Concurrent object-discrimination learning in rats

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Investigations employing primates have sometimes used tests of concurrent object-discrimination as indexes of multiproblem memory in comparative studies of neuropathological impairment. The present investigation was an attempt to employ a comparable test procedure with rats. Data from two experiments indicated that rats could indeed be trained on a concurrent object-discrimination task. Furthermore, results from the second experiment indicated that these performances and brightness discriminations shared the property of disruption by posterior decortication. Implications for the neuropsychology of learning and memory are discussed.

Although a variety of experimental tasks have been developed to assess learning and memory function in animals, comparable interspecies test procedures have not been easily devised. There are several advantages associated with having analogous tasks applicable to more than one species. First, from a comparative psychological perspective, such tests might aid in identifying analogous integrative mechanisms in different species. Some investigators have, in fact, begun to utilize this approach. For example, Oscar-Berman and her colleagues (Oscar-Berman, 1980; Oscar-Berman & Zola-Morgan, 1980a, 1980b), have compared concurrent object-discrimination learning in Korsakoff patients to that of monkeys with discrete cortical lesions in an attempt to identify the tissues that might be related to their common memory impairments.

A second reason for comparable tests is to assist in development of animal models of human neuropathological conditions characterized by learning and/or memory deficits (e.g., Alzheimer's disease, geriatric memory dysfunction, etc.). Thus, it is conceivable that researchers might identify tasks on which human patients are impaired, and then, using analogous assessment instruments, attempt to create similar behavioral abnormalities in animals with experimental lesions, drugs, and so forth. The resulting animal model would presumably represent the human condition and would potentially serve as a useful assay for possible treatments. An initial adoption of this general strategy has recently been attempted with respect to Alzheimer's disease (Kesner, Adelstein, & Crutcher, 1987) and human amnesic syndromes (Squire, Zola-Morgan, & Chen, 1988).

A third advantage of comparable test procedures is to provide opportunities to conduct more and varied investigations with rodents, in the hope that these results might serve as "screens" for limiting the number of studies that

require the use of monkeys as research subjects. In short, employing comparable test procedures would not only lead to a broader and better understanding of brain function, but might also result in the development of more appropriate and cost-effective animal models of human memory disorders.

In the present investigation, therefore, we attempted to develop a test for rats analogous to the concurrent object-discrimination procedure used with nonhuman primates. Although this test procedure was chosen in part because of a general concern with the properties of concurrent object-discrimination learning (e.g., Treichler, 1984; Treichler, Petros, & Lesner, 1981), it was our intention to emphasize the utility of interspecies comparisons employing both behavioral and biological measures. The specific aims of the present investigation were to (1) determine whether or not rats could learn concurrent object discriminations, (2) examine the effect of the number of concurrently presented problems on both acquisition and retention test performance, (3) compare concurrent object-discrimination learning with another task impaired by cortical lesions in rats (i.e., brightness discrimination), and (4) determine whether or not comparable lesions impair postoperative performance of concurrent object discrimination in the same manner as they do brightness discrimination (Meyer & Meyer, 1977; Santucci & Treichler, 1985).

EXPERIMENT 1

In Experiment 1, rats were required to learn four object problems one at a time (serial learning), four at a time (concurrent learning), or two at a time (serial plus concurrent learning). The effect of the number of intermixed problems on both acquisition and retention was assessed by comparing different groups of animals on the number of trials required to attain a performance criterion.

Method

Subjects. Seventeen adult (90- to 120-day-old) naive male Long-Evans rats served as subjects. The animals were housed individually during the course of the experiment. While water was available ad lib, food was restricted so that individual animals' weights

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were maintained at 80% of their preexperimental levels relative to normal weight gain for this strain. A 16:8-h light:dark cycle was in effect throughout the experiment.

