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Learning About Categories That Are Defined by Object-Like Stimuli Despite Impaired Declarative Memory

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Memory is not a single cognitive faculty but is composed of several different abilities that depend on different brain systems (Schacter & Tulving, 1994; Squire & Knowlton, 1994). The major distinction is between declarative memory, which depends on medial temporal lobe and diencephalic structures and supports conscious recollections about facts and events, and a collection of nonconscious (nondeclarative) memory abilities that are expressed through performance without affording access to any conscious memory content. An important source of support for the distinction between declarative and nondeclarative memory comes from studies of amnesic patients. Amnesic patients who have medial temporal lobe or diencephalic damage are impaired at recalling or recognizing previously encountered material but nevertheless are fully intact at a number of other tasks that assess, for example, the capacity for skill and habit learning, simple forms of conditioning, and the phenomenon of priming (Schacter, Chiu, & Ochsner, 1993; Squire, Knowlton, & Musen, 1993; Squire & Zola, 1996).

The ability to classify items according to the regularities that determine their category membership is one of the most fundamental human capacities. Recent studies have found that, in some cases, the acquisition of category knowledge is nondeclarative and independent of declarative memory for specific items encountered during learning. Thus, amnesic patients were as accurate as healthy volunteers at classifying novel dot patterns according to whether they did or did not belong to the same category as a set of training stimuli. In contrast, the patients were impaired at recognizing which stimuli had been presented for training (Knowlton & Squire, 1993; Kolodny, 1994; Squire & Knowlton, 1995). Because amnesic patients have severely impaired declarative memory, these findings suggest that the ability to acquire category knowledge involves the implicit cumulation of information from multiple exemplars and occurs independently of conscious memory for the exemplars themselves.

In the earlier studies (Knowlton & Squire, 1993; Kolodny, 1994; Squire & Knowlton, 1995), participants learned about two-dimensional displays composed of nine dots, as described originally by Posner and Keele (1968). The dot patterns tend to resemble one another, they are difficult to describe verbally, and there are no discrete features that distinguish the dot patterns from each other. Accordingly, the question naturally arises whether category knowledge might be acquired implicitly but only when the training stimuli exhibit these characteristics. It is likely that the dot patterns are difficult to memorize as

discrete items. If the training items were more discrete and easier to label and memorize, perhaps individuals would tend to acquire category knowledge declaratively, that is, explicitly as propositional knowledge about the regularities among the training items. Indeed, Kolodny (1994) found that amnesic patients did not learn to categorize paintings according to which of three artists had created them. Perhaps category knowledge is nondeclarative only in particular circumstances and only with narrowly defined kinds of training items.

In the current study, we asked whether category knowledge could be acquired by amnesic patients if the stimuli were a set of easily verbalized stimuli that exhibit discrete features. If in this case category learning depends on declarative knowledge, amnesic patients should not succeed. Amnesic patients and healthy volunteers studied a set of cartoon animals composed of nine discrete features (e. g. , a head, neck, legs, body). Each feature could have either of two appearances (e. g. , striped body or spotted body). The study items were distortions of a prototype animal that was never studied. After the study phase, participants attempted to classify new cartoon animals according to whether they belonged to the same category as the study items. Amnesic patients and the volunteers were equally adept at classifying the new stimuli, but the amnesic patients were impaired at recalling the training items themselves.

Experiment 1A

Method

Participants

Amnesic patients.

Eight amnesic patients were studied, 6 men and 2 women. Four patients had Korsakoff's syndrome. Three of the 4 Korsakoff's patients (all but M. H.) had participated in quantitative magnetic resonance imaging (MRI), which demonstrated reductions in the volume of the mammillary nuclei (R. C. , P. N. , and J. W. ; Squire, Amaral, & Press, 1990). Of the other 4 patients, A. B. is unable to participate in MRI studies because he wears a pacemaker. He had become amnesic in 1975 after an anoxic episode associated with cardiac arrest and was presumed to have hippocampal damage on the basis of this etiology. For patients P. H. (Polich & Squire, 1993) and L. J. (Reed & Squire, 1998), MRI had identified bilateral hippocampal formation damage. Patient P. H. (Polich & Squire, 1993) had a 6-year history of 1- to 2-min "attacks" (with a possible epileptic basis) that were associated with gastric symptoms and transient memory impairment. In July 1989, he had suffered from a series of brief episodes, after which he had a marked and persistent memory loss. Patient L. J. became amnesic with no known precipitating event during a 6-month period that began in late 1988. Her memory impairment has remained stable since that time. Neuropsychological data for all 8 patients are presented in

Table 1
Characteristics of Amnesic Patients

Patient	Year of birth	Education (years)	WAIS–R IQ	WMS–R				
				Attention	Verbal	Visual	General	Delay
R.C.	1916	9	106	115	76	97	80	72
M.H.	1947	16	101	77	73	80	69	60
P.N.	1927	11	99	81	77	73	67	53
J.W.	1936	14	98	104	65	70	57	57
A.B.	1937	20	104	87	62	72	54	<50
P.H.	1922	19	120	117	67	83	70	57
L.J.	1937	12	98	105	83	60	69	<50
E.P.	1922	12	103	94	57	82	61	56
M		14.1	103.6	97.5	70.0	77.1	65.9	56.9

Note. The Wechsler Adult Intelligence Scale—Revised (WAIS–R) and the Wechsler Memory Scale—Revised (WMS–R) yield mean scores of 100 in the normal population, with a standard deviation of 15. The WMS–R does not provide numerical scores for individuals who score below 50.

