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AN INVESTIGATION OF ODDITY CONCEPT LEARNING BY RATS

AILEEN M. BAILEY and ROGER K. THOMAS
The University of Georgia

Four male rats (*Rattus norvegicus*, Long-Evans) 114 days old at pretraining were tested using ping pong balls with food-flavoring odors as discriminanda. Two same-odor and one different-odor balls were presented on each trial, and 60 different problems were administered each to an 80% correct criterion or 100 trials. To assess conceptual use of oddity the first trial of each problem was used; Trials 2 and 3 were used to assess learning set performance. One rat had two significant runs of correct first trials, but he did not sustain it. All rats showed rapid improvement on Trials 2 and 3 affirming their excellent learning set formation. The need and means for continued investigation of oddity concept learning by rats are discussed.

The oddity concept task is representative of what has been defined as a relative class concept as opposed to an absolute class concept (e.g., Thomas, 1980). The defining features of exemplars of absolute class concepts are inherent in each discriminandum (e.g., "tree," "water," and "a person"; Hernnstein, Loveland, & Cable, 1976), but relative properties such as "oddity" are not inherent in the discriminandum that represents a relative class concept. Operationally, this reduces to the need-to-compare (relative) versus no-need-to-compare (absolute) discriminanda in order to affirm whether a discriminandum represents the concept.

The oddity concept appears to have been the most investigated relative class concept using the most different species of animals, including birds (e.g., Lombardi, Fachinelli, & Delius, 1984; Pastore, 1954; Wright & Delius, 1994; Zentall & Hogan, 1974), rodents (e.g., Langworthy & Jennings, 1972; Nakagawa, 1993; Wodinsky & Bitterman, 1953), carnivores (e.g., Strong & Hedges, 1966; Warren, 1960), and primates (e.g., Bernstein, 1961; Levine & Harlow, 1959; Thomas & Frost, 1983). Despite many claims that nonprimate animals have been shown to be able to perform oddity problems successfully on a conceptual

Reprint requests may be sent to Roger K. Thomas, Department of Psychology, The University of Georgia, Athens, GA 30602-3013. Telephone: 706-542-3101; Fax: 706-542-3275; E-mail: rkthomas@uga.cc.uga.edu.

basis, it has been suggested that the studies using nonprimate animals likely have all been subject to confounding variables or competing interpretations that render interpretations of successful oddity concept-based performance inconclusive (e.g., Premack, 1978; Steirn & Thomas, 1990; Thomas, 1994, 1996). However, it has not been contended that oddity concept learning is beyond the ability of nonprimate animals, only that the definitive investigation appears to be lacking.

Perhaps the most promising method to investigate oddity concept learning by rats was introduced by Langworthy and Jennings (1972) who described a clever, effective, and inexpensive way to present olfactory discriminanda to rats. It is well known that olfactory discriminanda are inherently more appropriate for rats (e.g., Lu, Slotnick, & Silberberg, 1993; Slotnick & Katz, I974; Thomas & Noble, 1988), although some of the better known or more recent investigations of rat oddity concept learning have used visual discriminanda (e.g., Wodinsky & Bitterman, 1953; Nakagawa, 1993). Langworthy and Jennings concluded that their rats had shown use of the oddity concept, but they did not provide statistical validation. Thomas and Noble (1988) confirmed that Langworthy and Jenning's findings were statistically significant; however, Thomas and Noble noted that Langworthy and Jennings had only baited the correct food well, the one covered by the odd discriminandum. Baiting only the correct food well left open the possibility that the rats smelled the food and used that as the discriminative cue.

Thomas and Noble (1988) used Langworthy and Jennings' (1972) task but with a considerably modified procedure, intended to be more rigorous, to investigate whether rats could learn and use the oddity concept. Thomas and Noble used 16 odoriferous substances compared to 8 for Langworthy and Jennings; Thomas and Noble administered 300 five-trial problems instead of Langworthy and Jenning's 30 problems each one administered to a criterion (16 of 20 successive trials correct) or a maximum number of trials (100); and Thomas and Noble baited all three food wells. Thomas and Noble's rats showed very good learning set performance (responding correctly, better-than-chance on Trial 2), but they showed no evidence of correct responding on Trial 1. If the animals had acquired the oddity concept, then they should have responded correctly on Trial 1 (see French, 1965).