Apparatus. All training/testing was conducted in a test arena constructed of 6-mm-thick black acrylic plastic with 34.5-cm-high side-walls. The arena enclosed a floor area of 101.5×101.5 cm with 16 (4 rows by 4 columns) 13.5×13.5 cm squares outlined on the central 55.5×55.5 cm of this open field. These 16 squares served as placement locations for the stimulus objects during pretraining and training/testing. Access to the open field was provided by guillotine doors located in the center of each sidewall.

Procedure. After 2 or 3 days of restricted feeding, the animals were placed in the open field for 0.5 h of adaptation. On the following day, a pretraining phase was initiated wherein 45-mg Noyes food pellets could be obtained from 4-cm-wide, 6-mm-deep food wells on top of $10.1 \times 10.1 \times 10.1$ cm wooden blocks that were always placed in the corner squares of the open field. If an animal failed to consume the pellet within 1 min, it was removed from the arena and placed in its home cage in the experimental room for 1 min before another trial was initiated. On the day after an animal had obtained food within 1 min on 10 consecutive trials, the requirements of correctional training were introduced. Accordingly, blocks appeared in various locations and pellets were placed in the well of only one block. The subject was required to find the baited block and consume a pellet within 1 min on 10 consecutive trials.

On the day after the successful completion of pretraining, object-discrimination training was initiated. During training, the subjects were required to learn four multidimensional two-choice object-discrimination problems. Each problem comprised two different "junk" objects made up of pieces of plastic, metal, glass, and/or wood glued together to form irregularly shaped, multidimensionally unique forms. Each object was less than 5 cm in its lateral dimensions and between 11 and 14 cm in height. The rats were required to rear on their hind legs and place their forepaws on the objects in order to see into or gain access to a round food well (2.5 cm wide, 1 cm deep) glued to the top of the object. For each problem, one object was designated "correct" for approximately half the animals in a particular treatment condition, whereas the other object served as the "correct" discriminative stimulus for the remaining half of the subjects. Responses were defined by placement of at least one forepaw on top of the object, and if correct, by consumption of a 45-mg Noyes pellet from that food well. During 10- to 15-sec intertrial intervals, the animal was retained in its home cage in the experimental room and the objects were changed, baited, and/or rearranged.

Each training session entailed 20 correctional trials (1 session/day, 5 days/week), and training continued until, for each object, a criterion of 9 correct initial choices within any 10 consecutive trials was reached. A randomized and counterbalanced sequence provided equal numbers of trials wherein the correct object was located near or far, and right or left of the entry door. Furthermore, to ensure that the rat's view of the objects was not obstructed, objects were never placed in the two squares nearest to and directly in front of the entry door.

On each trial, an animal entered the arena through one of the four guillotine doors. Selection of entrance doors was varied, with the four doors used equally frequently over the 20-trial sequence, and the same door was never used on more than two consecutive trials. Selection of object-placement squares was done according to a random procedure, with the restriction that the same square was never used on more than two consecutive trials. Furthermore, squares used on a particular trial were always located to both the right and the left of the entry door. The floor of the arena and the objects were wiped clean with an ammonia-based cleanser between test sessions of different animals.

The animals were required to learn the four object problems according to one of three procedures. One group of subjects ($n = 7$) was required to learn the four problems one at a time, or serially (SL). The animals in this condition were trained on only one problem during a 20-trial daily training session. Upon attaining the 9/10 criterion, a new problem was introduced in the next session and the subjects were trained to criterion once again. Training continued in this manner until an animal mastered all four problems. Presentation of particular problems was varied randomly so that each animal learned the four problems in a unique order.

A second group of rats ($n = 5$) learned the four problems four at a time, or concurrently (CL). That is, during any one 20-trial daily training session, the four problems were intermixed and each problem was presented on five trials. The animals were not required to reach criterion on the four problems simultaneously. Therefore, it was entirely possible for subjects in this group to reach criterion on one problem early in acquisition and then reach criterion on the remaining problems several training sessions later. In this case, the problem that was learned quickly was still intermixed with the other three problems throughout acquisition. Thus, all four problems continued to be presented concurrently until criterion on all problems had been attained.