Table 1 and

Table 2
Performance on Standard Memory Tests

Patient	Diagram recall	Paired associates			Word recall (%)	Word recognition (%)	50 words	50 faces
R.C.	3	0	0	3	19	85	37	30
M.H.	4	0	3	2	35	72	27	29
P.N.	2	1	1	1	29	83	31	31
J.W.	4	0	0	2	28	96	29	34
A.B.	4	1	1	1	33	83	32	33
P.H.	3	0	0	1	27	84	36	34
L.J.	3	0	0	0	40	93	33	29
E.P.	0	0	0	0	24	65	24	28
M	2.9	0.3	0.6	1.3	29.4	82.6	31.1	31.1
Control (n = 8) *M*	20.6	6.0	7.6	8.9	71	97	41.1	38.1

Note. The diagram recall score is based on the delayed (12-min) reproduction of the Rey–Osterrieth figure (Osterrieth, 1944; maximum score = 36). For copying the figure, the amnesic group and Patient E.P. obtained normal scores (29.6 and 27, respectively; Kritchevsky, Squire, & Zouzounis, 1988). The paired associates score is the number of word pairs recalled on three successive trials (maximum score = 10/trial). The word recall score is the mean percentage of 15 words recalled across five successive study–test trials (Rey, 1964). The word recognition score is the mean percentage of words identified correctly across five successive study–test trials (yes–no recognition of 15 new words and 15 old words). Note that scores on the recall test are above 0 because on this test of immediate recall, several items can be retrieved from immediate memory, which is intact in amnesia. Note too that recognition scores are above chance, also presumably because some items can be retrieved from immediate memory (E.P.'s score was not reliably above chance, $t[29] = 1.9$, $p = .07$). The scores for words and faces are based on a 24-hr recognition test of 50 words and 50 faces (modified from Warrington, 1984; maximum score = 50, chance = 25). The mean scores for the controls are from Squire and Shimamura (1986).

Table 2.

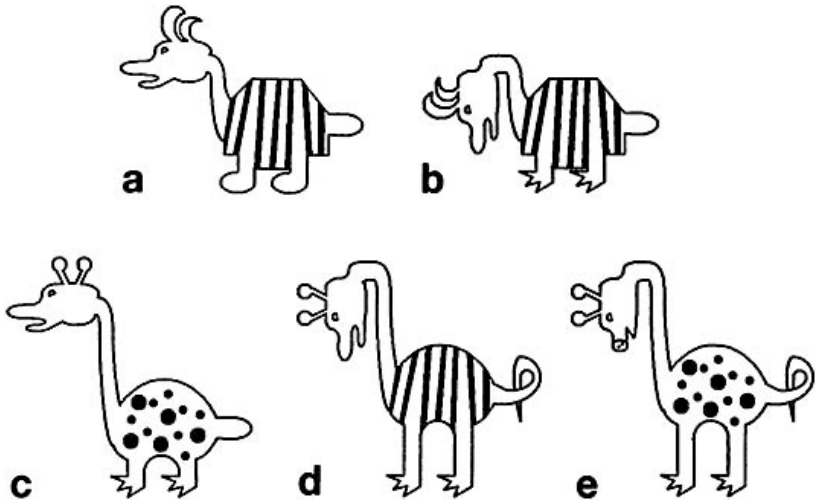
Finally, Patient E. P. had developed profound anterograde and retrograde amnesia in 1992 after contracting herpes simplex encephalitis. Neuroimaging studies revealed extensive damage to the medial temporal lobe (Buffalo, Reber, & Squire, 1998; Reed & Squire, 1998). The damage involves the amygdaloid complex, the hippocampal region (CA fields, dentate gyrus, and subicular complex), and the entorhinal, perirhinal, and parahippocampal cortices. E. P. 's damage was primarily medial temporal, but also involved the laterally adjacent fusiform gyrus at some levels.

Healthy volunteers.

These 5 men and 5 women were volunteers or employees at the San Diego Veterans Affairs Medical Center. As a group they averaged 68. 5 years of age and 14. 6 years of education. They scored means of 22. 3 and 57. 3, respectively, on the Information and Vocabulary subscales of the Weschler Adult Intelligence Scale—Revised (compared with 20. 2 and 52. 5 for the 8 amnesic patients).

Materials and Procedure

Line drawings of 82 different cartoon animals were constructed (see



Examples of the test items used in Experiment 1. For half of the participants, animals a, b, c, d, and e corresponded to prototype (nine prototypic features), low-distortion (seven or eight prototypic features), neutral (four or five prototypic features), high-distortion (one or two prototypic feature), and antiprototype (no prototypic features) animals, respectively. For the other participants, this order was reversed.

