This is the Final Manuscript version of an entry titled “Oddity” to appear in the forthcoming *Encyclopedia of Animal Cognition and Behavior.* The entry was invited, it has been accepted, and the typeset version that will be available electronically and in print has been provided to the author.

It seems unlikely that the *Encyclopedia* will be published before 2020 or possibly later, so final page numbers will not be known to this author until the electronic and print versions of the entire *Encyclopedia* are available.

March 9, 2019 Roger K, Thomas, PhD

Title of Entry: Oddity

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Synonyms: Oddity concept, Oddity problem, Oddity task, Matching-to-sample, Mismatch hypothesis, Non-match-to sample

Introduction

the easiest version of the oddity task requires an animal to choose among three discriminanda (typically objects, but sometimes two-dimensional illustrations, or computer images). Two objects are identical (the nonodd objects) and the third, odd object, differs in all properties (color, form, size, etc.) from the nonodd objects. Typically, objects are presented side by side in a row, and the animal learns to choose the odd one. Controls must include varying the position of the odd object (i.e., odd object must not appear predictably in a single position in relation to the nonodd objects). Also, when real objects are used, correct responses are usually reinforced with a bit of food hidden beneath the odd object, control must be use to prevent the animal from detecting the odd object based on the odor of the reinforcer. Inadvertent cueing by the experimenter must be controlled, and other controls may be necessary depending on the design of the oddity task. Assuming all necessary controls are used and the animal attains a statistically significant criterion of correct responses, one may conclude that the animal learned the oddity problem.

The Oddity Concept

Oddity problems involving the same discriminanda on each trial can be learned by rote via trial and error which is not of interest to most investigators. Rather, they want to know if an animal can learn the oddity concept. Investigation of oddity concept learning is achieved best by using new objects on each trial, although the same objects may be used more than once, provided the same odd and nonodd objects are never used together twice. Thomas (1996) discussed the kinds of evidence and control procedures necessary to show any kind of concept learning including oddity.

Many investigators using numerous avian and mammalian species have reported use of the oddity concept, but owing to methodological flaws most conclusive studies with robust results have been limited to research using primates.

The Oddity Concept: Theoretical Considerations

One of the 20th century's most brilliant but mostly forgotten behavioral primatologists, Henry Nissen wrote:

> Without taking the time now to elucidate the argument, let me categorically suggest that all reasoning reduces to three processes, responsiveness to identity and to difference, and, thirdly, the balance or relevant weight given to each of these (Nissen, 1958, p. 194).

Nissen did not suggest systematic ways to manipulate "the balance or relative weight given to each." However, Bernstein (1961) introduced dimension-abstracted oddity, which moved far beyond the easier oddity concept problems already described.

Bernstein used five discriminanda per trial, and to illustrate with one example, five objects differed in sizes and shapes, but four had the same color, a color that differed from the color of the odd object. On other problems, size or shape might determine the odd discriminandum.

Hierarchies of Oddity Concept Learning Problems

Building on Bernstein, Thomas and Frost (1983) developed and tested squirrel monkeys on a 6-level hierarchy of theoretically, increasingly difficult oddity problems based on variations of color, form, and size, together with manipulation of relevant, constant, and ambiguous cues; constant cues are identical for all objects and ambiguous cues vary among objects in noninformative ways. For example, level 1 (easiest) had three relevant cues; that is, the odd object differed from the nonodd objects in color, form, and size. Level 6 (difficult) might be a problem where all objects differed in form and size, but the odd object and nonodd objects differed in color. The hierarchy can be summarized as follows where R = Relevant cue, C = Constant cue, and A = Ambiguous cue.

A Hierarchy of Oddity Problems

1. 3R 0C 0A
2. 2R 1C OA
3. 1R 2C 0A
4. 2R 0C 1A
5. 1R 1C 1A
6. 1R 0C 2A

Thomas and Frost's monkeys' performances confirmed the hypothesized levels of difficulty except performances were worse on level 3 than level 4. This was explained by squirrel monkeys being protanomalous (deficiency in the retinal cone pigment, erythopsin, which reduces the ability to discriminate wavelengths of light at the red end of the visible portion of the electromagnetic spectrum), and often the single relevant cue at level 3 was color.

Thomas (1996) extended the 6 levels to 10 by adding numerousness as a cue. Thomas (1996) did not specify the 10 levels (which the reader can do by following the logic used to develop the 6-levels above), but Thomas illustrated an "easy" oddity problem with numerousness as an added cue with two sets of three small white circles as the nonodd discriminanda and two large black squares as the odd one; color size, and number were relevant. For "difficult," he showed a set of 4 small white circles, a set of 3 small black triangles, and a set of 2 large striped squares. in that case color, form, and numerousness were ambiguous; size was relevant.