Because there are good reasons to persist in trying to determine whether rats can use the oddity concept (e.g., having a good rat model for relative class concept learning in psychopharmacological research; see Thomas, 1996), the present investigation was designed to approximate more closely the more extended training on each problem that Langworthy and Jennings had used while also maintaining the rigor of using more odiferous substances and baiting all three food wells on each trial to eliminate the odor of the food as a discriminative cue.

Method

Subjects

Four male hooded rats (*Rattus norvegicus*, Long-Evans strain) purchased from Harlan Sprague Dawley were used. The rats were housed in individual polycarbonate cages (43.2 cm x 21.6 cm x 20.3 cm high) and maintained on a light:dark cycle with dark being from 10:00 a.m. to 10:00 p.m. local time. Testing was done during the dark phase. The rats were introduced gradually to a 22-hr food deprivation regimen (details provided on request or see Bailey, 1996) over a period of 24 days. The experimental testing began on Day 24, and the food was available for 2 hr immediately after daily training and testing. Each rat's daily weight was compared to a normal growth weight curve for its species and variety according to Harlan's data. It was planned that if a rat's weight decreased more than 10% from the normal weight curve, the time of daily food availability would be increased in 1-hr or 2-hr increments to maintain the normal weight curve. Initially it was necessary to increase the feeding time to 4 hr, but later an average of approximately 2.5 hr feeding time proved sufficient to maintain growth weight. Under no circumstances was a rat given less than 2 hr of availability to the food. The rats were approximately 90 days old at the beginning of the food deprivation regimen, approximately 114 days old at the beginning of the pretraining procedures, and approximately 135 days old at the beginning of oddity testing. Maintenance and use of the rats was approved by the University of Georgia's Animal Care and Use Committee whose policies and procedures meet and exceed those of the APA's Ethical Standards for use of animals in psychological research.

Apparatus and Stimuli

The testing apparatus had two compartments: a holding chamber for the rat and a stimulus-reinforcement chamber. The sides and the top of the holding chamber were constructed of wood and painted black. The floor of the holding chamber was constructed of stainless steel rods spaced 1.25 cm apart across the width of the chamber. The inside dimensions of the holding chamber were 31 cm (length) x 29 cm (width) x 20 cm (height). The wall facing the stimulus-reinforcement chamber had an aperture across its width, 7 cm from the grid floor, and which could be closed by a guillotine door.

The stimulus-reinforcement chamber was constructed of wood and painted medium gray. Its inside dimensions were 29 cm (width) x 20 cm (height) x 13 cm (length). It was designed to be juxtaposed to the holding chamber. It had no wall on the side closest to the holding chamber; instead, it shared the holding chamber's wall, which had the aperture described above. The stimulus-reinforcement chamber's wall opposite the side with the aperture had a guillotine door that could be opened to permit the experimenter to set up the stimuli on the stimulus tray. The rat could reach the stimulus tray through the aperture in the holding chamber.

The stimulus tray was constructed of wood and painted medium gray. It had three food wells with diameters of 2.5 cm and depths of 0.5 cm, the centers of the outer food wells were 4 cm from the sides of the tray and the center-to-center distance between the food wells was 8 cm. There was a front wall that mates with the aperture and the wall had three portals, each 4 x 5 cm, allowing access to the food wells. The portals were intended to minimize forward rolling of the stimuli (odor-saturated ping-pong balls). Each food well was covered by a small medium-gray board (3.5 cm x 22.5 cm x 0.5 cm) that the experimenter could slide to cover or uncover the food well. These small boards contained a small indentation centered over the food well to hold the ball in place until it was nudged by the rat. Although there were three food wells, only the outer two food wells were used to present the odd ball in the study.