Figure 1 for examples). Each animal varied with respect to nine discrete features (head, face, head ornaments, neck, body, body markings, tail, legs, and feet), and each feature could take either of two values—the prototypic value or the nonprototypic value (

Table 3
Descriptions of the Feature Values of the Cartoon Animals Used in Experiments 1A, 1B, and 2

	Experiments 1A and 1B		Experiment 2	
Feature	Value 1	Value 2	Value 1	Value 2
Head	Left-facing	Down-facing	Up-facing	Right-facing
Face	Dog	Pig	Bird	Rhino
Ornaments	Ears	Antennae	Antlers	Horns
Neck	Short	Long	Spiked	Banded

Body	Angular	Curved	Round	Boxy
Markings	Stripes	Spots	Dot rows	Dot columns
Tail	Nub	Curly	Fan	Demon
Legs	Short	Long	Wide	Narrow
Feet	Knobby	Pointy-toed	Claw	Webbed

Note. For Experiments 1A and 1B, Feature Value 1 was the prototypic value for half of the participants and Feature Value 2 was the prototypic value for the other half of the participants. For Experiment 2, Feature Value 1 was the prototypic value for all participants.

Table 3). For each feature, one value was designated as the prototypic value for half of the participants, and the other value was the prototypic value for the other participants. The prototype animal was one in which all nine features had the prototypic value.

Testing proceeded in three phases: study, categorization, and cued recall. The study phase consisted of 40 trials in which 20 of the cartoon animals were presented one at a time followed by the same 20 animals in a different order. Each animal was presented for 5 s, with instructions to study it very carefully. The animals presented for study were all "low distortions" of the prototype, that is, animals in which either seven or eight of the nine features were assigned the prototypic value, and the other features were assigned the nonprototypic value.

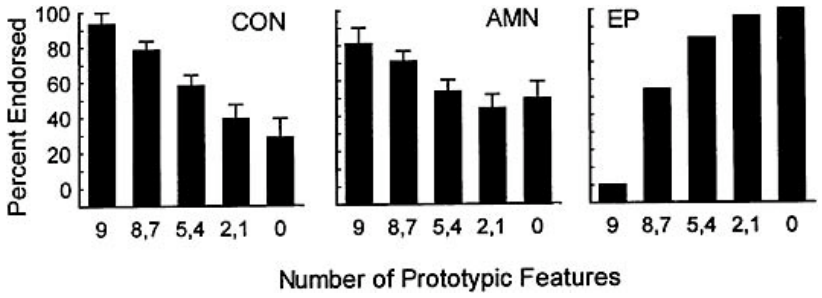
Immediately after the study phase, participants were instructed about the categorization phase. They were told that all of the animals they had studied were members of the category called "Peggle," and the nature of category membership was explained. Participants were then shown a series of new cartoon animals and were asked to indicate in each case whether or not the animal was also a Peggle. They were told that about half of the animals would be Peggles and about half would not, and they were discouraged from basing their judgments on a single feature. They were encouraged instead to base their judgments on the overall appearance of each animal.

Altogether, the categorization phase consisted of 96 trials and included five different types of animals (the prototype animal = 12 trials, low-distortion animals = 24 trials, neutral animals = 24 trials, high-distortion animals = 24 trials, the antiprototype animal = 12 trials). The prototype animal, which was composed entirely of prototypic features, appeared 12 times. New, low-distortion animals, which were composed of either seven or eight protypic features, were presented 24 times (16 presented once each and 4 others presented twice each). Neutral animals, which were composed of either four or five prototypic features, appeared 24 times (16 presented once each and 4 others presented twice each). Twelve of them had four prototypic features, and 12 had five prototypic features. High-distortion animals, which were composed of one or two prototypic features, were presented 24 times (16 presented once each and 4 others presented twice each). Finally, the antiprototype animals, which were composed entirely of nonprototypic features, appeared 12 times. The five trial types occurred in a mixed order, with the constraint that the same trial type never occurred on three consecutive trials. Further, the 12 presentations of the prototype animal and the antiprototype animal were spread evenly across the 96 trials.

Immediately after the categorization task, participants were tested for their declarative memory of the test materials. The names of the nine features were presented one at a time (e. g. , body markings), and participants were asked to identify how the feature could differ among the animals they had seen (e. g. , striped or spotted). Responses were scored as correct if a feature was described accurately. The response to each feature earned a score of 0, 1, or 2, with a maximum total score of 18.

Results

Categorization data were scored according to how often each type of test animal was endorsed (i. e. , judged to be a member of the category Peggle). Because E. P. 's amnesia was so profound, his data are shown separately from those of the other 7 amnesic patients. Overall endorsement rates were similar for the controls (58. 8%) and the 7 amnesic patients (59. 2%), $t(15) < 1.0$. The overall endorsement rate for Patient E. P. was somewhat higher (70. 8%), reflecting a bias toward endorsing the test items.