A third group of animals ($n = 5$) was required to acquire the four problems according to a procedure that combined both serial and concurrent learning procedures (S/CL). The subjects in this condition were presented with two problems during the 20-trial daily training session (10 trials/problem). The animals had to reach criterion on each problem in the two-problem set before being switched to learning the remaining two problems. Similar to the CL training procedure, training continued on both problems in a set until criterion on each problem was met. Selection of the two problems to be learned together and presentation sequence of pairs of problems were varied randomly among animals.

On the day after successful acquisition of all four problems, all subjects, regardless of their original learning condition, were tested on the four problems according to the concurrent learning procedure described above. Criterion was again set at 9/10 and daily sessions consisted of 20 trials. Although termed a "retention" test, we recognize that the procedure entails elements of transfer with respect to some transitions. Trials to criterion (TTC), not including the 9/10 criterion block, served as the dependent variable during training and testing, and nonparametric tests were used to assess within- and between-group differences.

Results

Median TTC scores in acquisition and retention for each object problem (A through D) by the animals comprising the SL, CL, and S/CL conditions are presented in Table 1.

Within-group comparisons, made with Wilcoxon matched-pairs, signed-rank tests, indicated that all groups were proficient in retaining the various object discriminations independent of the conditions in effect during acquisition. This was evidenced by the presence of statistically significant savings on all four problems when retention performances were measured after any of the acquisition procedures (all $ps < .05$). The several training procedures produced no significant differences on the acquisition of any of the four problems as indicated by Kruskal-Wallis tests (all $ps > .10$). Similarly, retention performances after the various acquisition procedures were nondifferential, except for retention on Problem C

Table 1
Median ($\pm$ Semi-Interquartile Ranges) Acquisition and Retention Trials to Criterion
for the Three Training Procedures of Experiment 1

Training Procedure	Problem							
	A		B		C		D	
	Median	Range	Median	Range	Median	Range	Median	Range
Acquisition								
SL	36	17	43	33	33	19	44	23
CL	27	11	30	12	39	10	48	14
S/CL	42	17	45	19	34	18	46	19
Retention								
SL	2	2	8	9	9	4	9	4
CL	0	6	0	0	0	2	21	11
S/CL	8	4	11	4	2	2	6	4

Note—SL = serial training, CL = concurrent training, S/CL = serial plus concurrent training. All subjects were tested for retention in a concurrent manner.

[$H(2) = 6.92, p < .05$]. On that problem, because many animals in the CL and S/CL groups exhibited 0 TTC at retention, significant differences were obtained when performances of CL and S/CL animals were compared to the performance of the SL group (both Mann-Whitney U s < 5 , both $ps < .05$).

To evaluate whether or not facility in acquisition might have improved over the course of training under the serial procedure, the TTC scores for the SL animals were compared using problem-presentation order (first, second, third, and fourth) as an independent variable. A Friedman two-way ANOVA indicated no differences among acquisition scores for the four problems ($p > .20$). A similar analysis of retention scores also indicated no reliable consequence of order of problem presentation ($p > .20$). In addition, for the group trained under the S/CL procedure, training order produced no reliable effects on either acquisition or retention scores (Wilcoxon tests, $ps > .20$).

Discussion

The results of Experiment 1 revealed that, like monkeys and humans, rats were capable of acquiring several two-choice object-discrimination problems at the same time, and they could acquire these problems with equal facility under serial, concurrent, or combined serial and concurrent, learning procedures. At least with a maximal set of four problems, the rats also remembered these discriminations equally well even when the retention test was presented exclusively as a concurrent task. Moreover, because the sequence in which the problems were learned had little influence on retention, it appears that memories for individual problems, once established, were retrievable with equal proficiency independent of the distribution and order characteristics in effect during acquisition.

It should be noted that, although some statistical differences were revealed between the groups at retention on Problem C (with the SL group requiring more TTC), all groups reached retention criterion on this problem rapidly

(all medians < 10) in comparison to acquisition requirements. Therefore, we do not consider this statistical outcome to be particularly relevant to defining the properties of the concurrent task as a measure of memory.

