

Research Report

LEARNING ABOUT CATEGORIES IN THE ABSENCE OF TRAINING: Profound Amnesia and the Relationship Between Perceptual Categorization and Recognition Memory

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Abstract—Previous evidence suggests that amnesics can categorize stimuli as well as normal individuals but are significantly worse at recognizing those stimuli. In an extreme case, a profoundly amnesic individual, E.P., was found to have near-normal categorization, yet, unlike most amnesics, was unable to recognize better than chance. This evidence has been used to argue against the possibility that a common memory system underlies these cognitive processes. However, we provide evidence that the experimental procedures typically used to test amnesic individuals may be flawed in that initial exposure to category members may be unnecessary to observe accurate categorization of test stimuli. We experimentally “induced” profound amnesia in normal individuals by telling them they had viewed subliminally presented stimuli, which were never actually presented. Using the same experimental paradigm used to test amnesics, we observed that participants’ recognition performance was completely at chance, as should be expected, yet categorization performance was quite good.

What cognitive processes are involved when a category is learned through encounters with category examples? Exemplar models assume that categories are represented in terms of stored instances and that categorization is based on similarity to those instances (Nosofsky, 1986). In these models, categorization of instances and recognition memory for instances are mediated by a single representational system involving stored exemplars. By assuming different decision rules for categorization and recognition, Nosofsky (1988, 1991) showed that a single-system exemplar model can account for both judgments.

Knowlton and Squire (1993) tested the notion that categorization and recognition rely on a common memory system by comparing amnesics with normal individuals. In a variant of the classic dot-pattern paradigm (Posner & Keele, 1968), participants in the categorization condition were exposed to 40 high-level distortions of a prototype. During testing, participants judged whether the prototype, low-level distortions of the prototype, new high-level distortions, and random patterns were members of the same category as the previously exposed patterns. Participants in the recognition condition were exposed to five random patterns eight times each. During testing, participants judged the five training patterns and five new patterns as old or new. In both conditions, participants were unaware during exposure that there would be any subsequent categorization or recognition task, but were simply asked to point to the center dot of each pattern.

As shown in the top panel of Figure 1, recognition was significantly impaired for amnesics compared with normal individuals. Yet no sig-

nificant difference between the two groups was found in categorization. Knowlton and Squire (1993) claimed that this dissociation implied the existence of separate memory systems, an implicit system for categorization and an explicit system for recognition that depended on the integrity of hippocampal brain regions often damaged in amnesia. Although this is one interpretation of these results, Nosofsky and Zaki (1998) recently demonstrated that by simply assuming that amnesics had poorer memory discrimination than normal individuals, a single-system exemplar model could account for this dissociation as well.

However, another set of results could prove problematic for Nosofsky and Zaki’s contention. Squire and Knowlton (1995) reported the case of E.P., a patient with profound anterograde and retrograde amnesia. E.P. was tested using a task similar to the one in Knowlton and Squire (1993). As shown in the bottom panel of Figure 1, E.P. categorized comparably to normal individuals. However, whereas most amnesics showed poor, but above-chance recognition, E.P. was completely unable to recognize the patterns. Squire and Knowlton argued that a single-process model could not account for this extreme pattern of results.

The top row of Figure 2 displays a sample sequence of recognition trials of stimuli from Knowlton and Squire (1993). Clearly, if someone were asked to judge which patterns were old without having been exposed to any training stimuli, guessing would be the only option. However, even without any prior exposure, it might be possible to perform quite well at categorization. The bottom row of Figure 2 displays a sample sequence of categorization trials. Although participants in Knowlton and Squire’s experiments were never exposed to stimuli all at once, this figure suggests the possibility of distinguishing between members and nonmembers without ever having learned the categories. In Knowlton and Squire’s experimental design, many members look similar to one another, and nonmembers look dissimilar from both the category members and other nonmembers. Even without memory for the training stimuli, participants might quickly realize that the similar patterns are most likely to be members of one category.

In the present study, we “induced” profound amnesia in college undergraduates engaged in a close variant of Knowlton and Squire’s (1993) task. To simulate amnesia in our normal participants, we simply eliminated the study session altogether. As a ruse, we presented participants with a word identification task. After they completed this task, we informed them that dot patterns had been flashed on the computer screen so quickly as to be perceived subliminally. In fact, dot patterns were never displayed. Participants were then asked to recognize or categorize patterns, without corrective feedback, on the basis of their alleged prior exposure to stimuli. In the case of E.P., Squire and Knowlton (1995) claimed to have found a case of learning about categories in the absence of memory. If our “profoundly amnesic” undergraduates demonstrated learning about categories in the absence of training, this result would raise serious concerns about the efficacy of Squire and Knowlton’s experimental paradigm for making strong claims about dissociations between recognition and categorization.

