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Olfactory oddity learning in rats

Ronald A. Langworthy

The University of Montana

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OLFACTORY ODDITY LEARNING IN RATS

by

Ronald A. Langworthy

B.A., University of Montana, 1969

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Master of Arts

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1971

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[Signatures]

Chairman, Board of Examiners

Dean, Graduate School

Date

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CHAPTER I

INTRODUCTION

Statement of Problem

The oddity problem, in its simplest form, involves presenting to the subject three stimuli which have one dimension in common. For example, the stimuli may all offer odor as the relevant dimension. Two of the stimuli belong to a certain subgroup of that dimension, and the other stimulus belongs to another subgroup. Using odor as the relevant dimension, the two similar stimuli may belong to the subgroup lemon, while the odd stimulus belongs to the subgroup mint. Each different pair of subgroups can be considered a different problem. In order to learn the oddity relation, the S must learn to consistently pick the odd stimulus throughout changes in problems. Described by the sentence, "That one of any three figures is correct which is different from the other two (Lashley, 1938a)," the oddity relation is an abstract one. The relation is abstract because in order to use it, the S must be able to store in memory a functional representation of the quoted sentence from day to day.

The main purpose of the use of oddity problems in research is for comparing the learning abilities of various animal species. The oddity problem has been chosen as a mode of comparison because it is convenient to use, permits within its structure the generation of simple or quite difficult problems, and involves the ability to abstract, an ability commonly associated only with the highest on the
phylogenetic scale. One of the main concerns of comparative research using the oddity problem is to establish norms in various species' abilities to learn. Thus, for instance, some day most researchers may be able to agree that monkeys normally learn a standard form of oddity problem in X number of trials. These norms should be established under conditions as close to optimal for the animal as possible. This study can be considered a small effort to establish norms for the rat under highly favorable conditions, i.e., providing communication in a way that the rat is most likely to understand.

The first use of the oddity problem as a test of abstraction was in a study by Robinson (1933) in which she introduced the three-position, six-configuration procedure to one cynomolgus monkey whose performance gradually improved despite frequent shifts of the odd object. Throughout, she used only one set of discriminanda, and it is possible that the monkey was learning a specific response to each configuration. This research was followed by workers at the University of Wisconsin Primate Laboratory, who illustrated the generalizability of oddity responding in multiple problems (Bromer, 1940, Young and Harlow, 1943b). In 1949 Meyer and Harlow originated the concept of oddity-principle-learning-set. The experimental use of oddity problems has matured and branched off a good deal since then. Oddity problems have been used as a reference point in the study of the effect on learning in monkeys of preoccipital ablations (Meyer, Harlow, and Ades, 1951) and electro-shock convulsions (Braun, 1952). Oddity problems have also been used as an educational tool (Suchman, 1967).
Most research using oddity problems has been done on primates, especially monkeys. In 1943 Spaet and Harlow induced monkeys to solve problems involving response to four antagonistic variables within 2440 to 4480 trials. Improved techniques enabled Moon and Harlow (1955) to report rapid and efficient learning, obtained on a series of six-trial, two-position problems in which seven error factors were defined. Using four-position oddity, Odoï (1954) indicated that monkeys learn the oddity principle in the following sequence: (1) learn stimulus values; (2) learn the similarity principle; (3) learn the oddity principle. Using the free choice technique, with no reward, Davenport and Menzel (1960) found that oddity can be a defining characteristic of a goal, for it increases the probability that a given stimulus will be attended to and manipulated.

A considerable number of studies have been done primarily to compare various animals' abilities to solve oddity problems. Strong et al (1966a, 1966b, 1967) undertook a series of three comparative experiments in simple oddity learning. In the first experiment cats and raccoons failed to learn one-trial oddity over 4800 trials, but monkeys and chimps did. Chimps are superior to monkeys. The second experiment compared children, adults, and seniles, and 64% of six year olds, and all 12 year and college students learned the problems. Some of the seniles showed insight-like learning curves. The third experiment studied apparatus transfer in chimps and children, and both groups showed this transfer, contrary to an earlier experiment (Strong 1965) by the same author. The capacity for solving oddity problems is not restricted to primates: canaries (Pastore, 1954), a pigeon (Nevin
and Niebold, 1966), rats (Wodinsky and Bitterman, 1953a, 1953b; Koronakos and Arnold, 1957), and cats (Boyd and Warren, 1957) have all solved oddity problems. Warren (1960) trained one cat on oddity problems and it attained a final level of performance within the range of rhesus monkeys trained under similar conditions, though the proportion of monkeys who learn the generalized oddity principle is far higher than the proportion of cats. Nevin and Niebold (1966), in their study with a pigeon, concluded that matching and oddity involve qualitatively different performances. Manifold differences in procedure preclude the direct comparison of primates and non-primates in oddity learning ability, but two conclusions seem obvious from the research: primates are more proficient and there is no qualitative difference between the two.