Related to oddity, Thomas also described comparable levels of Sameness-Difference discrimination problems where, typically, two identical or more similar discriminanda must be distinguished from two more clearly different discriminanda. An "easy" example might be two red balls for "sameness" and a green cylinder and a yellow block for "difference." A "difficult" example might be a medium-size small red ball and a large green ball for "sameness" and a small blue block and a large yellow cylinder for "difference." Thus, form is relevant, and size and color are ambiguous.

Oddity Concept and Learning Set formation

Harry Harlow, a pioneering investigator of animal learning wrote,

> . . . all concepts . . . evolve only through LS [learning set] formation [and] insightful learning through LS formation is a generalized principle [that] appears . . . in oddity learning (Harlow, 1959, p. 510).

In Harlow's typical experiment, learning set formation (LSF) was assessed by presenting animals (usually monkeys) with two new objects for six trials. The experimenter determined which of two objects when chosen would result in a food reinforcer, and the reinforced object's position varied unpredictably to the left or right of the nonreinforced object. The animal had no way to know on trial 1 which of the two was correct. After six trials, two new objects were presented for six trials and the reinforced object's location was varied. The animal could choose only by chance on trial 1, but if it learned to use the information gained on trial 1, it could respond successfully on trials 2-6. Performance on trial, 2 is typically used as the best measure of LSF.

Warren (1965) suggested that LSF might be a good way to compare species on learning ability, and he presented a graph where the ordinate was percent correct on trial 2 and the abscissa was the number of 6-trial problems. His graph had data for six species. Rhesus monkeys were 85% correct on trial 2 after 400 problems, but rats were 55% correct after 1800 problems. Hodos (1970) presented a similar graph that included two human children and 16 additional species. One human child (age unspecified but IQ = 136) achieved 100% correct on trial 2 in 100 problems, a chimpanzee achieved about 95% correct in 150 problems, and a rat achieved 55% in 1000 problems.

However, Warren (1974) changed his opinion and concluded that success on LSF better reflected visual capability than learning ability. Almost all testing had been done with discriminanda based on visual cues, and color was usually an important cue. Old world primates and apes have trichromatic color vision comparable to humans with normal color vision, whereas many mammalian species have poor color vision, and rats have poor vision overall.

Rats, Oddity, and LSF

Rats have significantly better olfactory than visual abilities, and Langworthy and Jennings (1972) used a simple and inexpensive way to present olfactory discriminanda to study oddity concept learning by rats. Their experiment might also show LSF. They used ping pong balls saturated with the odors of one of eight food flavorings. Because a given odor might be odd on some problems and nonodd on other problems, no odor could be associated exclusively with either odd or nonodd. Three balls, two of the same odors and the third of a different odor, were presented side by side in a mostly open-air chute (please see Figure 1 in Langworthy and Jennings, 1972, p. 88) in which the balls were inserted. Marks on the chute showed how far the rat had to nudge the ball aside to access the food cup beneath it. The rats' task was to nudge the "odd" ball aside sufficiently to get its food reinforcer. Langworthy and Jennings (1972) reported good results (which Thomas and colleagues later analyzed and found to be statistically significant), but it was unclear whether the food reinforcer was beneath only the odd ball. If so, it is possible that the rats detected the correct ball by smelling the food beneath it.

Bailey and Thomas (1998) also investigated oddity concept learning by rats using odoriferous ping pong balls. They used 18 odors. With 18 odors used two at a time where either might be odd or nonodd, 306 odor-unique problems can be constructed. Furthermore, because a given odor might be odd on one trial and nonodd on another, no odor was reliably odd. They baited all food wells each of which was covered by a small sliding board. Only the board for the correct choice was moved to exposed the food well upon a correct response; so, food odor could not influence the rats' oddity choices. They presented each new problem for 20 trials/day until a rat achieved 16 of 20 correct for two successive days, or until a maximum of 100 trials were presented, after which a new problem was presented. Bailey and Thomas found no evidence of oddity concept learning, because trial 1 performances were at chance levels. However, Bailey and Thomas (1998) found significant evidence of LSF. They found that their fours rats averaged 87% correct on trial 2 on problems 16-30 which compares favorably to the chimpanzee's performance seen in the graph in Hodos (1970). Using only first-trial data, one rat had two statistically significant, near-perfect runs, but it did not sustain those performances. Nevertheless, those data suggest that rats might learn the oddity concept with alternative training methods.

Concluding Remarks

The oddity concept appears to have been investigated in more species than any other concept learning task, and, historically, it appears that few, if any, nonprimate species have been robustly successful. However, more nonprimate species might be successful with improved methods including that contextual variables (sensory, effector, motivation, environmental, etc.) are suitably adapted to each species (see Thomas, 1996), such as, olfactory rather than visual discriminanda for rats.

Greater attention should be given to Nissen's theory (see above) of what most importantly constitutes reasoning, and the hierarchies of oddity tasks and sameness-difference tasked described here provide the means for further investigating Nissen's theory.

Cross-References

Categorization

Comparative

Concept Formation

Evolution of Animal Color Vision

Harry Harlow

Learning Curve

Olfactory Discrimination

Same/Different Learning

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