The discriminanda were odor-exposed ping-pong balls. To prepare the ping-pong balls with the odors, one-quart food-storage jars (Mason brand) were used to hold the balls and the odoriferous substances. Initially seven drops of an odoriferous substance were placed at the bottom of a jar. A wire screen was placed between the odoriferous substance and the ball to avoid direct contact of the liquid with the ping-pong balls. Two ping-pong balls were kept in each jar and the odoriferous substance was replenished as necessary. Eighteen odoriferous substances were used. Sixteen were the following Kroger brand food flavorings: almond, anise, banana, black walnut, brandy, butter, chocolate, coconut, lemon, maple, mint/peppermint, orange, pineapple, rum, strawberry, and vanilla. Two were Durkee brand food flavorings: cherry and rootbeer. Eighteen substances, using two at a time, where either could be the odd stimulus provides for the construction of 306 odor-unique problems. Taking into account the positions of the odd and nonodd stimuli, 1,224 unique configurations were possible. It may be noted also, that a given odor might be odd on one problem and nonodd on another. Therefore, a particular odor could not long be associated with oddity or nonoddity per se.

Pretraining Procedures

(a) For the first 3 days, a rat was placed in the holding chamber with the guillotine door between it and the stimulus-reinforcement chamber in the open position. Two food pellets were placed in one of the two, randomly selected, outer food wells, and the rat was allowed to remain in the holding chamber until it consumed both pellets. (b) For the next 3 days, the animal was placed in the holding chamber with the guillotine door closed. The door was raised after 60 seconds allowing access to the food, and the rat was allowed access until it

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Conceptual Oddity Testing

On the 16th testing day, all three ping-pong balls were introduced and the first oddity problem was presented. The two discriminanda were selected from a random number list generated by a computer. Each odor was presented only once until all of the 18 odors had been presented. This procedure was used to avoid any one odor being more frequently presented as odd or nonodd in the beginning of the study. The position of the odd ball, which was the correct choice, was limited to the left or right food well and was determined by the Fellows (1967) series. The rat had to nudge the odd ball out of place before the experimenter would slide back the board that covered the food well and expose the reinforcers. All of the food wells were baited to control for possible odor discriminative cues from the food reinforcers. Twenty trials per day were administered. The subjects were given one problem with 20 trials per day until either one of two conditions was met: (a) 16 correct responses out of 20, not necessarily on the same day, for two successive blocks of 20 trials or (b) 100 trials were given for one problem. The subjects were given a new problem beginning the day after reaching criterion or having the maximum of 100 trials. A total of 60 problems was given. In the event of an error, the trial was readministered until the correct choice was made or until a total of five such correction trials had been given. For purposes of data analysis, only the response to the initial presentation of the trial was used for evidence of conceptual responding. In addition to first trials of a given problem, data were analyzed for Trial 2 and Trial 3, to provide evidence related to learning set formation.

Results and Discussion

To summarize before presenting the statistical analyses, the data indicated that the total individual-rat or group-rat correct responses on Trial 1 did not exceed chance. However, one rat had two statistically significant, nearly perfect runs of correct responses on Trial 1. All rats performed significantly better than chance on Trials 2 and 3 demonstrating the acquisition of a learning set. Examining the 60 problems in successive 15-problem blocks, both Trial 2 and Trial 3 correct responses increased significantly between the first and second blocks; the mean percent correct for Blocks 2-4 on Trial 2 was 81%, and on Trial 3 it was 86%. No significant changes in performance were seen across the four blocks of problems on Trial 1 which averaged 45% correct per block. Because responses could be made to any of the three discriminanda and associated food wells, chance might be viewed as 33%. However, because the odd discriminandum occurred only with the two outer food wells, it was deemed to be more conservative to consider chance as 50%.

To assess Trial 1 performances, the first trials for each rat on the 60 problems were examined as a series from Problem 1 to Problem 60. Bogartz's (1965) tables were used to assess the probability of nearly perfect runs as a function of trials accrued. Such tables were initially developed for perfect runs by Grant (1946, 1947) to assess learning performances, and Grant's tables were extended to include nearly perfect runs by Bogartz (1965) and Runnels, Thompson, and Runnels (1968); Bogartz's tables included the probabilities for runs such as those seen in the present investigation. Rat 2 had a significant nearly perfect run of 9 correct in 10 successive first trials associated with Problems 2-11 ($p < .05$; see Bogartz's Table 8), and Rat 2 had a significant, nearly perfect run of 10 correct in 11 successive first trials associated with Problems 16-26 ($p < .05$; see Bogartz's Table 9). Rat 2 had no significant runs or nearly perfect runs of incorrect responses. No other rat had a significant run or nearly perfect run on any of the 60 first trials either of correct responses or incorrect responses.