Two experiments assessed the ability of mentally retarded humans to solve oddities. House (1964) found that the successive reversal method of training which combined object reversal problems with an added oddity cue was more effective than the random method. She held that qualitative differences exist between human and infrahuman subjects in the generalization of the oddity habit. She found strong transfer to new sets of objects. Ellis and Sloan (1959) found that mental defectives with a mental age of approximately four years solved 15% and showed negatively accelerated performance curves. Two studies indicated that ability to solve oddity increases with age in children. Gollin et al. (1967b) showed that perceptual enhancement (increasing number of identical stimuli) facilitates the transition to perceptual modes of problem solving but the potency of this variable depends on
the child's developmental level. In an earlier, less conclusive study, (Gollin, 1967a), the preceding conclusion was found to hold only in kindergarten age children, while younger and older children were not affected by the manipulation of non-odd cues. Lipsitt and Serunian (1963) found that the ability to solve oddity problems increases with chronological age and is not considerably affected by I.Q.

Dimension Abstracted Oddity (DAO) has been developed as a sophistication of simple oddity learning, and appears harder to solve, for objects may differ on several dimensions, though only one is relevant. Several recent studies using DAO have contributed greatly to oddity research. Strong et al (1968) reported that no naive monkeys learned DAO, but those experienced in simple oddity did. In preschool children, I.Q., not experience, was significant and the reverse was true for 12 year olds. In all Ss color and form were significantly easier to learn than height. Hedges (1966) abstracted the same three dimensions. Cats and raccoons were unable to learn simple oddity, and performed around chance for 4800 trials. The cats performed better than the raccoons, chimps learned faster than the monkeys and all reached the criterion for simple oddity. In the second part of the experiment, naive monkeys were unable to learn DAO but experienced ones did. Again, height was more difficult to learn than color and form. Lordahl (1967b) used three, four or five stimulus dimensions and found that trials to criterion were less when the relevant dimension was perceptibly dominant than when it was perceptibly equal to other dimensions. In previous work using the multidimension oddity problem (Lordahl, 1965, 1967a) the influence of a highly dominant...
stimulus dimension was found to be greater than the effects due to the number of
dimensions varied in the task. Thus the stimuli used in the 1967b experiment were
scaled in pilot work so that stimulus dimensions could be used which has known
degrees of perceptual dominance. Bernstein (1961) studied the use of visual cues
by monkeys, chimps, and humans in solving DAO problems and found no clear
dominance relationship between form and color, but that author suspects (in view
of past research, Nissen and McCulloch, 1937, for instance) that color is dominant.

Several studies have been carried out primarily with the intent of developing
more efficient oddity testing procedures, and better understanding of them.
Levine and Harlow (1959), in a study possibly biased by object sequences and
sophistication of Ss, reported learning appears to depend only on the number of
trials rather than how they are organized into problems. In an experiment (Young
and Harlow, 1943) utilizing the Weigl principle, monkeys were trained to respond
to three position oddity in which the color of the board upon which the discriminanda
were placed indicated the response to either odd form or color. Preferential respon­
ses to color as opposed to form were reported, but no general rule was established
from this. In an experiment by Lockhart and Harlow (1962) monkeys were trained
by either two-p or three-p procedures to respond to odd objects in sets of three
stimuli arranged in 10 different spatial configurations varying in the number of empty
compartments (0, 1, or 2) intervening between objects. After acquisition, differ­
ent percentages of reinforcement were used. No significant difference in acquisi­
tion appeared for two-p and three-p, but intra-problem learning curves differed.
Performance decreased slightly with change in percentages of reinforcement, and 12% reinforcement (the lowest percentage) resulted in the lowest performance. Riopelle (1959) reported that triangular presentation of discriminanda reduced rather than increased proficiency.