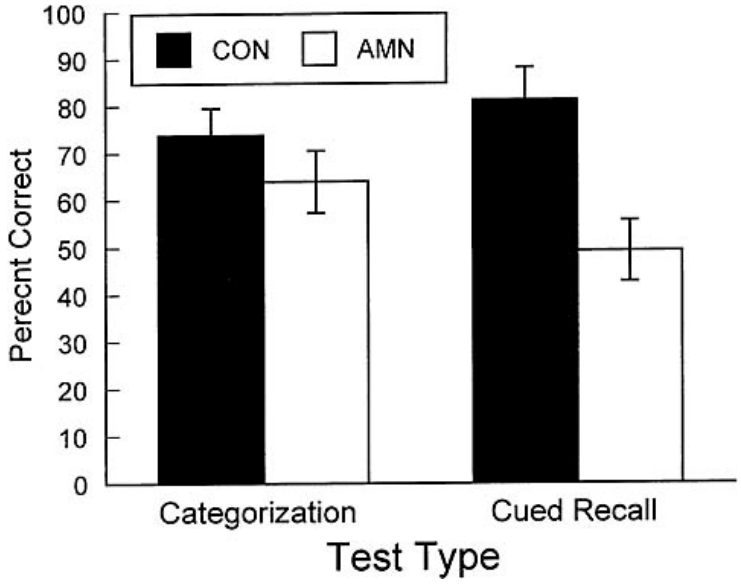


Categorization task performance of controls (CON), 7 amnesic patients (AMN), and the severely amnesic patient, E. P. , in Experiment 1A. The five types of test animals were defined by the number of prototypic features they exhibited: prototype, nine prototypic features; low distortions, seven or eight prototypic features; neutral, four or five prototypic features; high distortions, one or two prototypic feature; antiprototype, no prototypic features. Brackets represent the standard errors of the means.

Figure 2 shows endorsement rates for the five types of test items. For both the controls and the 7 amnesic patients, endorsement rates were positively related to how closely the test items resembled the prototype. A 2 (control vs. amnesiac) × 5 (type of test animal) analysis of variance (ANOVA) revealed a significant effect of item type, $F(4,60) = 15.51$, $p < .0001$. The effect of subject group, $F(1,15) < 1.0$, and the interaction, $F(4,60) = 1.54$, $p = .20$, did not approach significance. These results indicate that both controls and amnesic patients were able to categorize the animals accurately on the basis of their discrete feature values.

The performance of Patient E. P. clearly indicated that he was able to discriminate among the types of test items (see Figure 2). His pattern of results, however, was opposite to those of the controls and the other amnesic patients. Indeed, E. P. always endorsed the antiprototype, and he never endorsed the prototype. This reversed pattern of results was also observed for one of the other amnesiac patients (P. H.), whose endorsement rates were 33. 3%, 41. 7%, 54. 2%, 70. 8%, and 91. 7% for the prototype, low-distortion, neutral, high-distortion, and antiprototype animals, respectively. These results for E. P. and P. H. are considered below and in Experiment 2.

Overall accuracy on the categorization task was next calculated by using the total number of correct categorization responses. In the cases of the prototype and the low distortions, a correct response was scored when the test item was endorsed. In the cases of the antiprototype and the high distortions, a correct response was scored when the test item was not endorsed. Responses to the neutral animals were not considered in the calculation of correct responses. The total number of correct responses was then divided by the number of relevant trials (i. e. , 72) to obtain a percentage correct score. Categorization accuracy was similar for the controls (*M* = 73. 8% correct) and the 7 amnesic patients (*M* = 63. 9% correct), *t*(15) = 1. 15, *p* > . 10 (see left-hand side of



Comparison of categorization and cued-recall test performance for the controls (CON, filled bars) and 7 amnesic patients (AMN, open bars) for Experiment 1A. Brackets show standard errors of the means.

Figure 3). The numeric difference in categorization accuracy (9. 9%) was especially influenced by the reversed pattern of results exhibited by Patient P. H. When the data for Patient P. H. were excluded, categorization accuracy for the controls and the 6 remaining amnesic patients was very similar (73. 8% vs. 69. 4%). The scores for P. H. and E. P. were 30. 6% and 16. 7% correct, respectively.

Performance on the cued-recall test was also scored as the percentage of correct responses. There were two correct responses for each of the nine features. Cued-recall performance was much better for the controls (*M* = 81. 1%) than for the 7 amnesic patients (*M* = 49. 2%), *t*(15) = 3. 46, *p* < . 005. P. H. 's cued-recall score was 44. 4% correct. As was consistent with the severity of his amnesia, Patient E. P. was unable to provide any accurate responses on the cued-recall test and obtained a score of 0% correct.

It is important to note that, although the pattern of endorsement rates of the control group and the amnesiac patients was consistent with the idea that the individuals had learned about the Peggle category, the same pattern of data could have been obtained if individuals had based their categorization judgments on any single feature of the animals. Basing judgments on a single feature would have sufficed because the frequency of each feature's appearance in a test item was positively correlated with how closely that item resembled the prototype. Accordingly, if participants were to make categorization judgments by attending to a single feature, they would endorse the prototype most often, the low distortions next most often, and so on. To perform well on the categorization task, participants would need only to remember a specific prototypic feature (e. g. , striped body) and then endorse test items according to the presence or absence of that characteristic.