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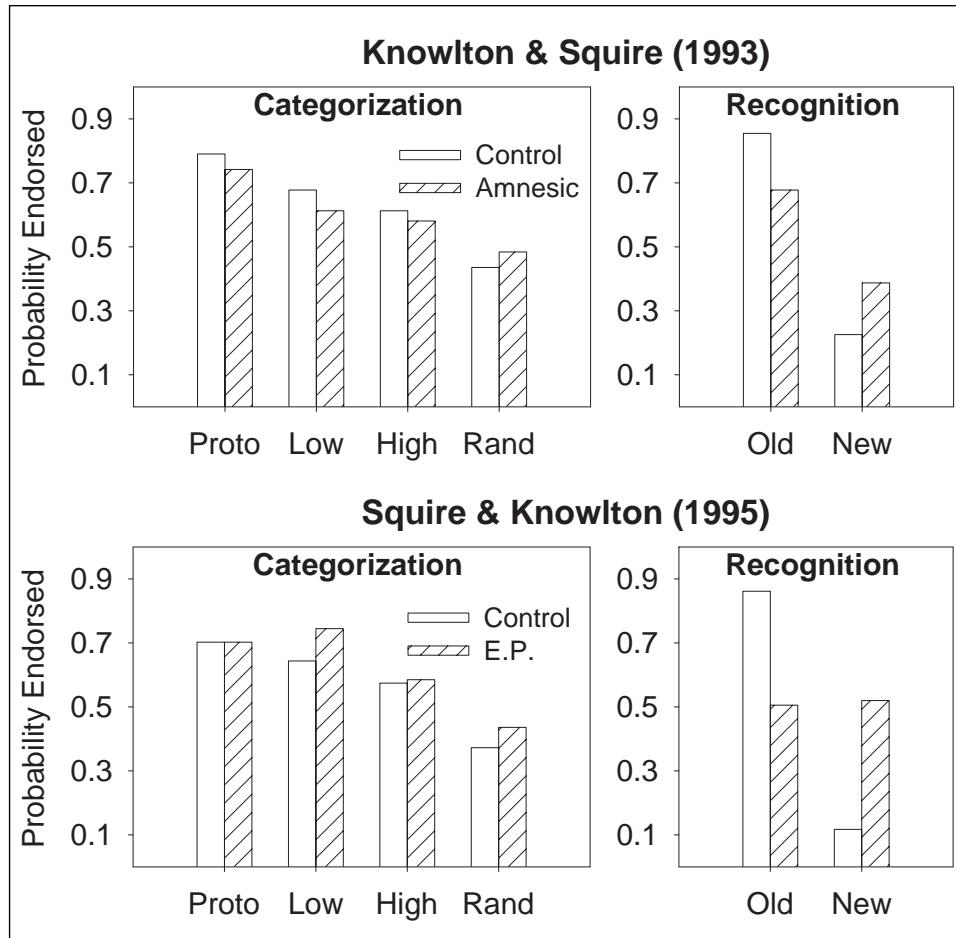


Fig. 1. Categorization and recognition memory performance by amnesic and normal individuals. The top panel displays data from Knowlton and Squire (1993) comparing amnesics with normal individuals. The bottom panel displays data from Squire and Knowlton (1995) comparing E.P. with normal individuals. Each panel shows the probability of endorsing a pattern as a category member (categorization) and as a previously seen pattern (recognition). The probability of recognition of new patterns in the bottom panel is averaged across three types of new patterns used in Squire and Knowlton (1995). Proto = category prototype; Low = low-level distortion of prototype; High = high-level distortion of prototype; Rand = random pattern.

METHOD

Participants

Seventy undergraduate students from Vanderbilt University participated in the main experiment to fulfill a course assignment; 27 participated in the recognition condition, and 43 participated in the categorization condition. Twenty additional Vanderbilt undergraduates participated in another categorization condition in which initial exposure to category members was actually provided.

Stimuli and Procedure

In the first phase of the experiment, stimuli were 40 pairs of four-letter words differing by a single letter (e.g., *word* vs. *work*). The location of the changed letter was roughly equated across positions; because this phase was just a ruse, we did not systematically control

other aspects of the word pairs. In this task, participants were asked to identify which word from the pair had been flashed on the computer screen. On each trial, one pair was selected and one word from the pair was designated the target. A crosshair appeared at the center of the screen, the target word was displayed for 25 ms, and the two words were then displayed side by side. Participants judged which word had been presented.

