Investigating the Relationship Between Perceptual Categorization and Recognition Memory Through Induced Profound Amnesia

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Abstract

Are perceptual categorization and recognition memory subserved by a single memory system or by separate memory systems? A critical piece of evidence for multiple memory systems is that amnesics can categorize stimuli as well as normals but recognize those same stimuli significantly worse than normals (Knowlton & Squire, 1993). An extreme case is E.P., a profound amnesic who can categorize as well as normals but cannot recognize better than chance. This paper demonstrates that the paradigm used to test E.P. and other amnesics may be fundamentally flawed in that memory may not even be necessary to categorize the test stimuli in their paradigm. We "induced" profound amnesia in normals by telling them they had viewed subliminally presented stimuli that were never actually presented. Without any prior exposure to training stimuli, subjects' recognition performance was completely at chance, as expected, yet their categorization performance was quite good.

Single Versus Multiple Memory Systems

What processes are involved in judging whether an object belongs in a particular category (a categorization decision) and in judging whether an object is something that has been seen before (a recognition decision)? Formal theoretical accounts have suggested that both of these fundamental types of cognitive judgments are subserved by a single memory system. By contrast, many neuropsychological accounts have suggested that there are separate neural systems subserving categorization and recognition memory. This paper will briefly review the evidence for single memory systems and for multiple memory systems and then present recent experimental work that may challenge some of the critical evidence used to support the multiple memory systems view.

Exemplar-based models, such as the Generalized Context Model (GCM; Nosofsky, 1986; see also Nosofsky & Palmeri, 1997; Palmeri, 1997), assume that both categorization and recognition rely on memory for stored instances but differ in the way that memory is probed. According to the GCM, categorization is based on the relative summed similarity of a probe item to the stored instances of the possible category responses whereas recognition is based on the absolute summed similarity of a probe item to all instances stored in memory. In other words, categorization and recognition decisions rely on the same memories, but differ in the decision rules they use. Nosofsky (1988, 1991) has shown the GCM to provide excellent accounts of observed categorization and recognition data in a variety of experimental paradigms using normal individuals.

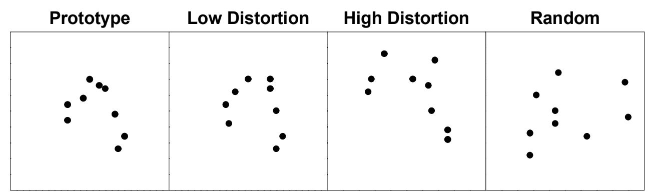

Figure 1: Examples of a prototype, a low-distortion, a high-distortion, and a random pattern.

Knowlton and Squire (1993) provided evidence for multiple memory systems by contrasting performance of amnesics and normal individuals on categorization and recognition memory tasks. They used a variant of the well known dot pattern classification and recognition paradigm (Posner & Keele, 1968). In a categorization task, amnesics and normals were initially exposed to forty high-level distortions of a prototype pattern (see Figure 1) without being told that the patterns belonged to the same category. At test, subjects were told that the patterns they had just seen were all members of the same category and were then asked to judge whether a new set of patterns were members or nonmembers of that category. Subjects were tested on the prototype, low distortions of the prototype, and high distortions of the prototype, which were all to be judged as members, and new random patterns, which were all to be judged as nonmembers. In a recognition task, amnesics and normals were initially exposed to five random patterns repeated eight times each without being told that they would later be tested on their memory for those patterns. At test, subjects were shown the five training patterns and five new random patterns and were asked to judged which were old and which were new.