Some years ago Lashley (1938a) trained rats in an attempt to establish the generalized reaction described by the sentence, "That one of any three figures is correct which is different from the other two." He was unable to develop such reaction in the rat. Some of his Ss were trained to choose a cross presented with two circles in a three window jumping apparatus (white on black background), then to choose a circle with two crosses. After the third to fifth reversal all Ss became confused and either refused to jump or jumped persistently at one figure despite bumps and falls.

In a subsequent experiment (Lashley, 1938b) he found it possible to develop a conditional reaction which could easily be interpreted in terms of stimulus compounding (i.e., upright and inverted triangles were presented black and striated grounds, with upright positive on one ground and inverted on the other). However, the Ss could not learn to react on the basis that any stimulus which is correct in situation A is incorrect in situation B. In neither experiment could Lashley's rats derive the general principle from the series of specific incidents.

Krechevsky (1932) has reported that after a series of reversals in a light-dark discrimination it was possible for the rat to shift preferences rapidly from light to dark and back. In Wodinsky and Bitterman's (1953) experiment Ss selected had
considerable training in jumping situations. The Ss trained first to a black card vs. two white cards and the following method of correction was used: after three incorrect responses to any one arrangement, the Ss were guided in the correct direction. There were 18 trials per day. After the first errorless day, the problem was shifted to white vs. two black and the Ss were trained to the same criterion. After the fourth reversal, the criterion for mastery was reduced to three successive errorless trials. After 30 reversals each shift was accomplished without error.

Then the two parts were merged into a complete oddity problem. After a slight initial disturbance, the Ss responded perfectly over a series of several days. All subsequent problems were presented as wholes. In the second problem a white triangle was presented on a black background and black circles on white backgrounds and the opposite. The Ss could thus respond either to color or form. In the third problem the figures were white on black ground and the Ss could only respond to odd form. The fourth problem was similar to the third except that figure-ground colors were reversed. The discriminanda in the fifth problem were striated black and white with one horizontal vs. two vertical and the opposite. Each problem was learned more rapidly than the predecessor. The next experiment by Wodinsky and Bitterman (1953b) was similar in procedure, and compared the oddity method with its opposite, matching-to-sample. The authors found learning significantly more rapid in the oddity group.

In a subsequent study Koronakos and Arnold (1957) employed five-p discrimination oddity with eight successive dissimilar problems of white forms on
black grounds and the opposite. Using a modified Fields serial multiple choice
discrimination apparatus, the authors trained 20 rats to a criterion of 80% (16
errorless choices out of 20 in one day), or a maximum of 160 choices. A con-
siderable amount of variability was found in the capacity of the rats to perform
this response, and only five rats clearly demonstrated the formation of learning
sets. Some rats did not reach criterion on any of the problems. The authors
stated that the Wodinsky and Bitterman (1953a) study "showed only fragmentary
data for two rats which seem to indicate that these rats formed learning sets," so
the later experiment was an improvement.