EXPERIMENT 2

With the results of Experiment 1 verifying that rats are indeed capable of learning and retaining concurrent object discriminations proficiently, Experiment 2 was conducted in an effort to explore the potential utility of this task as an index of neurological status. Because posterior decortication has been demonstrated to yield distinctive impairments of two-choice problems based on brightness discriminations (N. D. LeVere & T. E. LeVere, 1982; Meyer & Meyer, 1977), and because we have observed this same lesion-based behavioral impairment in a brightness test situation very similar to that used for the present concurrent task (Santucci & Treichler, 1985; Santucci, Treichler, & Ahlers, 1986), we attempted to evaluate posterior cortical lesion effects on concurrent task performance. Accordingly, the procedures of Experiment 2 were instituted.

Method

Subjects. Twenty-eight adult (90- to 120-day-old) naive male Long-Evans rats were employed. All other subject characteristics were identical to those described in Experiment 1.

Apparatus. The open-field arena and the four object problems employed in Experiment 1 were used in the present experiment. In addition, two identically constructed translucent cubes with 13.5×13.5 cm sides (with food wells atop), which could be illuminated from within, served as the discriminative stimuli for the brightness-discrimination problem. With one cube lighted, these stimuli provided values of 270 and 0.8 cd/m² for the brighter and dimmer discriminanda, respectively, as measured by a Textronic J6511 digital photometer placed 22.5 cm from the cubes (the average distance from entry door to discriminanda).

Procedure. The subjects were pretrained according to the procedures of Experiment 1. Following pretraining, two groups (Group 1, $n = 7$, and Group 2, $n = 6$) of subjects were trained on the four object-discrimination problems (A, B, C, and D). The animals in

a third group (Group 3, $n = 8$) received training on Object Problems A, B, and C. However, for this group, a brightness-discrimination problem (dim stimulus as correct) was substituted for problem D. A fourth group (Group 4, $n = 7$) of animals received training on only the brightness-discrimination problem (dim stimulus as correct). Training on multiple problems was performed according to the concurrent learning procedures of Experiment 1, with all subjects receiving 20 daily trials. Immediately after reaching the 9/10 acquisition criterion on all problems, the subjects were given free access to food. Two to 3 days later, all animals, except those in Group 1, underwent aspirative lesions of the posterior portion of the neocortex. Surgery was performed under Chloropent anesthesia (Fort Dodge Laboratories, Inc., Fort Dodge, IA; 3.33 ml/kg, i.p.) with extents of damage intended to include the areas removed by Meyer and Meyer (1977), Treichler and Conley (1982), and T. E. LeVere, N. D. LeVere, Chappell, and Hankey (1984). A postoperative period of approximately 14 days followed surgery. The unoperated group of subjects (Group 1) served as controls and had a period of no experimental activity after the completion of acquisition training. Following its postoperative or rest period, each subject was tested for retention in a manner identical to acquisition training. Criterion was once again set at 9/10 consecutive correct choices for each problem and TTC served as the dependent measure.

At the completion of retention testing, the animals were injected with an overdose of Nembutal anesthesia (Abbott Laboratories, North Chicago; 100 mg/animal, i.p.) and perfused through the heart with 0.9% saline followed by 10% formalin solution. Upon removal of the brains, extent of cortical surface damage was traced on standard Lashley diagrams with dimensions like those of a model rat brain. A Sigma Scan Digitizer Tablet (Jandel Scientific Corp., Corte Madera, CA) connected to a Zenith personal computer was used to quantify the extent of cortical surface damage. Brains were then embedded in celloidin and subsequently sectioned at 40 μ m. Every fifth section through the lesion was stained with cresyl violet. In addition to gross inspections of brain specimens, light microscopic examinations of retrograde degeneration in the dorsal lateral geniculate nucleus (dLGN) and other thalamic nuclei were performed.