As shown in the top panel of Figure 2, Knowlton and Squire (1993) found that recognition memory was significantly impaired for amnesics compared to normals. However, no significant difference was observed between amne-

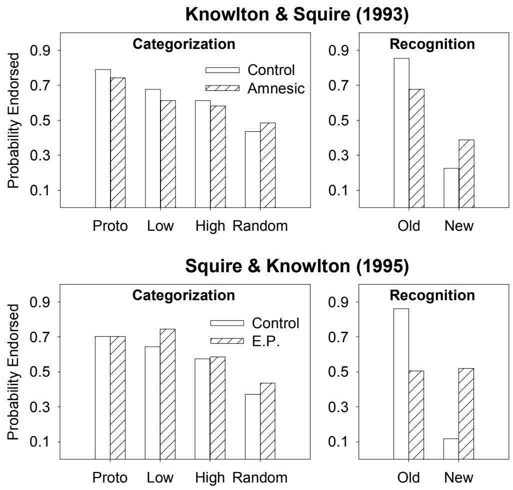

Figure 2: Top panel displays data from Knowlton and Squire (1993) comparing amnesics with normals. Bottom panel displays data from Squire and Knowlton (1995) comparing E.P. with normals. Each panel shows probability of categorization and recognition for each type of pattern.

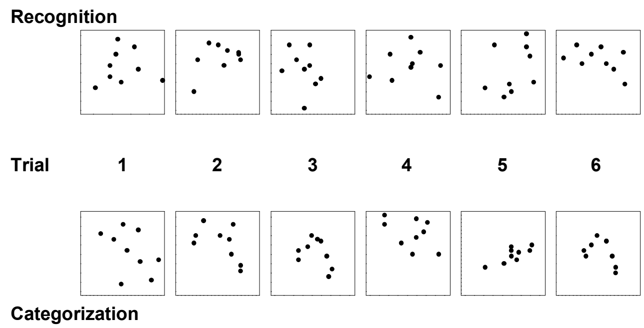

Figure 3: Example sequences of recognition (top row) and categorization (bottom row) using stimuli from Knowlton and Squire (1993). For the recognition trials, correct answers are: (1) Old, (2) New, (3) Old, (4) New, (5) Old, (6) New. For the categorization trials, correct answers are: (1) Nonmember, (2) Member (high), (3) Member (prototype), (4) Nonmember, (5) Nonmember, (6) Member (low).

sics and normals at categorization. This pattern of results was used as evidence for two separate, independent memory systems: an explicit system subserving recognition memory, which is impaired in amnesia, and a separate implicit categorization system, which is spared in amnesia. Knowlton and Squire conclude that *"single-factor models in which classification judgments derive from, or in any way depend on, long-term declarative memory do not account for the finding that amnesic patients perform well on the classification tasks"* (p. 1748).

While these results seemed to suggest the existence of multiple memory systems, Nosofsky and Zaki (1998) recently reported theoretical analyses that showed the GCM capable of accounting for this apparent task dissociation in a fairly straightforward manner. By simply assuming that amnesics had poorly discriminated memory traces compared to normals, which was instantiated by variation in a single parameter of the model, the GCM was able to account for the observed difference in recognition and categorization performance. In addition, by experimentally producing poor memory discrimination in normal individuals through the use of a delay between study and test, Nosofsky and Zaki were able to reproduce the exact pattern of categorization and recognition results observed with amnesics.

One of the reasons for the success of the GCM in accounting for the Knowlton and Squire (1993) results is that amnesics had poor but above chance recognition memory. More recent evidence reported by Squire and Knowlton (1995) may be more challenging. They tested E.P., a profoundly amnesic individual, on a task similar to that used by Knowlton and Squire (1993). As shown in the lower panel of Figure 2, E.P. was able to categorize as well as normals, but was completely unable to recognize above chance levels. It may prove impossible for a single-system model, such as the GCM, to account for this extreme pattern of results (see Nosofsky & Zaki, 1998). In summarizing these results, Squire and Zola (1996) concluded that "*these results suggest that category knowledge can develop independently of and in the absence of normal declarative memory ... the information supporting classification learning must be distinct from declarative knowledge about the specific items presented for training. Models in which classification judgments derive from, or in any way depend on, long-term declarative memory do not account for the finding that amnesic patients can acquire category knowledge as well as normal subjects"* (pp. 13517-13518).