Examination of data for individual participants revealed that they had in fact learned about all the features, not just one feature. They did not base their judgments on a single feature. Consider, for example, the most frequently endorsed feature and the least frequently endorsed feature for each subject. The endorsement rate across the controls and the 7 amnesic patients for the most frequently endorsed feature was well below 100% (*M* = 77. 3%), *t*(16) = 6. 9, *p* < . 05, and the endorsement rate for the least frequently endorsed feature was significantly above the chance score of 50% (*M* = 59. 4%), *t*(16) = 3. 26, *p* < . 05. These findings indicate that participants did not use a single-feature strategy during the categorization task. Accordingly, the pattern of endorsement rates in Figure 2 indicates that participants had learned about the prototypical category in a broad sense by learning something about each of the nine features.

The two amnesic patients who exhibited inverted patterns of endorsement rates (E. P. and P. H.) also did not employ the single-feature strategy. The endorsement rates for the most frequently endorsed feature were 42% and 31% for Patients P. H. and E. P. , respectively. The endorsement rates for the least frequently endorsed feature were 15% and 14% for P. H. and E. P. , respectively. This observation is important because inverted endorsement patterns would be expected whenever the following set of conditions existed: (a) an individual had no knowledge of the prototype, (b) categorization judgments were based on a single feature, (c) the individual had arbitrarily chosen a particular feature value to endorse consistently, and (d) the individual had happened to choose the nonprototypic value of the feature to endorse. Because E. P. and P. H. did not employ the single-feature strategy, this explanation does not account for their behavior. Instead, it appears that these two patients had acquired information about the trained category and had also learned that prototypes and antiprototypes represented opposite ends of the feature continuum. However, these two patients were unable to assign the

test items to the category they had studied. It is as if they had learned about the trained category but, once in the categorization phase, could not remember which kind of item represented a Peggle and which kind of item represented an anti-Peggle. This idea was explored further in Experiment 2.

Experiment 1B

The results of Experiment 1A suggest that both amnesic patients and healthy volunteers can learn about a prototype that is defined by discrete features. It is important, however, to confirm that the pattern of data in Experiment 1A was not the result of any learning that occurred during the categorization test itself. Experiment 1B tested this possibility directly by giving the categorization test to a new group of volunteers without providing a study phase.

Method

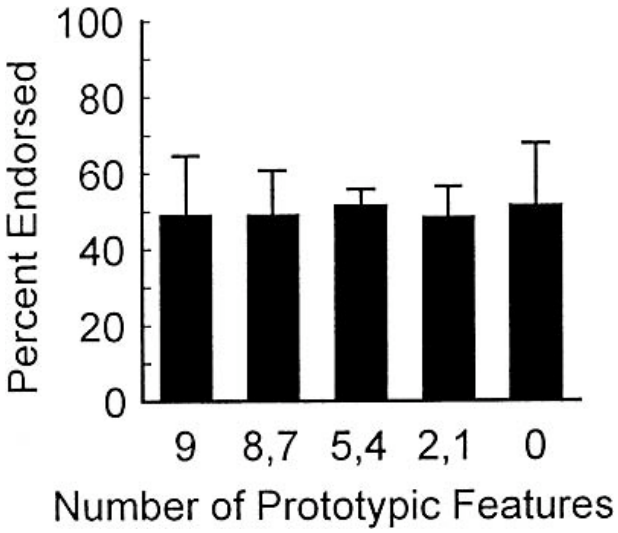
Participants

Seven new healthy volunteers (3 men and 4 women) selected in the same way as in Experiment 1A were tested. As a group, these participants averaged 67 years of age and 15. 3 years of education.

Materials and Procedure

The materials and procedure for Experiment 1B were identical to those of Experiment 1A, except that there was no study phase. Thus, the test items were the same cartoon animals used in the categorization phase of Experiment 1A. Participants were first instructed to imagine that they had seen a set of cartoon animals that belonged to the category called Peggle. They then completed the categorization task by following the procedure from Experiment 1A. Scoring also followed exactly the procedure of Experiment 1A in the sense that half of the participants were assumed to have seen one set of prototypic values and the other half were assumed to have seen the opposite set of values. If these participants categorized as well as those in Experiment 1A, we reasoned, it would indicate that the results of the first experiment were not the result of participants learning during the study phase.

Results



Performance of 7 healthy volunteers on the categorization task in Experiment 1B, when the study phase of the task was omitted. Brackets show the standard errors of the means.

Figure 4 shows the endorsement rates for the five types of test items. A one-way ANOVA confirmed that type of test item was not a significant factor in determining categorization responses, $F(4,24) = 0.03$. Examination of the data from individual participants revealed that the performance of 3 of them matched the averaged data closely. The other 4 participants had adopted a single-feature strategy, despite having been instructed not to do so. Specifically, these 4 participants had endorsed a particular value of a single feature on every test trial (e. g. , 1 participant endorsed every animal that had an angular body).

