress has been made during the past year toward achieving the project's main goals of elucidating the representations and processes involved in implicit and explicit memory for novel visual objects. Experiments have been completed or initiated that a) clarify the effects of structural and functional encoding manipulations on priming and explicit memory, b) help to specify the nature of the structural representation that underlies priming effects on the object decision task, c) extend findings on priming of novel objects to tests other than possible/impossible object decision, d) elucidate the extent to which implicit memory for novel objects is spared in subject populations with explicit memory deficits, and e) examine conditions under which priming of novel objects may be observed.

Status of the Research

This report first considers progress during the past year in Schacter's Harvard laboratory and then dicusses progress at Cooper's Columbia laboratory (site of the subcontract). Unless otherwise stated, priming or implicit memory was assessed with a possible/impossible decision tasks in which previously studied and nonstudied possible and impossible objects were flashed briefly (i.e., 50 msec) and subjects decided whether each object is possible or impossible. Explicit memory was assessed with a yes/no recognition task. Our previous research has revealed that object decision priming a) requires structural encoding of objects, b) is observed for possible but not impossible objects, c) can be dissociated experimentally from explicit memory by manipulating depth of encoding, d) is robust across study-to-test changes in size and reflection of objects, and e) is preserved in amnesic patients who have serious explicit memory deficits. These findings have led us to hyopthesize that priming on the object decision task reflects the operation of a presemantic structural decription system that computes size-and reflection-invariant representations and can function independently of episodic system that supports explicit memory.

Harvard laboratory

In Schacter's laboratory, several different lines of work have progressed. First, we have continued a series of studies comparing the effects of encoding structural and functional aspects of visual objects on object decision and recognition performance. Previous experiments had already established that encoding tasks that require

subjects to think about an object's functional properties (e.g., is it best used as a tool or for support) produce higher recognition, but no more priming, than do encoding tasks that require subjects to think about an object's structural properties (e.g., whether it is facing primarily to the left or to the right). In recently completed studies, we examined whether combining structural and functional encoding tasks would produce more priming than either structural or functional encoding tasks alone. If the priming that was observed following the functional encoding task is attributable solely to structural analyses that are carried out in the course of making a functional judgment, then priming should not differ among the various conditions. On the other hand, if priming in the functional condition is based on a different type of information than priming in the structural condition, then performing both structural and functional encoding tasks should enhance priming. In two experiments, we found equivalent levels of priming across the various encoding conditions, consistent with the idea that priming in the functional condition is attributable to encoding of structural information, which may be an obligatory part of the functional encoding t k.

Second, research on implicit and explicit memory for novel objects in memory-impaired populations has continued. Two experiments with elderly adults were completed that show intact object decision priming despite impaired recognition memory in the elderly. However, these experiments also revealed that elderly adults performed quite poorly on the object decision task despite showing a normal priming effect -- that is, their baseline levels of object decision accuracy was lower than that of young control subjects and not significantly different from chance. These observations raise the possibility that the structural description system is not entirely normal in elderly adults, although it can support robust priming. To investigate the matter further, we asked whether elderly adults would show size invariant priming, as we have observed previously in young subjects. The experiment yielded an unexpected, but interesting, outcome. Following a study trial in which they viewed large objects (that subtended a visual angle of about 18 deg), elderly adults showed similar amounts of priming when tested with large objects or with small objects (that subtended a visual angle of 6 deg). Thus, they exhibited size-invariant priming. However, when the elderly subjects studied small objects, they showed no priming when tested with either small or large objects. These observations suggest that the elderly had difficulties in extracting three-dimensional structural information from small objects. We are currently pursuing additional experiments to further clarify the matter.

A new series of studies on object decision priming in amnesic patients has also been initiated. A previous experiment had shown intact priming in patients with organic memory disorders. The new experiment, inititated in the summer of 1991 with the patient population available at the Boston VA Hsopital, is similar to th above-described experiment with elderly adults in that it examines properties of priming in amnesics by assessing whether object decision priming in amnescis

shows size invariance. Because of our findings with the elderly, we used only large objects for the study task (many of the amnesics are elderly), and then presented all objects in the small size. Although the experiment is not yet completed, results thus far indicate that the across-size priming effects exhibited by amnesic patients are similar to those exhibited by control subjects.

In a third and related line of work, we have completed experiments with college students following up on our earlier findings of size invariant priming that. To explore the limits of size invariance, we have used objects that are considerably smaller than those used in the previous study, in part because of some evidence from the neuroscience literature suggesting that size invariance of structural descriptions may not be observed with very small objects. An initial experiment provided evidence of size change effects on object decision when small (i.e., 2.6 deg of visual angle) objects are studied and large objects (i.e., 7.7 deg of visual angle) are tested. These results raised the possibility that there are limits on size-invariant priming, a finding that would have important implications for our thinking about the properties of the structural description system. However, we also considered an alternative explanation. The size-reduced objects in this experiments, unlike those used in our previous studies, were not "true" photographic reductions: the thickness of the lines that represent the edges of the objects remained the same in the small and large objects (this reflected a limitation on the Psychlab program on which we ran this experiment that was not present in the Iris system on which we ran the previous experiment). Thus, the lines themselves covered a larger proportion of the total area of the small objects than of the large objects. There were empirical and theoretical reasons to suspect that under these conditions, it would be more difficult to extract appropriate three-dimensional information from the small objects. Accordingly, we performed an additional experiment using newly-designed software than enabled to create small objects that were true photographic reductions of the large objects (i.e., line thickness reduced proportionally). Under these conditions, size-invariant priming was observed.