The Squire and Knowlton (1995) findings may appear to be devastating to the single system models. However, in this paper, we will suggest that the experimental procedures used to test E.P. and other amnesics may be fundamentally flawed in that prior exposure to training stimuli may be unnecessary to perform the categorization task they used. To illustrate, the top row of Figure 3 displays a sequence of recognition test trials from Knowlton and Squire (1993). Clearly, if asked to judge which of these patterns were old or new without ever having been shown any training patterns, it would be impossible to perform better than chance. The bottom row of Figure 3 displays a sequence of categorization trials. Recall that subjects were required to judge as members the prototype, low distortions of the prototype, and high distortions of the prototype, and to judge as nonmembers a set of completely random patterns. Without previous exposure to any training patterns, it may be quite easy to discover that the set of very similar patterns all belong to the same category and that the set of very dissimilar patterns are all nonmembers of that category. This determination can possibly be made after only a few test stimuli have been shown. Thus, a profound amnesic, such as E.P., who has relatively intact working memory and other cognitive functions, may be able to accurately judge category membership without any memory for the studied patterns.

Experiment 1

Our basic claim is that even without memory for having seen any category members, it may be possible to correctly categorize members versus nonmembers in the particular type of categorization task used by Knowlton and Squire (1993; Squire & Knowlton, 1995). By contrast, it is simply impossible to judge old from new members without remembering which stimuli had been presented before.

Our first goal was to demonstrate that information about the category structure can be extracted from the sequence of patterns used in the categorization test. As a way of maximally assessing how much information about the category structure could possibly be extracted from the test sequence, a particularly well-motivated subject (the second author) participated in ten categorization test sessions. These categorization tests had the exact same structure as those used by Knowlton and Squire (1993); however, in our experiment, the subject did not receive any prior exposure to category members. Although she was aware of how the category members and nonmembers were defined abstractly, she had absolutely no prior knowledge of the particular prototypes and distortions that were used within a given test session – she needed to discover the category structure (judging members versus nonmembers) without the benefit of any prior exposure and without the benefit of any corrective feedback.

It is important to emphasize that even with a complete understanding of the procedure for how old and new patterns in a recognition test were generated, without any prior exposure to study patterns it would be absolutely impossible to recognize old from new patterns better than chance.

Method

Subject. The second author (M.A.F.) completed ten categorization sessions over a two week period.

Procedure. On each trial of the categorization task, a dot pattern was displayed and the subject was asked to judge whether it was a member or nonmember of a category; no prior exposure to category members had been provided. The subject judged four instances of the prototype, 20 low-level distortions, 20 high-level distortions, and 40 random patterns (identical to procedures used by Knowlton and Squire, 1993). Order of stimuli was randomized and no corrective feedback was supplied.

Stimuli. Stimuli were patterns of nine dots. At the start of each session, the computer randomly generated a pattern and designated it the prototype of the category. Distortions of the prototype were created with a commonly used statistical distortion algorithm (Posner, Goldsmith, & Welton, 1967). Random nonmember patterns were also newly created at the start of each session. The subject was completely unaware of the particular set of dot patterns that had been created until they were presented during the experiment.

Results

Figure 4 displays the probability of endorsing each type of stimulus as a member of the category. Without any prior

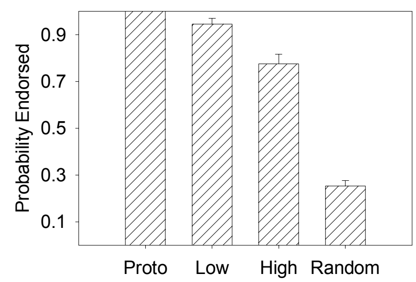

Figure 4 : Proportions of categorization decisions for each type of pattern from Experiment 1.

exposure to category members, M.A.F. was able to categorize the prototypes perfectly, the low distortions nearly perfectly, and the high distortions and random patterns extremely well. Overall, M.A.F. was 81.3% correct at classifying members and nonmembers. A statistically significant effect of stimulus type was observed, $F(3,39)=153.28$, $MS_e=0.008$, and planned comparisons confirmed the observed ordering of levels.