Following this phase, participants were informed that we were not interested in word identification after all. Rather, participants were told that during the previous task, patterns of dots had been flashed on the computer screen so quickly that they could be perceived only subliminally.

Participants in the categorization condition were provided with the following instructions:

During the previous word identification task, patterns with nine dots were quickly flashed on the computer screen so as to be perceived subliminally

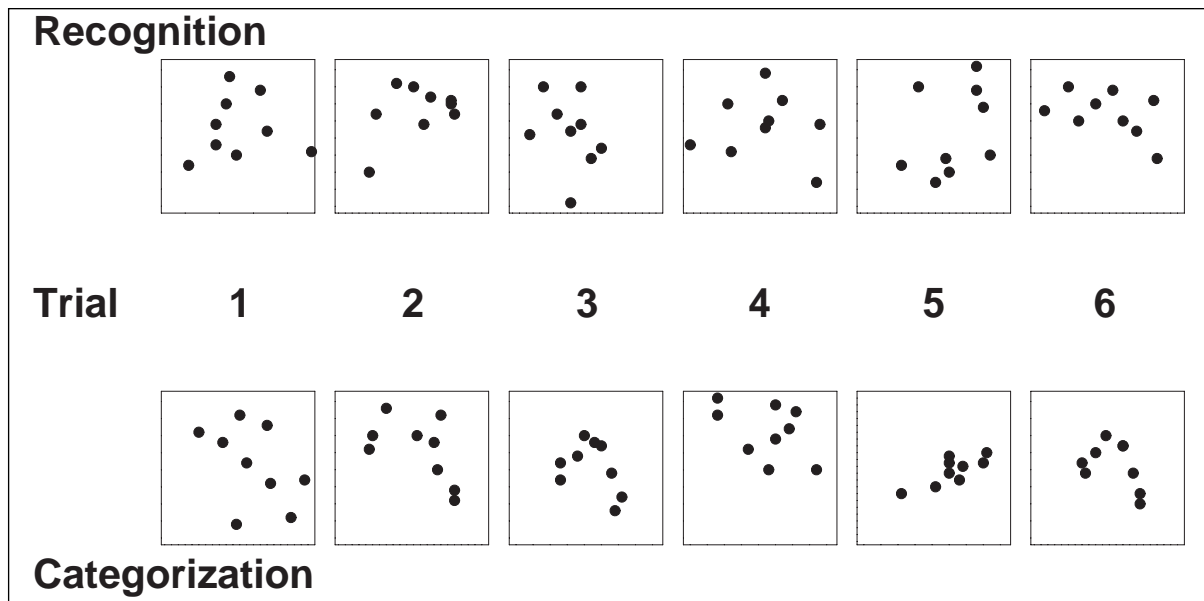


Fig. 2. Example sequences of recognition trials (top row) and categorization trials (bottom row) from Knowlton and Squire (1993). For recognition, Trials 1, 3, and 5 show old patterns, and Trials 2, 4, and 6 show new patterns. For categorization, Trials 1, 4, and 5 show nonmembers, and Trials 2, 3, and 6 show category members; Trial 2 shows a high-level distortion of the prototype, Trial 3 shows the prototype, and Trial 6 shows a low-level distortion of the prototype.

(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 members. (adapted from instructions used by Reber, Stark, & Squire, 1998, and Squire & Knowlton, 1995).

If a participant did not understand what we meant by “category,” he or she was 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 the animals shown in the picture.

Participants in the recognition condition were provided similar instructions, except that they were asked to decide which patterns were old or new.

Stimuli in the categorization and recognition phases were patterns of nine dots. The patterns we used were the same as those used in the first experiment of Knowlton and Squire (1993), who created the patterns by randomly positioning dots on a square grid. The categorization stimuli were the category prototype, 20 low distortions of the prototype, 20 high distortions of the prototype, and 40 random patterns; distortions were created using a statistical algorithm developed by Posner, Goldsmith, and Welton (1967). The recognition stimuli were 10 random patterns, 5 of which were designated “old” patterns and 5 of which were designated “new” patterns, as per Knowlton and Squire (1993).

On each trial of the categorization condition, a dot pattern was displayed, and participants judged whether it was a member or nonmember of the previously exposed category (they had actually seen no patterns before); participants judged 4 repetitions of the prototype, 20 low distortions, 20 high distortions, and 40 random patterns, for a total of 84 test trials. In the recognition condition, participants tried to correctly judge the five patterns designated old and five patterns design-

nated new; four blocks of 10 recognition trials were presented. In both the recognition and the categorization conditions, order of stimuli was randomized for every participant, no corrective feedback was supplied, and participants were informed that approximately equal numbers of members and nonmembers or old and new stimuli would be presented.