Table 1 shows the percentages correct for each rat on each of Trials 1-3 for each of the four successive 15-problem blocks as well as for all 60 problems combined. Group and individual Trial 1 performances were analyzed using the binomial approximation (following Meyer, 1976). Group and individual Trial 1 performances over all 60 problems did not differ significantly from chance except for Rat 6 whose performance (32% correct) was significantly worse than chance, $p < .01$ (see Table 1).

The percentages correct for Trials 1, 2, and 3 for problem-blocks 1-4 (Problems 1-15, 16-30, 31-45, 46-60; see Table 2) were analyzed using a two-way repeated measures analysis of variance (ANOVA), trial x problem-block. The ANOVA revealed a significant effect of Trial [$F(2, 6) = 41.142$, $p < .001$], and a significant trial by block interaction [$F(6, 18) = 2.897$, $p = .04$]. Planned comparisons revealed a significant increase in percentage correct between Trial 1 and Trial 2 [$t(6) = 8.435$, $p < .01$], and consumed the food. (c) On the 7th testing day, the boards covered about one third of the food well; on Day 8, about one half; and on Day 9, about two thirds. Beginning on Day 10, the boards completely covered the food wells, and after 60 seconds the boards were moved and the rats were allowed access to the food. (d) On the 11th pretraining day, the ping-pong balls were introduced. A ping-pong ball was randomly placed over an outer food well such that it covered half of the food well. Thus, the animal had to slightly nudge the ball to gain access to the food pellets. This procedure was done twice. On the next three trials the ping-pong ball completely covered the food well, and the rat had to nudge the ball out of place before the experimenter would slide back the board that covered the food well and expose the reinforcers. Testing Days 12 and 13 followed the same procedure as Day 11. (e) The 14th day began with 2 trials where the ping-pong ball covered half of the food well, and then 18 trials followed where the food well was completely covered by the ping-pong ball. The ball's position over either the right or left food well was randomly determined by the Fellows (1967) series. (f) The 15th testing day consisted of 20 trials where the food well was completely covered by the ping-pong ball.

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Table 1

Percentages of Correct Responses on Trials 1, 2, and 3 of New Problems for Each Rat on Four 15-Problem Blocks with Better-Than-Chance (50%) Performances Noted

	Problems				
Rats/Trials	1-15	16-30	31-45	46-60	1-60
Rat 1					
Trial 1	47%	60%	53%	27%*	47%
Trial 2	47%	93%***	80%*	67%	72%***
Trial 3	73%	87%**	67%	80%*	77%***
Rat 2					
Trial 1	60%	67%	53%	27%*	52%
Trial 2	80%*	93%***	93%***	67%	83%***
Trial 3	80%*	93%***	73%	93%***	85%***
Rat 4					
Trial 1	40%	47%	60%	47%	48%
Trial 2	73%	87%**	73%	80%*	78%***
Trial 3	67%	67%	93%***	87%**	78%***
Rat 6					
Trial 1	20%*	33%	40%	33%	32%**
Trial 2	40%	73%	80%*	87%**	70%***
Trial 3	60%	93%***	93%***	100%***	87%***

*$p < .05$, **$p < .01$, ***$p < .001$.

between Trial 1 and Trial 3 [$t(6) = 7.108$, $p < .01$]. Group Trial 1 and Trial 2 performances were significantly different for Block 1 [$t(18) = 2.638$, $p < .01$]; Block 2 [$t(18) = 5.036$, $p < .05$]; Block 3 [$t(18) = 4.317$, $p < .05$]; and Block 4 [$t(18) = 5.996$, $p < .05$].

Table 2

Percentages of Correct Responses Combined for All Rats on First Three Trials of New Problems for Four 15-Problem Blocks with Better-Than-Chance Performances Noted

	Problems				
Trials	1-15	16-30	31-45	46-60	1-60
Trial 1	42%	52%	52%	33%**	45%
Trial 2	60%	87%***	82%***	75%***	76%***
Trial 3	70%***	85%***	82%***	90%***	82%***

*$p < .05$, **$p < .01$, ***$p < .001$.