In 1963 Wright, et al, observed that shape discrimination problems are
hardly the ideal situation to present to the rat, with its comparatively poor visual
system and suggested that procedures should be developed which would allow
quicker learning of individual problems in order that a study of the rat's learning
set behavior over many problems might be conducted. In the same vein, Kay and
Oldfield-Box (1965) explained that Koronakos and Arnold's (1957) findings may
have been the result of two difficulties: (1) the visual capacities of the rat are
inferior to those of some species with which they have been compared, and (2)
the learning of individual problems has taken so long that investigators have been
unable to present enough problems to study the phenomenon completely. In this
study the authors presented two choice discrimination problems and reported learn-
ing sets were formed quicker using the trials-to-criterion method than the fixed-
trials-per-problem method.
As Driver and Corning (1968) have suggested, rats have presumably evolved sensory structures for dealing with their environment, and the experimenter must examine these sensory predispositions in order to develop techniques for a meaningful assessment of the animal's behavior. The past research, which depends in some way on the rat's perceptual modalities, has, with few exceptions, emphasized visual ones. This trend seems unjustified in view of the fact that the rat is a basically nocturnal species, possessing a retina composed mainly of rods (Munn, 1950), and in a nocturnal species the importance of the olfactory modality should be increased (Cloudsley-Thompson, 1961). Many mammals have relatively poor vision, especially color vision, and depend on smell more than sight to assess their environments (Parkes and Bruce, 1961). Several experimenters (Kay and Oldfield-Box, 1965; Wright, et al, 1963) have observed that the rat has a comparatively poor visual system. Rosen and Shelesnyak (1937) dramatically demonstrated the potency of the olfactory modality in rats by inducing pseudopregnancy by stimulation of the nasal mucosa with silver nitrate. Jennings and Keffer (1969) demonstrated that rats can easily learn a two-element olfactory discrimination problem and progressive improvement was interpreted as evidence for learning set. The very structure of the rat's brain reflects olfactory dominance (Barnett, 1963). If olfaction is as important a modality for the rat as it appears to be, it is conceivable that the rat may be capable of developing a learning set for olfactory oddity problems. Thus it is hypothesized that the use of olfactory cues will enable the rat to learn a set for oddity problems more efficiently than the research to date using visual cues (Wodinsky and Bitterman, 1953; Koronakos and Arnold, 1957).
CHAPTER II

METHOD

Subjects

Twenty-three male hooded rats of the Long-Evans strain were used. The subjects ranged in ages from the 16 youngest, all 90 days old, to the 6 oldest, all 160 days old at the beginning of the experiment. Male rats were used, as previous research has indicated that the ovarian cycle may affect the olfactory sensitivity of rats (Schneider and Wolff, 1955). All Ss were housed in pairs, and had constant access to a water supply. The seven Ss in the first half of the experiment were handled a short time each day for 25 days before the experiment began, and spent a short time in the apparatus each day for 21 successive days immediately before the experiment began. For the 16 Ss in the second half the same periods were 36 and 18 days, respectively. This handling procedure represents an attempt to familiarize the Ss with the experimenter and the apparatus. The Ss in the first half were subjected to a 22-hour food deprivation schedule for 18 days immediately preceding the beginning of the experiment, those in the second half, 14 days. This deprivation schedule was used to provide a higher drive level necessary in the process of shaping the S to obtain food from the feed dishes under the ping-pong balls. During the first half of the experiment Ss were kept on a 17-hour deprivation schedule, and those in the second half on a 17 1/2-hour deprivation schedule. The drop in length of deprivation at the beginning of the actual 11
experiment was effected in an effort to deprive the Ss as little as possible and still induce a drive level strong enough for the Ss to respond adequately. The 17-hour schedule was thus established in a pilot study.

**Apparatus**

The box, pictured in Figure 1, was 15 1/2" high, 9" wide, and 12 1/2" long, with three openings at the bottom of the nine-inch wide front. The openings were two inches wide, open at the bottom of the box, and two inches high, rounded at the top. The three openings were separated by two 1/2" wide (at the bottom) strips. Attached to the front inside of the box on the two narrow strips which separate the three openings, were two masonite sections two inches high and one inch wide. These sections were positioned so that the rat must move his head backwards in order to inspect each ball in its opening. The box was made of 1/2" plywood except for the front side, which was made of masonite. Thus the back end of the box was slightly heavier than the front end, and acted as a counterbalance to the apparatus extending from the front of the box. The box had no bottom or top. The front of the box was placed even with the edge of a 32-inch high wooden table.