An additional group of participants was tested in an exact replication of the categorization condition in the original Knowlton and Squire (1993) study (see also Nosofsky & Zaki, 1998). This group was initially exposed to 40 high-level distortions of the category prototype, with the task being to simply point to the center of each pattern using the computer mouse. After a 5- to 10-min delay, they were then informed that all of the patterns they had seen before belonged to the same category (the instructions were virtually the same as those provided the nonexposed group). They were then given the same categorization test that was given to our nonexposed participants.

RESULTS

Figure 3 displays the probability of endorsing each type of stimulus as a category member in the categorization condition or as an old pattern in the recognition condition. In the absence of any prior training, participants categorized quite well; prototypes had the highest percentage of being endorsed as category members, followed by low distortions, high distortions, and random patterns. A statistically significant effect of stimulus type was observed in categorization, $F(3, 126) = 18.872$, $MSE = 0.049$, and planned comparisons confirmed the observed ordering of levels (an alpha level of $p = .05$ was established for all statistical tests). Also, as expected, participants were completely unable to differentiate “old” from “new” items. Comparison with Figure 1 reveals that, in the absence of training, categorization probabilities were comparable to those observed by Knowlton and Squire

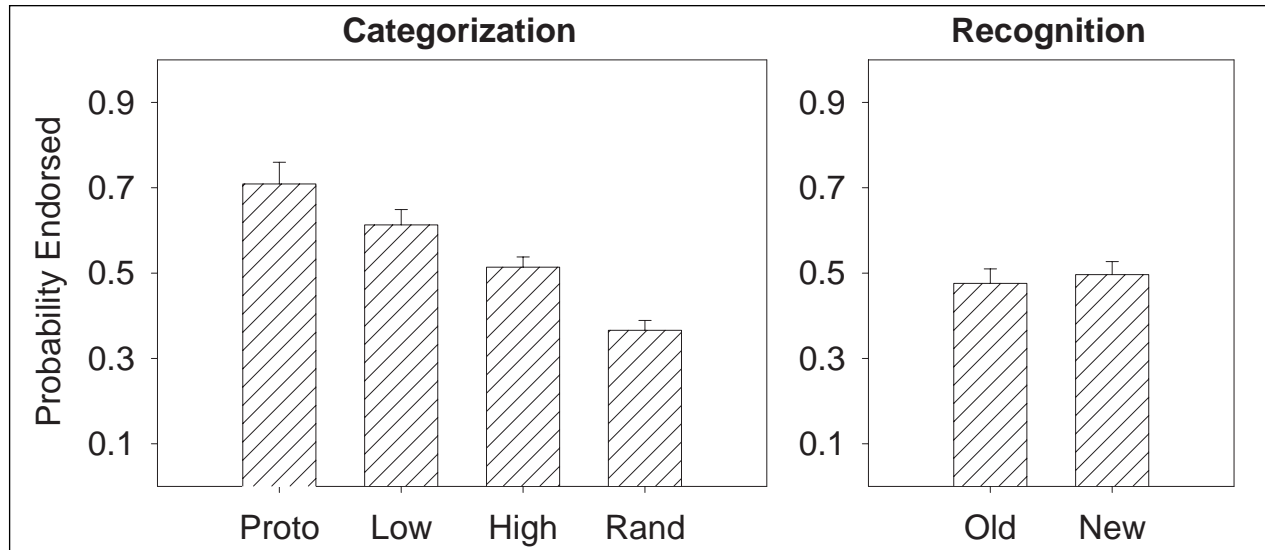


Fig. 3. Categorization and recognition decisions for each type of pattern in the present experiment. The left panel displays the categorization data (probability of a stimulus being endorsed as a category member). The right panel displays the recognition data (probability of a stimulus being endorsed as old). Proto = category prototype; Low = low-level distortion of prototype; High = high-level distortion of prototype; Rand = random pattern.

(1993; Squire & Knowlton, 1995) for amnesics and normal individuals, and that recognition probabilities were comparable to those observed by Squire and Knowlton (1995) for E.P.