Because significant differences were found between the group Trial 1 and Trial 2 performances, the group Trial 2 performance was analyzed. The group Trial 2 performance over all problems was found to be significantly greater than chance, 75.75% correct, $p < .01$. Trial 1 performances did not increase significantly over successive blocks. However, a significant decrease in performance was observed between Block 2 and Block 4, [$t(18) = 2.214$, $p < .03$], and between Block 3 and Block 4 [$t(18) = 2.214$, $p < .03$]. Significant increases in Trial 2 performance occurred between Block 1 and Block 2 [$t(18) = 3.220$, $p < .01$], between Block 1 and Block 3 [$t(18) = 2.617$, $p < .01$], and between Block 1 and Block 4 [$t(18) = 1.812$, $p < .03$]; Trial 3 performances significantly improved between Block 1 and Block 2 [$t(18) = 1.812$, $p < .03$], and between Block 1 and Block 4 [$t(18) = 2.415$, $p < .03$].

To determine whether there were Trial 1 position preferences, the binomial approximation was used. Rat 2 (60%, $p < .02$) and Rat 6 (58%, $p < .05$) responded more frequently to the right side. Rat 1 ($p > .05$) and Rat 4 ($p > .05$) showed no position preferences. The rats did not appear to differ significantly on their overall performances for Trial 1, Trial 2, and Trial 3, except that Rat 6 performed significantly worse than chance on Trial 1. However, it may be recalled that it is debatable whether chance should be viewed as 33% or 50% in the present work, and the more conservative 50% was used. If 33% had been used, then Rat 6's Trial 1 performance (32%) would have been interpreted as chance. Rat 2 tended to perform with higher percentages correct on Trials 1, 2, and 3 than the other rats.

General Discussion

Rat 2 had two significant, nearly perfect runs of correct Trial 1 responses, therefore, indicating that he used the oddity cue to gain reinforcers during those runs. However, his Trial 1 performances decreased to chance levels following the second nearly perfect run which ended with Problem 26. Thus, Rat 2's performance indicates that he began by using the oddity cue (viz., through Problem 26) but changed to an alternative strategy. These data also indicate that he did not *learn* the oddity cue but that he perceived it and almost immediately associated it with reinforcers. This seemingly unlikely result had been anticipated before. In fact, one of us (see Thomas & Ingram, 1979) had occasion to agree with Hayes and Nissen (1971) who had written, "We cannot imagine any set of operations, applied to any subject, that could detect a concept without at the same time operating to induce its formation (p. 79). Thomas and Ingram (1979) added:

> In other words, the acquisition of new concepts and the detection of existing concepts are hopelessly confounded with the subject's acquisition of the reinforcement contingencies, thus, the distinction between newly learned and existing conceptual behaviors is scientifically meaningless. (p. 42)

It is reasonable that oddity per se is a highly salient perceptual cue, and the transition from percept to concept is represented in the ability to learn that oddity is relevant regardless of the discriminanda that manifest it and that oddity can be a reliable associate of reinforcement.

Two questions regarding Rat 2's performance need to be considered. Why was he the only rat of four to show significant first-trial-correct responding, and why did he abandon a successful strategy? Regarding the first question, it appeared to the experimenter (AB) that Rat 2 was the only rat in the beginning who investigated all three balls before making a choice. This might suggest that a procedure that increases the probability that the rat will investigate all balls before responding (e.g., placing a screen barrier between rat and balls for a few seconds) might yield a larger number of rats that will investigate the discriminanda more carefully before making a response.

Regarding the question why Rat 2 abandoned a successful strategy, a partial explanation might be related to the following. All four rats erred on the first trial of Problems 12-15. This may have been the result of an unexpected ability of rats to remember odoriferous stimuli. With 18 unique odors the first nine problems involved odors being presented to these rats for the first time, 9 odd and 9 nonodd odors. This procedure was used to avoid any odor being presented more frequently either as the odd or nonodd odor in the beginning of the study. However, beginning with the 10th problem the odors per se were no longer new although new combinations of the odors were used. The odors for Problems 12-15 were randomly chosen, nevertheless the nonodd odor on these trials had all previously served as the odd odor. Thus, these four nonodd odors represented the incorrect choice, whereas they had previously represented the correct choice. The rats may have responded incorrectly on the first trials of these problems because they remembered the previously correct odor. Rat 2 might have been more affected by this than the other rats, as he had performed best in the early training and would have had more associations with the odor-reinforcement contingency. As noted earlier, he did return to a successful strategy for Problems 16-26. After that he likely encountered further conflicting experiences (he was incorrect on the first trials of Problems 27-30). It is reasonable to suggest that Rat 2 may have learned to "distrust" Trial 1 data, except as information to be used to choose correctly on subsequent trials within a problem.