Extending 15 inches from the front of the box at the bottom was an aluminum track upon which rode three brass wire chutes. Each chute was made of three brass wires, four, four, and 3 1/2" long, and was soldered longitudinally at equal intervals inside of two perpendicular wire rings 2 1/2" apart, so that 1/2 inch of the wires extended beyond the back ring and one inch of the bottom two wires extended beyond the front ring. The shorter top wire extended
Figure 1. The entire apparatus
1/2 inch beyond the front ring, and the front ends of the three wires were bent inward slightly. Thus the shape of the chute allowed a ping-pong ball to fit in the back of the chute and roll freely along the bottom two wires. With a slight tilt of the chute down in front, the ball rested at the front end against the inward-bent ends of the longitudinal wires. If a plane extended between each wire, connecting all three with planes, the resulting geometric shape would be a four-inch long equilateral prism, the base of which would be formed by the two bottom wires. The top wire was soldered along the uppermost point described by the inside of the rings, so the bottom two wires were on a precise longitudinal plane with one another. There was a red mark on a perpendicular plane on all three wires 1 1/4 inches back from the front end of the bottom two wires. This mark provided the criterion length of movement of the ball for a trial. At the front end, attaching to the bottom two wires, was a piece of aluminum sheet 1 x 2 inches which was rolled slightly so that it fitted very closely along the underside of the ball. In construction the ends of the sheets were rolled partially along a wire with the same thickness as the wire in the chute so that they slid on and off the front of the bottom wires. The rolled ends were not rolled far enough into a circle to hinder the freedom of the ball to roll on the wires, but just enough to attach it securely. Thus when one looked through the front of the chute, the aluminum sheet fitted neatly along the bottom of the ball without touching it. The sheet slid onto the wires as far as the front rings permitted. In the very middle of the sheet a hole 1/2 inch in diameter was bored, and on the underside
of the sheet a copper cup was soldered. The cup was just a bit larger at the mouth than the hole and was 3/8 inch deep. Since the cup was in the middle of the sheet, a lip of 1/4 inch was formed by the wide edge of the sheet on either side of the cup. The cup, then, opened exactly under the bottom of the ball and fitted close enough so that the inside of the cup could not be seen when the ball was in place. Connecting the two rings at their bottom-most point was a 2 1/2-inch long piece cut from a flat bar of "mild" steel. One inch in from the front end of this steel piece was a short segment of a 1/2 inch in diameter steel rod which had a 1/4-inch deep notch filed across the middle of one end. This notched bar was attached to the flat steel piece by a short length of a bolt through a hole bored through the steel piece and the steel rod. The bolt was pounded down on one side of the rod and tightened on the other side with a wing nut. Thus one end of the steel rod segment was connected to the flat steel piece. The other end had a hole bored into it and a 3 1/2-inch bolt screwed and soldered into it. This method of attaching the 3 1/2-inch bolt to the flat piece connecting to the rings allowed adjustment of the angle of tilt of the entire chute. The 3 1/2-inch bolt was attached to a frame, or cart, upon which all three chutes rested. The cart rolled on wheels on the main track which extended from the experimental box, and slid easily enough to be controlled by one hand. When pushed all the way forward, the positions of the chutes were adjusted so that the front ends with the balls and cups fitted snugly into the three openings in the box.
The frame was made of two sizes of "mild" steel bars: 3/4 inch and 1/2 inch. The two 4-inch long bars which connect the front and back ends of the cart were 1/2 inch steel, and so were the four pairs of two-inch strips which held the wheels and axles. The rest was 3/4 inch steel. The main steel segment in the front of the cart was nine inches long, and had three segments 1 1/2 inches long soldered even with the front edge and extending backwards. The three segments were 2 1/2 inches apart, measured from the middle of each. Through the middle of each segment, 1 1/4 inches back, a hole had been drilled which permitted the entry of the bolt upon which the chutes were fastened. A nut on top of the segment and a wing nut on the bottom allowed the bolt and chute to be adjusted in height. The steel segment on the back of the cart was five inches long. The two pairs of two-inch strips which hold the wheels extended perpendicularly downward from the five-inch segment and were 4 1/4 inches apart, measured from the middle of each pair. The two pairs which dropped from the front steel segment were also 4 1/4 inches apart and were lined up with the ones in back. About 1/4 inch down from the connecting point a hole had been drilled through the middle of each pair which permitted the entry of a brass rod axle 1/8 inch in diameter. The wheels were 11/16 inch in diameter and had been machined on a lathe. Each wheel had a flange like a railroad car wheel on both sides. Tiny holes had been drilled through each end of each axle and a small segment of fine wire had been pushed through the hole and bent to form a cotter pin.
The aluminum track which extended from the experimental box was made of one segment of 3/4-inch flat aluminum bent into a rectangle, 15 inches by 4 1/2 inches. The track was attached to the front of the box by two 8-inch segments of 1/2-inch steel which extended down the two strips which separated the three openings in the box, so they did not obstruct the openings. The top edge of the track was 2 1/2 inches below the bottom of the box. Another 2-inch steel segment, 24 inches long, was attached at the top of the box and the end of the aluminum track.