A fourth line of experiments has been initiated in collaboration with Dr. Stephen Kosslyn of Harvard that examine whether object decision priming is mediated primarily by the right or left hemisphere. In these studies, target drawings are presented in either the left or right visual field on the object decision test. We are now in the process of carrying out the experiment. There is some reason to speculate that structural descriptions of the kind that support object decision priming are represented primarily in the right hemisphere, and these experiments will provide pertinent data.

Finally, in collaboration with a neuroimaging research center headed by Dr. Eric Reiman at Good Samaritan Hospital in Phoenix, we have recently completed a PET imaging study of object decision priming. Our paradigm was modified to meet the demands of the PET laboratory by carrying out pilot work in Schacter's

laboratory, and the appropriately modified task was given to 16 subjects undergoing PET scans. Data are now being analyzed. We have hypothesized that regions of extrastriate cortex are crtitically involved in object decision priming, and are hopeful that this experiment will provide information that bears directly on this hypothesis.

Columbia laboratory

During the past year, progress has been made along several lines. First we have continued our examination of the nature of the structural description system for representing information about the global structure and relations among components of objects, using the drawings of possible and impossible structures that have proved so fruitful in earlier phases of our work. Second, we have developed and baseline-tested a new set of stimulus materials consisting of realistically rendered, depth cued models of symmetric and asymmetric three-dimensional structures. Third, we have begun a series of experiments with these stimuli using a new ("symmetric/asymmetric") object decision task. We are attempting to establish the conditions under which priming of object decision judgments occurs, and whether such priming is exhibited to test objects transformed in theoretically meaningful ways.

With respect to the first line of work, a number of experiments examining the effects on object decision priming and explicit recognition of study-to-test changes in the depicted picture-plane orientation of possible and impossible objects have been completed. In addition, an experiment evaluating changes in object color was recently finished. These experiments used the same general method and follow from the same logic as those examining changes in object size and reflection, reported in Cooper, Schacter, Ballesteros, and Moore (1992), and summarized in the last progress report. In four separate experiments examining a variety of different study and testing orientations, the same finding has repeatedly emerged: Both priming on the "possible-impossible" object decision task and explicit recognition performance are significantly impaired by study-to-test transformations of rotation in the picture plane. This result contrasts sharply with our finding of priming invariance (but, recognition impairment) over transformations of size or reflection. It suggests strongly that structural description representations, presumed to support priming on the object decision task, are axis- and reference-frame based and thus code information about an object's two-dimensional orientation in the plane. Consistent with this analysis, changing the attribute of colorfrom study to testing produces no statistically significant decrement in either the level of priming or explicit recognition memory.

Of great potential interest is the question of how changes of orientation in depth might be treated by the structural description and episodic systems for representing information about visual objects. In order to address this question (and others), it

has been necessary to develop a new set of objects based on "real" three-dimensional models and to introduce a new test of implicit memory, since impossible structures cannot be described or modeled in three-dimensional space. A major portion of our effort during the past year has been directed toward developing a complete stimulus set and the corresponding test of implicit memory. A set of 58 symmetric and 68 asymmetric three-dimensional objects have been modeled on the Personal IRIS computer graphics system; baseline studies identifying 36 useable objects of each type have been completed. For inclusion in experiments, the objects must satisfy the criteria of (a) being identified correctly as symmetric or asymmetric structures by 90% of subjects under conditions of unlimited viewing, and (b) yielding accuracy in the range of 60-80% under conditions of brief (50 -100 ms) exposure.

We have established that priming of "symmetric" judgments (but not of "asymmetric" judgments) can be obtained when the objects are encoded under structural (left/right) conditions. Experiments currently in progress are attempting to set boundary conditions for this priming, by using encoding manipulations that encourage non-structural encoding. In one experiment, we are examining the effects of local encoding (judging whether the objects have more horizontal and vertical vs. obliquely-oriented edges) on both object decision and explicit recognition performance. In another, we are asking subjects to encode the objects in a semantically meaningful fashion (by indicating some familiar object that each abstract structure reminds them of). If the effects of these manipulations parallel those found with the possible and impossible line drawings used in previous experiments, then priming should not be exhibited under the "local" and "elaborative" conditions of encoding. It is possible, however, that the three-dimensional structure of these depth-cued objects is so compelling that subjects encode structural description representations of them, regardless of the nature of the encoding task. Should this latter outcome be obtained, we plan to perform an experiment in which only two-dimensional silhouette versions of the objects are presented at the time of study, with the full three-dimensional version of each object presented for the object decision (or recognition) test. Presumably, no three-dimensional representation should be available for encoding under such conditions, so no priming should be exhibited on the object decision task.

In addition to establishing that priming of "symmetric" judgments can be obtained with our new set of objects, we have begun exploring the effects of study-to-test changes in orientation on the occurrence and magnitude of this priming. In one recently completed experiment, test orientations that represented 30 degree and 90 degree rotations about a vertical axis in depth were introduced. Results suggest that priming continues to be exhibited despite such transformations -- an outcome that strongly supports our theoretical notions concerning the nature of structural description representations of objects (see above). Unfortunately, a parallel experiment evaluating the effects of rotations of these three-dimensional objects in the picture plane yielded somewhat mixed and inconclusive results. Accordingly,

we are undertaking a more systematic exploration of both the picture- plane and the depth transformations, using a larger and more sensitive set of both encoding and test orientations.

In summary, we have made considerable progress during the past year both in examining further the effects of study-to- test transformations on priming and recognition of possible and impossible objects, and in developing a set of new three-dimensional objects and initiating an extensive series of experiments employing these stimuli.

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