Regarding the conflicting associations that Problems 12-15 posed for all rats, it is notable that the initial odor-reinforcer associations had been made at least 8 days earlier and some as many as 49 days earlier which suggests the possibility of long term memory for learned associations between specific odors and reinforcers. This alone might lead to a valuable rat model for physiological memory research. The random assignment of the discriminanda had unforeseen consequences, and a replication of the present study including systematic investigation and control of this potential source of conflicting cues may prove informative.

Three of four rats showed significant improvement in correct responding on Trial 2 by the end of Block 2 (Problems 16-30), and the fourth rat was above chance by the end of Block 3 (31-45). To many this will seem unusually quick compared to a variety of species, including nonhuman primates, that were tested on visual learning set problems (e.g., Hodos, 1970). At one time, it was suggested that rate of learning set formation might be a useful measure to compare species' learning abilities (e.g., Hodos, 1970; Warren, 1965). However, Warren (1974) subsequently discredited this use of learning set data when he observed that species differences in learning set performance are closely related to species differences in *visual capacity*. However, it may be noted that comparable results to those in the present study were also evident in a previous study from this laboratory using 300, five-trial problems olfactory oddity learning set problems (Thomas & Noble, 1988) as well as in Langworthy and Jennings' study (1972); their rats were at 93% correct on Trial 2 by Problem 29 in a comparable olfactory oddity task. In addition to the inherent advantage to rats of using olfactory cues, it seems likely that the rapid learning set performances seen in these rat studies attributed to the perceptual salience of the odd stimulus as a cue (see earlier discussion re Rat 2). These learning set data suggest the rat's ability to use the win-stay/lose-shift hypothesis (e.g., Levine, 1965) which is, itself, arguably (Thomas, 1989) a kind of conceptual learning.

Aside from Rat 2's apparent use of conceptual oddity via the two nearly perfect runs among Problems 2-26, there was no other evidence that these rats used the oddity cue. This does not mean that the rat is incapable of performing a conceptual oddity task. In addition to the possibly conflicting information that resulted from random assignment of odors as discussed above, there may have been insufficient incentive to perform conceptually. As a result of the development of learning set, the rats were able to respond correctly on the second trial and thereafter, and thus, were subsequently reinforced most of the time. If the first attempt (Trial 1) was incorrect, the rats shifted to the correct discriminandum on the second trial and gained a reinforcer typically in less than a minute. The rats did not need to use oddity to gain most of the reinforcers. Perhaps, as noted earlier, a "forced" investigation of all balls before responding, or some use of punishment or time out for incorrect Trial 1 responses or use of a reinforcer that provides greater incentive might motivate rats to respond correctly on Trial 1 and increase the possibility that conceptual performances would be demonstrated. With the evidence of Rat 2's apparent conceptual responding and a modification of the present method, it seems likely that a procedure can be developed to show that rats can use oddity as a cue that can be associated reliably with reinforcement.

The present study can be compared to the two previous studies using odoriferous oddity tasks, Langworthy and Jennings (1972) and Thomas and Noble (1988). While Langworthy and Jennings (1972) concluded that they had shown the conceptual use of oddity by rats, their study had the confounding that the odor of the food reinforcers may have been a discriminative cue associated with the odd discriminandum. Neither the present study nor the study by Thomas and Noble (1988) found strong evidence that rats respond to oddity conceptually. However, both studies revealed significantly better Trial 2 performances than had previously been reported for rats. Further, both studies confirmed the need to analyze Trial 1 and Trial 2 data separately in terms of providing evidence for concept rule use. In view of the possibility that Langworthy and Jennings' rats did respond to oddity conceptually as well as the indication of some conceptual oddity use by Rat 2 in the present investigation, it may be useful to replicate Langworthy and Jenning's study more closely but with all food wells baited to control for the food reinforcer's possible, odor cues, together with greater consideration given, as discussed earlier, to (a) "forcing" the rats to smell all discriminanda before choosing, (b) using punishment or time out following incorrect choices, and possible use of alternative incentives.

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