The results of Experiment 1B show that the findings in Experiment 1A cannot be due to learning during the test phase. Without the opportunity to learn about the prototype (i. e. , in the absence of a study phase), participants were unable to exhibit knowledge about the prototypic category. The few individuals who did produce endorsement patterns similar to those of Experiment 1A all employed a single feature strategy, unlike any of the participants in Experiment 1A.

Experiment 2

Taken together, the results of Experiments 1A and 1B suggest that amnesic patients can learn about a prototypic category when it is defined by discrete features. Even the two patients that exhibited reversed patterns of endorsement rates (E. P. and P. H.) nevertheless demonstrated an ability to discriminate among the five types of test items.

To understand these data, we considered that good performance on the categorization task requires two things: First, individuals must learn to discriminate among the test items. In particular, they must acquire knowledge of the prototypic features and the nonprototypic features that define the endpoints of a symmetric set of test items. One endpoint is a group

of animals that have primarily prototypic features, and the other endpoint is a group of animals that have primarily nonprototypic features.

The second requirement for good performance is that individuals be able to remember which endpoint of the learned continuum is the one that should be endorsed. They must be able to map their category knowledge onto the appropriate response. We suggest that healthy volunteers, as well as amnesic patients with sufficiently spared declarative memory, can meet this second task requirement. In contrast, severely amnesic patients like E. P. and P. H. fail to meet this requirement. They can distinguish between prototypes and antiprototypes. However, whether their endorsement rates exhibit the normal pattern or the reverse pattern may be a matter of chance, depending on how they happen to map the two categories of test items (prototype or antiprototype) onto the two test responses (endorse or not endorse).

Experiment 2 was designed to test this hypothesis by using a categorization task in which the test items ranged from prototypic to neutral rather than from prototypic to anitprototypic, as they had in Experiments 1A and 1B. That is, we changed from a test that included both endpoints of a symmetric set of test items to a test that included only a single category endpoint (prototypical animals) and other test items that were not members of any category (neutral animals). To perform well on the revised test, participants would not need to remember which end of the continuum needed to be endorsed. Instead, they would merely need to distinguish items at the end of the continuum from those in the middle. We therefore predicted that all participants, even those with profound amnesia, would exhibit the normal pattern of endorsement rates.

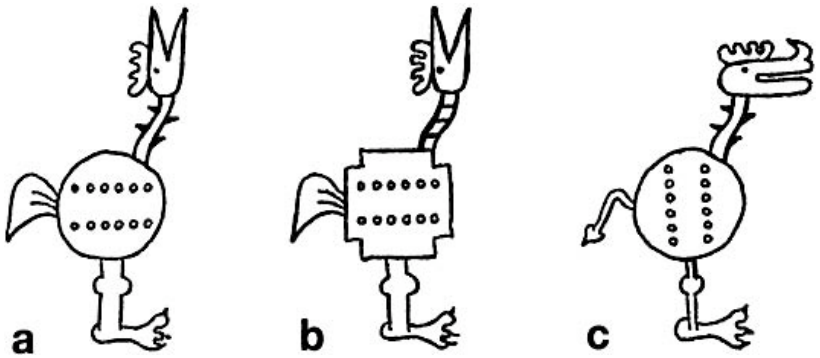
Method

Participants

The same 8 amnesic patients and 8 of the 10 controls from Experiment 1A were tested. Testing occurred at least 1 month after Experiment 1A.

Materials and Procedure

Line drawings of 61 different cartoon animals were constructed (



Examples of stimuli used in Experiment 2. Animals a, b, and c correspond to prototype (nine prototypic features), low-distortion (eight or seven prototypic features), and neutral (five or four prototypic features) animals, respectively. During the study phase, participants saw only low-distortion animals. During the categorization phase, participants made judgments about all three types of animals.

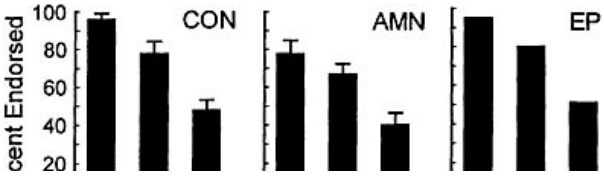
Figure 5). As in Experiments 1A and 1B, each animal was composed of nine discrete features (head, face, head ornaments, neck, body, body markings, tail, legs, and feet). Each feature could take on one of two values—a prototypic value or a nonprototypic value. The feature values were different from those used in Experiments 1A and 1B (see Table 3). For each feature, one value was designated as the prototypic value, and the other value was the nonprototypic value.

The testing procedure was identical to the procedure of Experiment 1A. Participants began with a 40-trial study phase. Twenty low distortions of the prototype were presented, followed by the same 20 animals in a different order. For these items, either seven or eight of the nine features were assigned the prototypic value, and the other features were assigned the nonprototypic value. The categorization phase came immediately after the study phase and consisted of 60 trials. In the categorization test, the prototype animal appeared 12 times, new low-distortion animals appeared 24 times (16 of them once and 4 of them twice), and neutral animals appeared 24 times (16 once and 4 twice). The three trial types occurred in a mixed order, and the 12 presentations of the prototype were spread evenly across the 60 test trials.