Discussion

As we predicted, there was sufficient information in the sequence of categorization trials at least for a particularly well-motivated subject to accurately categorize the test stimuli in the Knowlton and Squire (1993) paradigm without any prior exposure to category members. It is now necessary to demonstrate that naïve subjects can also categorize without any prior exposure to category members.

Experiment 2

In the previous experiment, the subject knew that category members were distortions of a prototype pattern whereas category nonmembers were random patterns. Obviously, the amnesic subjects tested by Knowlton and Squire had no such intimate knowledge of the experimental procedures. Could naïve individuals categorize the test patterns without prior exposure to category members? If so, then it is quite possible that amnesic individuals, without memory for training patterns, could do the same thing.

Without access to an amnesic population, we wanted to test normal individuals under conditions that closely mimicked those used to test amnesics. As a way of inducing profound amnesia in college undergraduates, Palmeri and Flanery (in press) eliminated the study session altogether but led subjects to believe they had seen a set of patterns. In their experiment, subjects first completed a simple word identification task. As a ruse, after the word identification task was completed, subjects were informed that dot patterns had been flashed on the computer screen during the task so quickly that they could only be perceived subliminally. In fact, no dot patterns had ever been presented. Subjects were then given the exact same categorization and recognition memory tasks used by Knowlton and Squire (1993). The expectation was that subjects would be completely unable to recognize the old patterns but would be able to categorize members versus nonmembers.

Not surprisingly, Palmeri and Flanery (in press) found that subjects were completely at chance at recognizing old versus new patterns. However, subjects were 60.4% correct at categorizing members versus nonmembers (endorsing as members 70.9% of the prototypes, 61.3% of the low distortions, 51.4% of the high distortions, and 36.6% of the random patterns). These data are in close correspondence to categorization performance by amnesics (59.9%, Knowlton & Squire, 1993), by E.P (61.1%, Squire & Knowlton, 1995), and by college students after a one week delay (57%, Nosofsky & Zaki, 1998).

Palmeri and Flanery (in press) used the same testing procedures used by Knowlton and Squire (1993), which involved presenting all subjects with one particular set of dot patterns. It is important to rule out the possibility that the ability to categorize without prior exposure is limited to a small subset of dot patterns, such as were used in those experiments. Therefore, in the present experiment, every subject was tested on a different set of dot patterns, randomly generated by the computer.

In the present experiment, we also included a group of subjects that had received prior exposure to dot patterns (thereby replicating the original Knowlton & Squire experiment). This allowed us to explicitly measure the relative effects of prior exposure on categorization and recognition performance. Although Palmeri and Flanery (in press) did test a group of individuals on categorization with prior exposure, finding that they did not perform significantly better than the nonexposed “amnesic” group, these two groups of individuals were not tested at the same time.

Method

Subjects. Subjects were 88 undergraduates students from Vanderbilt University who received course credit for their participation. Subjects were randomly assigned to the categorization-exposure, categorization-nonexposure, recognition-exposure, and recognition-nonexposure conditions.

Procedure. The exposure conditions were replications of Knowlton and Squire (1993). In the exposure phase, subjects viewed dot patterns and were asked to point to the center dot of each pattern. In the categorization condition, the dot patterns were forty high-level distortions of a prototype patterns. In the recognition condition, the dot patterns were five random patterns repeated eight times each.

The nonexposure conditions were replications of Palmeri and Flanery (in press). In the "study" task, subjects were asked to identify words rapidly flashed on a computer screen. On each trial, a pair of words differing by one letter was selected and one word from the pair was designated the target. A crosshairs appeared at the center of the screen, the target word was displayed for 25ms, and then the pair of words was displayed side by side. Subjects judged which of the two words has been flashed.

Following this task, subjects were informed that we were not really interested in word identification after all. Rather, they were told that during the word identification task, patterns of dots had been flashed on the computer screen, centered at the crosshairs, so quickly that they could only be perceived subliminally. The reason for doing the word identification task, they were told, was so that they would attend to the location on the screen where the dot patterns were being subliminally presented. Extensive pilot work was conducted to construct a believable cover story.