Results

Histology. Examination of brains from the subjects with cortical lesions indicated that the extent and nature of the damage was similar to that reported in previously published studies noted above. Computer-aided quantification of the extent of posterior decortication revealed that an average of 29.1%, 23.2%, and 23.6% of the dorsal cortical surface area was removed from the brains of subjects serving in Groups 2, 3, and 4, respectively [$F(2, 18) = 1.35$, $p > .20$]. The rostral-caudal extent of the lesion was approximately 5 mm anterior from the far posterior margin of the cerebrum. With respect to the medial-lateral aspect, the lesion extended to the upper bank of the rhinal sulcus and as close to the midline as possible without involving the sagittal sinus. According to the nomenclature of Ziles (1985), most of the tissue aspirated was "visual" in nature. Lesions typically included primary (both monocular and binocular) visual cortex, and mediolateral and mediomedial occipital cortices, with limited destruction of temporal and entorhinal cortices. The hippocampus proper was not disrupted to any significant extent in any animal.

Histological analysis of cresyl violet-stained sections revealed extensive gliosis and retrograde degeneration in the dLGN of all cortically damaged animals. Some de-

generation, but much less than that observed in the dLGN, was seen in surrounding nuclei, particularly in the nucleus ventralis.

Behavioral. Median acquisition and retention TTC for the four groups of subjects are presented in Table 2.

Analysis of acquisition scores with the appropriate non-parametric test (Kruskal-Wallis one-way ANOVA or Mann-Whitney U test) revealed that the four groups of subjects required statistically equivalent numbers of trials to reach criterion on the various object-discrimination problems and on the single brightness-discrimination problem (all $ps > .20$). This was true even when performance on the brightness-discrimination problem (Groups 3 and 4) was compared to performance on Object Problem D (Groups 1 and 2) (all $ps > .20$).

Examination of postoperative scores revealed that posterior decortication required additional exposure to the test situation to induce restitution of performance. Compared to Group 1 (the unoperated group), Group 2 required more trials to reach postoperative criterion on all four object problems (all $Us < 7$, all $ps < .04$), whereas Group 3 exhibited more TTC on Problems A and C (both $Us < 12$, both $ps < .05$). The postoperative performances of Groups 2 and 3 on the three object problems on which both groups were tested (i.e., A, B, and C) were not statistically different (all $ps > .20$).

The postoperative performances of Groups 3 and 4 on the brightness-discrimination problem were also impaired, at least relative to the performance of the intact subjects (Group 1) trained on Object Problem D (both $Us < 11$, both $ps < .05$). The extent of impairment on the brightness problem, however, was not related to the fashion in which this problem was presented (i.e., singly or concurrently); Groups 3 and 4 exhibited statistically comparable TTCs for the brightness problem at postoperative test ($p > .20$).

Within-group comparisons with Wilcoxon tests confirmed that the lesions disrupted performance. Relative to their own preoperative scores, Groups 2 and 3 (except Group 3 on Problem B, $p < .02$) failed to exhibit statistically significant savings in the number of trials required to attain the postoperative criterion (all $ps > .20$). Typically, the subjects with posterior lesions needed about the same number of trials to reach both pre- and postoperative criteria, and this absence of postoperative savings was also seen in the subjects trained and tested on only the brightness-discrimination problem (Group 4, $p > .10$). The acquisition-to-retention pattern of results associated with Groups 2, 3, and 4 was in marked contrast to the pattern seen with Group 1. The animals in Group 1 exhibited significant acquisition-to-retention savings on Problems A, C, and D ($ps < .025$); the effect approached significance on Problem B ($p = .07$).