Immediately after the categorization task, participants were given a cued-recall test concerning how each of the nine features could differ among the animals that had been presented. The procedure followed that of Experiment 1A.

Results

Categorization data were scored according to how often each type of test animal was endorsed. Overall endorsement rates were higher for the controls (69. 4%) than for the 7 amnesic patients (58. 1%), $t(13) = 1.9$, $p > .05$. The overall endorsement rate for patient E. P. (63. 4%) was intermediate to the controls and the other amnesic patients.

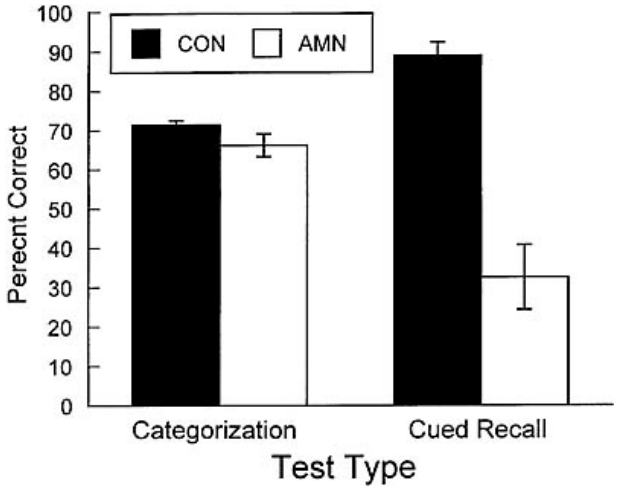




Categorization task performance of controls (CON), 7 amnesic patients (AMN), and the severely amnesic patient, E. P. , in Experiment 2. The three types of test stimuli were defined by the number of prototypic features they exhibited: prototype, nine prototypic features; low distortions, eight or seven prototypic features; neutral, five or four prototypic features. Brackets indicate the standard errors of the means.

Figure 6 shows endorsement rates for the three types of test items. For both the controls and the seven amnesic patients, endorsement rates for the prototype, low-distortion, and neutral animals were positively related to how closely the test item resembled the prototype. A 2 (control vs. amnesic) × 3 (type of test animal) ANOVA revealed a significant effect of type of test item (i. e. , number of prototypic features), $F(2,26) = 40.8$, $p < .0001$. The main effect of subject group was also significant, $F(1,13) = 4.89$, $p < .05$, indicating that the amnesic patients tended to endorse test items less often than controls. The interaction was not significant, $F(2,26) < 1.0$. These results indicate that participants were able to categorize animals accurately on the basis of discrete feature values and that amnesic patients categorized as accurately as controls.

Patient E. P. was also able to discriminate among types of test items (see Figure 6). With this version of the categorization task, he exhibited the same pattern of endorsement rates as the other participants. Similarly, Patient P. H. , who in Experiment 1A had exhibited a reverse pattern of endorsement rates, exhibited the normal pattern of endorsement rates (100%, 79. 2%, and 54. 2% of the prototype, low-distortion, and neutral animals, respectively).



Comparison of categorization accuracy and cued-recall test performance for the controls (CON, filled bars) and 7 amnesic patients (AMN, open bars) for Experiment 2. For each subject, the number of correct responses for the categorization task was calculated as the total number of times that the prototype and the low distortions were endorsed and the number of times that the neutral items were not endorsed. The percentage correct was calculated as the total number of correct responses divided by the total number of test trials ($n = 60$). The cued-recall test consisted of nine trials. The maximum possible score for this test was 18 (two correct responses to each of the nine feature names). Brackets represent standard errors of the means.

Figure 7 shows overall accuracy on the categorization task based on the total number of correct responses. Correct responses were calculated as the number of times that the prototype and the low-distortion animals were endorsed and the number of times that the neutral animals were not endorsed. Categorization accuracy was similar for the controls ($M = 71.0\%$) and the 7 amnesic patients ($M = 66.2\%$), $t(13) = 1.55$, $p > 0.10$. Patients E. P. and P. H. obtained accuracy scores of 66. 7% and 70%, respectively. The findings were similar when the responses to the neutral animals were not included, as in Experiment 1A (controls, 83. 7% correct; 7 amnesics, 70. 2% correct; E. P. , 75. 0% correct; P. H. , 86. 1% correct).

Performance on the cued-recall test was scored as the percentage of correct responses when the nine feature names were given as cues and participants were asked how each feature had varied among animals. Cued-recall performance was better for the controls ($M = 88.9\%$) than for the amnesic patients ($M = 32.5\%$), $t(13) = 6.32$, $p < .0001$. Patient P. H. obtained a score of 11. 1% correct. Patient E. P. was unable to provide any accurate responses on the cued-recall test (0% correct). Thus, although the amnesiac patients performed as well as the control group on the categorization task, they were impaired on the cued-recall test.