Subjects in the categorization task were provided the following instructions (adapted from instructions used by Reber, Stark, & Squire, 1998, and Squire & Knowlton, 1995):

> “During the previous word identification task, patterns with nine dots were quickly flashed on the computer screen so as to be perceived subliminally (without conscious awareness). All of these patterns belonged to a single category of patterns in the same sense that, if a series of dogs had been presented, they would all belong to the category dog. While you probably have no conscious recollection of the patterns, we would like you to try as hard as possible to figure out which of the following patterns are members of the same category which was displayed earlier and which are not.”

If subjects claimed not to completely understand what we meant by a "category" they were then shown a picture of some dogs and asked to think about what it would mean for a new animal to belong to the same category as these animals. Subjects in the recognition condition were provided similar instructions, except they were asked to decide which patterns were old or new.

On each trial of the categorization task (for subjects exposed and nonexposed to previous patterns), a dot pattern was displayed and subjects were asked to judge whether it was a member or nonmember of the previously exposed category (for which they had been exposed in the exposure condition but for which they had never actually been exposed in the nonexposure condition). Subjects judged four instances of the prototype, 20 low-level distortions, 20 high-level distortions, and 40 random patterns (identical to procedures used by Knowlton and Squire, 1993). On each trial of the recognition task (for subjects exposed and nonexposed to previous patterns), a dot patterns was displayed and subjects were asked to judge whether it was old or new. Subjects judged five patterns old and five new patterns; four blocks of ten recognition trials were presented.

In both recognition and categorization, order of stimuli was randomized for every subject, no corrective feedback was supplied, and subjects were informed that approximately equal numbers of members/nonmembers or old/new stimuli would be presented.

Stimuli. In the "study" task of the nonexposure conditions, stimuli were forty pairs of four-letter words that differed by a single letter (e.g., WORD vs. WORK). The location of the changed letter was roughly equated across positions. Because this task was just a ruse, we did not systematically control other aspects of the word pairs.

In the categorization conditions (both exposure and nonexposure), the computer randomly generated a pattern and designated it the prototype of the category. Distortions of the prototype were created with a commonly used statistical distortion algorithm (Posner, Goldsmith, & Welton, 1967). Random nonmember patterns were also newly created at the start of each session. The subject was completely unaware of the particular set of dot patterns that had been created until they were presented during the experiment.

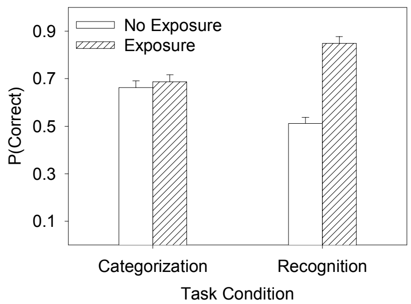

Figure 5: Categorization and recognition accuracy as a function of exposure versus nonexposure to prior patterns from Experiment 2.

In the recognition conditions (exposure and nonexposure), the computer randomly generated ten dot patterns, designating five as old and five as new. In the exposure condition, subjects saw the five old patterns.

Results

Figure 5 displays probability correct as a function of task (categorization versus recognition) and as a function of exposure (exposure versus no exposure). A two (task) x two (exposure) between-subjects ANOVA was conducted on the accuracy data revealing a significant main effect of exposure, $F(1,84)=40.635$, $MS_e=0.018$, and a significant two-way task x exposure interaction, $F(1,84)=30.403$, $MS_e=0.018$. Planned comparisons revealed no significant difference between exposed and nonexposed subjects at categorization but revealed a significant difference between exposed and nonexposed subjects at recognition. Recognition accuracy for nonexposed subjects was not different from chance.