Finally, to determine whether the extent of the lesion in individual animals was associated with the degree of postoperative impairment, lesion size was correlated (Pearson r) with retention TTC. No significant coefficients were revealed when lesion size was correlated with reten-

Table 2
Median ($\pm$ Semi-Interquartile Range) Acquisition and Retention Trials to Criterion
for the Four Groups of Subjects in Experiment 2

Group	Problem							
	A		B		C		D/BD	
	Median	Range	Median	Range	Median	Range	Median	Range
Acquisition								
1	26	4	22	8	39	18	34	11
2	36	18	52	31	54	29	38	15
3	25	15	29	14	41	17	35	11
4	—	—	—	—	—	—	37	9
Retention								
1	9	5	14	7	12	11	10	9
2	28	4	28	3	53	16	31	15
3	32	14	16	11	34	11	38	22
4	—	—	—	—	—	—	56	16

Note—Group 1 was given a rest period between acquisition and retention testing; Groups 2, 3, and 4 were given posterior cortical lesions between acquisition and retention testing. A, B, C, and D = object-discrimination problems; BD = brightness-discrimination problem. Groups 1 and 2 were trained and tested on Problems A, B, C, and D; Group 3 was trained and tested on Problems A, B, C, and BD; Group 4 was trained and tested on Problem BD. Training and testing for Groups 1, 2, and 3 were conducted in a concurrent fashion.

tion performance on the object problems (Groups 2 and 3) or with retention performance on the brightness problem (Groups 3 and 4) (all $r_s < .51$; all $p_s > .10$).

Discussion

Multiple object-discrimination learning in the rat was further characterized in Experiment 2. First, the data from Group 1 (unoperated animals) of the present experiment complement and extend the results of Group CL in Experiment 1 by demonstrating that rats are capable of proficient retention of concurrently learned object problems despite a retention interval of about 2 weeks. Second, the results illustrate several similarities between concurrent object-discrimination learning and another type of visual learning, brightness discrimination. The two problems required approximately equivalent amounts of training for the animals to reach the 9/10 acquisition criterion. Furthermore, posterior decortication not only disrupted postoperative performance on both the object and the brightness tasks, but also influenced them in a similar manner. For both tasks, the animals required about as many trials postoperatively as were needed to reach the original acquisition criterion. This severe impairment and subsequent restitution of performance is reminiscent of many other reports of posterior cortical lesion effects on brightness discrimination (N. D. LeVere & T. E. LeVere, 1982; T. E. LeVere, 1980; Meyer & Meyer, 1977; Santucci & Treichler, 1985; Santucci et al., 1986; Treichler & Conley, 1982). The similarity of consequences observed on both the multidimensionally different object problems and the unidimensionally different brightness (flux) problem suggests that the object problems might have been solved as visual problems on the basis of differential brightness and/or array of flux cues.

On the brightness-discrimination problem, neither acquisition nor retention scores were differentially affected

by the learning procedure employed. That is, the animals trained on the brightness problem alone (Group 4) exhibited acquisition and postoperative retention scores that were not significantly different from the scores obtained by the subjects trained on a concurrent mix of brightness- and object-discrimination problems (Group 3). These data suggest that concurrently presenting four problems does not induce a special difficulty of acquisition or reattainment of the brightness habit by decorticates.

With respect to the effects of posterior cortical lesion on brightness-discrimination performance, one might argue that from a methodological perspective, the design should have included a nonoperated control group. However, because previous observations have indicated that singly administered brightness discriminations (N. D. LeVere & T. E. LeVere, 1982; Meyer & Meyer, 1977), including the one employed here (Santucci & Treichler, 1985; Santucci et al., 1986), yield only a few errors in a relearning test administered 2 weeks after acquisition, such a control seemed unwarranted.