A masonite door eight by nine inches extended across the front of the box and was held in position by guides on either side of the box made of two 8 x 2-inch sections of masonite glued together, forming a right angle. The guides fitted tight enough on the door so that the door would hold position but was not so tight that it could not be moved with one hand. A wooden handle had been glued on the middle of the door.

A 12 x 8 1/2-inch mirror, glued to a plywood board 20 x 4 inches, was suspended at the back of the top of the box to permit the E to watch the rat inside the box from a seated position in front of the box. The plywood board extended four inches from either long end of the mirror and the bottom four inches were attached to a triangular wedge which had been cut to provide the optimal angle of the mirror for the E.

The olfactory stimuli were pure extracts of orange, wintergreen, peppermint, almond, mint, anise, lemon, and vanilla manufactured by McCormack Foods.
and marketed under the brand name of "Schilling." These eight odor sources were used previously by Jennings and Keefer (1969) in the demonstration of olfactory learning sets in rats, so there was no doubt that the odors could be discriminated by rats.

Ping-pong balls made by Halex, Inc. were used. The balls were stored in gallon glass jars at the bottom of which was a rag moistened with one of the extracts, separated from the balls by a screen. The balls to be used in the control group were stored in a jar without any such rag and screen.

Sucrose food pellets, 4.0 mm x 3.3 mm x 45. mg, manufactured by P. J. Noyes Co., were used as reinforcement.

Procedure

The experiment was split into two halves because the total number of Ss desired for the experiment would have taken too much time to run in one day. In the first half of the experiment the seven Ss were divided randomly into a control group of four Ss and an experimental group of three Ss. The second half Ss were randomly divided into control and experimental groups of eight each. The Ss were given 20 trials a day until either of two criteria was reached: (1) 16 correct responses out of the last 20, not necessarily on the same day, or (2) 100 trials had been given on one problem. The first criterion was selected so that learning on each problem would be defined by a customary degree of improbability. The maximum of 100 trials per problem was set somewhat arbitrarily inside a range that would allow the Ss enough trials to learn the problem, and few enough so that
the Ss that did not learn a particular problem would not be spending too much time on the same problem. Correct responses on one day carried over to the next day in determining the criterion, and Ss were put on a different problem the next day after reaching criterion on one problem. The control group completed eight problems, and the experimental group completed 30.

The eight odors allowed for 28 pairs of odors, and each pair made two problems, a total of 56 possible problems. Using the pair lemon and mint as an example, two problems were obtained when one first paired lemon with reinforcement, then mint with reinforcement. In this instance, when lemon was positive, it was presented on one ping-pong ball and the other two balls smelled of mint. Thus there was always one positive odor and two balls carrying the negative odor. The positive ball was never presented in the center position, as this practice has been customary in three-oddity research. In order to minimize the effects of position and alternation preferences the position of reinforcement was alternated according to the series recommended by Fellows (1967). The 56 problems were randomly assigned positions in the series to be used with the exception that consecutive problems did not contain the same reinforcement contingency.

Each S was weighed each day just before being placed in the box. The Ss to be run were placed inside the box with the balls in place, and were not removed until the first criterion was met or 20 trials had taken place. A trial was defined as the rat’s moving the ball beyond a red mark on the three brass wires on which the ball rested. The mark was placed on the chute in such a position as to satisfy
the E that the S, in pushing the ball forward, would reveal the presence or absence of reward. The placing of this mark was empirical in that the E would know that the mark was in approximately the desired position if the control group performed at a chance level. Each time the S moved the ball past the mark, the E recorded a response, pulled back the frame upon which the chutes were attached, and pulled the door down over the three openings. The E then replaced the reinforcement if it had been taken. If the reinforcement had not been taken, the E made sure the position of reinforcement corresponded to the next position in the Fellows series. A time interval of 15 seconds was maintained between pulling the chutes away and pushing them back in. If the S did not respond within 30 seconds of pushing the chutes in, the trial was completed.