Discussion

Replicating and extending Palmeri and Flanery (in press), we induced a state of profound amnesia in a group of normal college undergraduates by convincing them that they had been subliminally exposed to a series of dot patterns that were never actually presented. We compared performance of this group of "profound amnesics" to performance of a group who received normal exposure to stimuli in a study task. Not surprisingly, without exposure to any training patterns, recognition was at chance, but with exposure to training patterns, recognition was quite good. Yet, categorization by the "profound amnesics" was quite good, and was statistically indistinguishable from performance by an exposed group of subjects. Moreover, performance of both groups was comparable to what had been observed with amnesics and normals in studies by Knowlton and Squire (1993; Squire & Knowlton, 1995).

The apparent dissociation between categorization and recognition reported by Knowlton and Squire had been taken as evidence for multiple memory systems. However, our results suggest that their findings could simply reflect intact cognitive abilities that amnesics might have for detecting categories of similar patterns presented within a relatively short period of time, without any need to rely on long-term memory for those patterns. Unlike the recognition memory test, prior exposure to category members is unnecessary to perform the categorization test.

It should be noted that Knowlton and Squire did conduct a control condition similar to the nonexposed categorization condition reported here. They instructed subjects to imagine that they had seen a series of dot patterns but were never presented any training patterns, and then were given the same instructions and test stimuli as were given to a group of experimental subjects (amnesics and normal individuals in the second experiment of Knowlton and Squire, 1993). They reported that these subjects performed at chance on the classification test. So what explains the difference between their findings and ours? One potentially important difference is that we led our subjects to believe that they had actually seen patterns and that this subliminal exposure should be sufficient for them to perform the categorization task. By contrast, Knowlton and Squire (1993) simply told their subjects to imagine that they had seen patterns, probably leaving subjects uncertain as to whether it would be possible to perform the categorization task (consistent with this hypothesis, data from these subjects revealed an overall bias to classify every pattern as a nonmember). Even with little or no recollection for the training patterns, their amnesics subjects, like our induced amnesics, probably believed that it would be possible to perform the categorization task.

Many amnesics, including E.P., are elderly. One potential criticism of this experiment (and of Palmeri & Flanery, in press) is that we tested young college students, thereby raising questions about the validity of directly comparing our work with that of Knowlton and Squire. The main defense to this criticism is to note that performance of our undergraduates was not much different from that of the elderly individuals that had been previously studied; in addition, Nosofsky and Zaki (1998) also tested young college students and found similar results as we report.

General Discussion

Are various fundamental cognitive processes, such as categorization and recognition, subserved by a common memory system or by independent memory systems? While a dissociation between categorization and recognition in amnesics and normals has been taken as evidence for multiple memory systems (Knowlton & Squire, 1993), this dissociation is apparently consistent with a single memory system as well (Nosofsky & Zaki, 1998). However, the results from E.P., who has no detectable recognition memory yet categorizes nearly as well as normals, have been taken as powerful evidence against this single-system view.

While this remains a viable possibility, our results suggest that the evidence from E.P. may not be as compelling as once believed. We induced profound amnesia in undergraduates by telling them they had seen patterns which we never presented. While completely unable to recognize, they categorized as well as amnesics and normals who had prior exposure to training patterns. We have shown that the categorization task used by Squire and Knowlton allows subjects to discover which clusters of patterns are likely to be members simply because all members are similar to one another and all nonmembers are dissimilar from one another.

Our results emphasize the importance of equating categorization and recognition studies prior to testing memory-impaired individuals. Without prior exposure to any patterns, subjects should be entirely at chance at recognizing old versus new stimuli and at categorizing members versus nonmembers. One simple way of improving the present categorization paradigm is to have nonmembers be distortions of a different prototype; induced profound amnesics might notice that there are two clusters of patterns, but without prior exposure to one of the categories, it would be impossible to correctly label the members versus the nonmembers.

Finally, these results also point out some important oversights by formal theories of categorization and recognition (e.g., Nosofsky & Zaki, 1998). Our subjects categorized quite well without memories for training exemplars. Yet, exemplar models account for the observed dissociations by relying entirely on such memories. Although exemplar models can be augmented to allow test items to become part of the category representations (e.g., Nosofsky, 1986), the mechanisms by which this kind of unsupervised category learning takes place have yet to be fully investigated.

Acknowledgments

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