Examination of data for individual participants revealed that endorsement of prototypic features was well distributed across the nine features, although 2 control subjects did endorse every item that exhibited a particular feature. When the most frequently endorsed feature and the least frequently endorsed feature were identified for the controls and all 8 amnesic patients, it was determined that the endorsement rate for the most frequently endorsed feature was well below 100% ($M = 78.3\%$), $t(15) = 5.66$, $p < .001$, and the endorsement rate for the least frequently endorsed feature was significantly above the chance score of 50% ($M = 61.6\%$), $t(15) = 4.12$, $p < .001$. These findings indicate that, for the most part, individuals did not use the single-feature strategy during the categorization task and that instead they had learned something about each feature.

General Discussion

After studying a group of related cartoon animals, amnesic patients and healthy volunteers performed similarly at classifying new animals according to how closely they resembled the animals they had studied (Experiments 1A and 2). In contrast, the amnesic patients were impaired at recalling the appearance of the animals. Experiment 1B showed in addition that the ability to categorize accurately did not require that learning occur during the test phase itself. Thus, in agreement with

previous studies involving the learning of dot patterns (Knowlton & Squire, 1993; Kolodny, 1994; Squire & Knowlton, 1995), these new findings show that category knowledge can be acquired implicitly, that is, independently of and in the absence of normal declarative memory for the individual items presented during learning.

In previous studies of category learning, amnesic patients learned to discriminate random dot patterns from nonrandom dot patterns that belonged to the same category in the sense that they all resembled a nonstudied, prototypical dot pattern. Same-category dot patterns were constructed from a prototypic pattern by displacing the individual dots a variable distance in any of several directions. This method had the effect of creating dot patterns that were visually continuous and that lacked any discrete features. The present study used stimuli composed of discrete features that were easy to describe verbally. In this respect, we investigated the kind of category learning that occurs in everyday experience. Just as our study participants learned about cartoon animals, individuals can learn about dogs and cups and cars by combining together information about discrete, discontinuous stimuli to create knowledge about categories. The present results suggest that implicit learning of category-level knowledge commonly occurs as a result of encountering any large group with prototype structure. In one earlier study where amnesic patients did not acquire category knowledge about discrete stimuli (Kolodny, 1994), the training stimuli consisted of sets of only four items, which healthy volunteers likely remembered explicitly in order to make their category judgments.

Note that the categorization task, on which amnesic patients performed well, involved presenting a cartoon animal and asking for a yes-no judgment about its category membership. By contrast, the cued-recall test, on which amnesic patients performed poorly, presented a feature that all the animals possessed (e. g. , body markings) and asked participants to recall how the feature had differed among the animals they had seen (e. g. , stripes or spots). It was not intended that these two tests should provide parallel and matched assessments of categorization ability and recollective memory, respectively. The cued-recall test was included simply to document the memory impairment in the amnesic patients.

In previous work involving the categorization of dot patterns, matched tests were administered to the severely amnesic patient E. P. (Squire & Knowlton, 1995). E. P. was as able as controls to classify novel dot patterns after inspecting 40 different training stimuli, but he was unable to recognize as familiar an individual dot pattern after it was presented 40 times in succession. This finding provides particularly strong evidence for the idea that category learning is independent of declarative memory. It will be useful to try to extend this demonstration to the case of the discrete stimuli studied here by constructing matched tests of categorization ability and recognition memory.

Nosofsky and Zaki (1998) have suggested that dissociations between categorization ability and recognition memory can often be interpreted in terms of a single-system memory model, in which the exemplars stored in a single memory system provide the basis for both categorization ability and recognition memory (see also Shanks & St. John, 1994). Such an interpretation begins with the observation that on categorization tasks amnesic patients often perform numerically below the level attained by healthy volunteers, even if not significantly so (cf. Knowlton & Squire, 1993). In these instances, if one supposes that categorization and recognition proceed by different decision rules, one can in fact model the performance of amnesic patients by using a single-system model (Nosofsky & Zaki, 1998). The results of Experiment 1A (Figure 3) may provide another instance of this kind, insofar as a single-system model might account for both a nonsignificant numerical difference in categorization ability (73. 8% and 63. 9% for amnesic patients and controls, respectively) and a larger difference (81. 1% vs. 49. 2%) in cued recall. However, this proposal may be difficult to extend to the results of Experiment 2, where a difference of only 4. 8% was obtained between amnesic patients and controls for categorization (71. 0% vs. 66. 2%). By contrast, the difference between the two groups in cued recall was substantial (56. 4%). Consider also the results for the two amnesic patients, E. P. and P. H. In Experiment 2, the controls scored 71% correct on the categorization task, and patients E. P. and P. H. scored 66% correct and 70% correct, respectively. Yet E. P. could not answer any of the cued-recall questions, and P. H. scored only 11% correct (controls = 88. 9%). Although the cued-recall test does not permit categorization and recollective memory to be rigorously compared, it is unclear to us that these data can be modeled by a single-exemplar-based memory system. Other cases where amnesic patients perform numerically better than controls on classification tasks create similar difficulties for single-system models (Knowlton & Squire, 1994).

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