Overall, our participants without any prior exposure to training stimuli were $60.4 \pm 2.3\%$ correct at categorizing test stimuli (averaged across all stimuli), which is comparable to what was reported by Knowlton and Squire (1993) for amnesics (59.9%) and normal individuals (63.9%), by Squire and Knowlton (1995) for E.P. (61.6%) and normal individuals (62.2%), and by Nosofsky and Zaki (1998) for college undergraduates tested immediately (61%) and after a 1-week delay (57%). After the 10th categorization testing trial, our participants had achieved 60.0% accuracy. An individual-subjects analysis was revealing about how participants performed this task. We discovered that 10 of the 43 participants differed significantly from chance performance by actually judging members as nonmembers and vice versa. We recoded these participants' accuracy in terms of their (reversed) internal categories and found 80.2% "accuracy" at classifying prototypes, 72.4% accuracy at classifying low distortions, 57.2% accuracy at classifying high distortions, and 65.6% accuracy at classifying random patterns.

Finally, our group of 20 participants who categorized the test stimuli following initial exposure to 40 high-level distortions endorsed as category members $63.8 \pm 8.4\%$ of the prototypes, $55.0 \pm 6.5\%$ of the low distortions, $62.0 \pm 3.2\%$ of the high distortions, and $43.5 \pm 4.2\%$ of the random patterns; the effect of stimulus type was significant, $F(3, 57) = 3.449$, $MSE = 0.049$. Overall, this group was $57.8 \pm 3.6\%$ correct at categorizing the test stimuli. Overall, these results are not significantly different from the endorsement probabilities we observed with the nonexposed group, shown in Figure 3.

DISCUSSION

Are various fundamental cognitive processes, such as categorization and recognition, subserved by common or independent memory

systems? Although a dissociation between categorization and recognition in amnesics and normal individuals has been taken as evidence for multiple memory systems (Knowlton & Squire, 1993), this dissociation may also be consistent with a single memory system (Nosofsky & Zaki, 1998). However, the results from E.P., who has no detectable recognition memory yet categorizes nearly as well as normal individuals, have been used as evidence against this single-system view:

These results suggest that category knowledge can develop independently of and in the absence of normal declarative memory. . . . 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. (Squire & Zola, 1996, p. 13518)

Although this interpretation 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 that we never presented. Although completely unable to recognize the patterns, they categorized the patterns as well as the amnesics and normal individuals in published studies by Knowlton and Squire (1993; Squire & Knowlton, 1995; see also Nosofsky & Zaki, 1998). We have shown that the categorization task used by Squire and Knowlton allows participants to discover which clusters of patterns are likely to be members simply because many members are similar to one another and all nonmembers are dissimilar from one another. Successfully performing the categorization task may require only the use of working memory, which is known to be spared in amnesia.

Other tests of E.P. using the same basic paradigm may prove to be more informative. For example, if E.P. categorized training patterns more accurately than new transfer patterns, holding level of distortion constant, then the case for multiple memory systems might be strengthened—"induced" amnesics would never show a distinction between old and new patterns in categorization. In addition, nonmem-

bers could be generated from a contrasting prototype, rather than being generated randomly. Although induced amnesics might randomly select one of the two clusters of similar patterns to be called members, if E.P. consistently categorized the patterns appropriately, this might bolster the claim for multiple memory systems. Finally, E.P. could also be made completely amnesic by eliminating prior exposure to training patterns. Any benefit of exposure relative to nonexposure for categorization, without concomitant benefits for recognition, might also bolster the claim for multiple memory systems.

It must be noted that Knowlton and Squire (1993) did test categorization by normal individuals who had never seen any training patterns and found them to perform at chance levels. One potentially critical difference between their study and ours is that we led participants to believe they had actually seen patterns through the use of an elaborate deception, whereas Knowlton and Squire merely instructed participants to imagine having seen a series of patterns. People may find our results particularly intriguing because one might initially expect that it would be utterly impossible to classify test stimuli without any prior exposure to category members; we suspect that even naive control subjects may have similar negative expectations about their own ability to classify test stimuli without prior exposure to category members. That is, the control group studied by Knowlton and Squire may have been unable to classify the test patterns because they believed that it would be impossible to do so. By contrast, both our simulated amnesics and Knowlton and Squire's true amnesics were led to believe that classification was possible, even though they had no explicit memory for any prior category members.

Another potentially important difference is that we studied college students, whereas Knowlton and Squire (1993; Squire & Knowlton, 1995) studied elderly amnesics. Although our participants, without prior exposure to training stimuli, classified test stimuli as well as the elderly participants studied by Knowlton and Squire, one might argue that our young college students were simply highly motivated to discover categories without prior exposure. Although possible, this explanation seems less plausible because our group who had no exposure also performed similarly to our group of students who had prior exposure (and performed similarly to students tested by Nosofsky & Zaki, 1998).

Finally, these results also point out some oversights by formal theories of categorization and recognition (e.g., Nosofsky & Zaki, 1998).

Our participants 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 certainly 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.

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