Since different Ss were often on different problems in a day, a change in the stimulus balls was necessitated often between Ss. The balls could not be handled with tongs with efficiency, so the E washed his hands often in order not to contaminate the smells. The entire set of balls used in the first half of the experiment was replaced at the beginning of the second half. The only difference between experimental and control designs was that the balls used with the control group had no odor applied to them. The reinforcement was one sucrose pellet of the type described earlier.
CHAPTER III

RESULTS AND DISCUSSION

The hypothesis is supported by the results obtained. A comparison of the two groups on mean trials to criterion in Figure 2 shows immediately that the odor cue enabled the experimental group to attain a stable, minimal rate after 14 problems, while the control group continued at a stable maximum rate throughout the eight problems. The stable rate after eight problems can be offered as evidence that a learning set is operating in the experimental group. The bottom of the first great drop in the experimental group curve at the fifth problem indicates that most Ss reached criterion on that problem in one day. From this point onward, the curve simply flattens out. By the 14th problem the flattening out is relatively complete, and the oddity relation has been learned, subject to the limitations mentioned below. Thus, the use of olfactory cues has enabled these rats to learn the oddity relation more efficiently than in research using visual cues.

Tables 2 and 3 are included in an attempt to answer the following question: "How does one know that the experimental group is actually learning an abstract relation?" The group may be simply learning to identify the reinforced odor sooner. The critical trial is the first. If the Ss are indeed learning an abstract relation, a relation that can be carried over from day to day, then
Figure 2. --Mean trials to criterion and middle ball errors for both groups
Table 2. Percent of the 11 experimental and the 12 control animals making correct responses on the first and second trials.

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Table 3. Percent of the 11 experimental animals making correct responses by five problem blocks for the entire 30 problems.

<table>
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<th>Problem block</th>
<th>Trial 1</th>
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<td>26-30</td>
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their performance on the first trial should improve as they learn the relation.

Note that there are sufficient cues available to detect the correct response on the first trial. If, however, the $S$s are not learning an abstract relation, they would not improve on the first trial, because they would need more cues than the pure oddity cues present on the first trial. They should improve on the second trial, since one trial is enough to gather two cues, either of which is sufficient to solve the problem: the chosen odor is correct (reinforced), or the chosen odor is incorrect, making the other odor the one to choose on the next trial. In this case it is assumed that the $S$ is learning to remember the smell of the chosen ball and its value until the next trial.

Table 2 indicates the percentage of animals making correct responses on the first and second trials on 30 problems for the experimental group, and on eight problems for the control group. The most meaningful comparison in this data seems to be over the first eight problems on both trials between the two groups. The experimental group continues the improvement of the first eight problems throughout (see Table 3). This data, then, favors the observation that the experimental group is learning the abstract relation of oddity. The slight improvement of the control group is unexpected. A possible explanation of this improvement might be that it is a manifestation of their learning to avoid the non-reinforced middle ball, and thereby decreasing the probability of error.

Two groups of data are graphed in Figure 2. The curves of middle ball errors were included in order to point out that both groups learned to avoid
the non-reinforced middle ball. In spite of this learning, no Ss in the control group reached the first criterion on any problem. The main reason why the experimental group starts out so much lower on the graph and drops to a minimal level so quickly is that the experimental group took far less trials to reach a criterion, and took even less as they learned. Thus there were fewer trials on which to make middle ball errors. The rate of change is comparable, though, and it appears that the experimental group decreases middle ball errors more quickly. This difference might be expected, since the experimental group has an odor cue in addition to the non-reinforcement cue employed by the control group.

The sequence of problems is listed in Table 1. As mentioned earlier, the one qualification on this random sequence is that consecutive problems do not contain the same reinforcement contingencies. This qualification must be interpreted here to mean that consecutive problems do not contain the same odd odor. The fact that the sequence does contain one pair of problems (problems five and six) in which the non-odd odors are the same is the fault of the E in generating the sequence. Intuitively, the problem may be a little more simple for the S if the non-odd odor is the same as in the previous problem. However, the experimental Ss did not solve the sixth problem appreciably faster than the fifth.