GENERAL DISCUSSION

Both of the present experiments examined the ability of rats to perform a concurrent object-discrimination task using multidimensional stimuli as discriminanda. The results demonstrated that the animals were proficient in learning and retaining several object-discrimination problems even when the problems were presented in a concurrent fashion. Thus, the present outcome is in agreement with the results of Rothblat and Hayes (1987), who also successfully employed a multiple-problem object-learning procedure and suggested that rats could indeed be trained using a methodology like that employed with primates (Squire & Zola-Morgan, 1983). The present results supplement those of Rothblat and Hayes by provid-

ing another multiple-problem object-test technique, concurrent discrimination, as a potential evaluator of the rat's retention characteristics. As a consequence of the use of the concurrent paradigm, it appears possible to evaluate functions different from the short-term processes represented by the within-trial information of matching (and nonmatching) tasks. Although the distinction between working- and reference-memory components in such tasks is difficult to specify (see Roitblat, 1984, p. 80), the concurrent task's requirement for utilization of intertrial information suggests that it may provide greater emphasis on reference or long-term memory, in contrast to the working (short-term) memory requirements of the matching task. Although neuroanatomical bases of these systems have not yet been distinguished, the existence of such relationships does provide prospective integrative mechanisms.

Two possible alternative explanations of the kind of consistent object choice that were observed in the present concurrent tasks require consideration. First, perhaps the animals biochemically marked the objects and then chose or avoided them systematically on the basis of these signs. Another prospect is that the animals might have made olfactory discriminations on the basis of presence of pellets in the food cup of correct objects. However, broad consideration of the results suggests that neither of these interpretations is well supported. Marking would be extremely difficult because (1) the tall, nonporous objects were deodorized between subjects, and (2) placement changed from trial to trial, so that residual marking biochemicals would have remained at old locations. In addition, the patterns of acquisition that would accord well with an olfactory or marking tactic were not observed. That is, there did not appear to be especially rapid intrasession improvement, nor was there an absence of intersession improvement. A further contraindication of such influences was the absence of rapid problem solution upon introduction of new problems as was done in the SL and S/CL conditions of Experiment 1, or when successive reversals of the present brightness discrimination were provided in previous studies (Santucci & Treichler, 1985). Furthermore, some current testing procedures of ours entail using sugared cereal or peanut butter as incentives in an attempt to speed acquisition. Because of the distinct olfactory properties of these foods, reinforcement is placed in both food wells but a fly screen prevents access to the food in the incorrect well. This arrangement allows emission of olfactory cues from both wells even though reward is accessible only from the correct object. In refutation of an olfactory-cue interpretation, we have noted that the use of these reinforcements yields TTC scores strikingly similar to those of the present report. In fact, in the present reported experiments, since there was a substantial amount of pellet debris in the bottom corners of the food wells, the control we are now imposing was probably provided implicitly.

In Experiment 2, where aspirative lesions were made, the results revealed that object-discrimination learning

shared some properties with brightness-discrimination learning. The rats needed similar amounts of training to reach an acquisition criterion on the various object and brightness problems. Furthermore, postoperative performances on the two problem types were equally disrupted, with both tasks requiring about as many trials to attain the postoperative criterion as had been necessary for original learning by normals. The finding that object discrimination shares such properties with brightness discrimination, especially with respect to its sensitivity to posterior decortication, suggests that rats might rely upon the luminous flux characteristics of objects as a salient feature common to the solution of both types of problems. However, we suggest some caution in the interpretation of lesion influences upon concurrent performance. The results reported here are certainly preliminary and do not allow precise specification of the task or lesion properties necessary and sufficient for attribution of this effect. More optimistically, the outcomes do seem to pose issues that may be investigated by further empirical tests.

Taken in concert, the present experiments show that rats can be trained on a task comparable to one that has been a reliable detector of neuropsychological impairment in nonhuman primates (Mishkin, 1971). This task offers a departure from typical rodent tests by utilizing object discriminations rather than spatial characteristics in task solution. In keeping with the views of Becker and Olton (1980), a deemphasis of spatial properties is effected by providing multiple locations for placement of discriminanda and by requiring various entry locations when trials are initiated. We suggest that the development of test procedures with sensitivity to neurological damage as evidenced by the present study might encourage the wider use of multiple-problem object-discrimination learning and similar tasks in comparative study. Adoption of this approach might lead to a better understanding of brain-behavior relationships and may eventually aid in the development of appropriate animal models of human neuropsychological disorders.

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