The main difficulty in the entire experiment was that the first trial, the most crucial trial, was slightly different from the subsequent trials. The S was put into the box when the door was opened and the balls were in place, allowing the S to make a response immediately. The door should have been closed at
Table 1. — The sequence of oddity problems

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W = Wintergreen  
AL = Almond  
A = Anise  
O = Orange  
L = Lemon  
V = Vanilla  
M = Mint  
P = Peppermint
this point, so that the S could position itself and anticipate the opening of the door, as in all other trials. Instead, the S was placed in the middle of the box facing the back, and merely turned one way or the other and chose. Of course, the experimental Ss often smelled before they chose, and this behavior increased as the Ss learned the relation. Nevertheless, this flaw in the procedure limits the inferences one can make on the basis of the first trial. This limitation must be taken into account in considering the earlier cited evidence supporting the view that the experimental group did learn an abstract relation.

Seven rats out of 31 total were eliminated before the experiment began, and one was eliminated on the fourth day of the second half of the experiment. Those seven were eliminated as a result of failure to learn to take pellets from the feed dishes under the ping-pong balls. Most of the seven were far more excitable than those used as Ss. The one eliminated from the actual experiment failed to make one correct response after 60 trials, and actually made only 10 responses.

All three experimental Ss in the first half finished the 30th problem on the 48th day of the experiment, but in the second half most Ss finished before 40 days, and the last finished on the 43rd day. So a marked difference is evident in the rate of learning between the experimental Ss in the first half and those in the second half. The author attributes this difference to the fact that the first batch of rats was obtained from a commercial source in California, and as a group, was comparatively docile.
Some observations on the animals' behavior in the box should be considered. Since the S was able to hear the E manipulating the balls in replacing reinforcement, care was taken to make sure no consistent auditory cues were presented. As the experimental group learned the relation, the E observed more often that the S would smell balls, while the control group always pushed forward the ball that was closest to their nose when the door opened. The experimental animals often nudged a ball far enough to constitute a response without checking under the ball for food, and immediately moved toward another ball, appearing to "know" that the odor was wrong. This judging response dropped out for the most part after 15 problems because of lack of reinforcement, though it was never completely eliminated. A few Ss often thrust their heads through an opening as soon as the door was pulled up, so the speed at which the chutes were pushed forward could have become a factor in whether or not a correct response was recorded. If the chutes were pushed forward quickly, the experimental Ss would not have time to smell and pull back if it was the wrong smell. The E took special care to push the chutes forward at an even, consistently moderate speed. A mechanized apparatus would control this factor.

Optimally, in order to be exact in detecting the criterion length of movement of the ball for a trial, the E would have to view the criterion marks from above the apparatus. Since this position would be uncomfortable and probably distracting to the S looking upward, the E remained seated and judged the criterion movement from a less than optimal position. The position of the red mark
in the first place was such that very little movement of the ball constituted a trial. The point is that the E may not have been entirely accurate in recording responses due to the angle of his vision with respect to the red marks and an imaginary plane between them. This problem, then, is a limiting factor on the generalizability of the results.

Finally, vanilla extract, though never in contact with the balls, had a tendency to slightly discolar the balls over a long period of exposure. This effect apparently did not facilitate learning by adding a cue. Out of the five high points after problem five on the experimental group's curve in Figure 2, three involve vanilla. The rag in the jar containing vanilla exposed balls required frequent replenishing with the extract in order to satisfy the E that the balls had an odor on them. The E suspects that the Ss have more trouble discriminating vanilla than any of the other odors. In view of the problem encountered with vanilla extract, the E recommends that this odor be omitted in subsequent experiments combining such extracts and ping-pong balls.
CHAPTER IV

SUMMARY

This study was designed to assess the ability of the rat to learn the abstract relation of oddity under conditions which provide a close fit to the animal’s abilities. The hypothesis stated that the use of olfactory cues should enable the rat to learn oddity problems more efficiently than in research to date using visual cues. There were two halves to the experiment. In the first half three experimental and four control animals were tested, and the second half eight experimental and eight control animals were tested. All control Ss covered eight problems, while all experimental Ss covered 30 problems. The hypothesis was confirmed, though certain limitations were enumerated. The main limitation to inferences on the results was that the most crucial trial, the first, was slightly different in procedure from the subsequent trials.
REFERENCES


