Oddity and dimension-abstracted oddity (DAO) in humans

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Six conceptual oddity and dimension-abstracted oddity (DAO) tasks were administered to college students. Hypothetically, the tasks varied in difficulty as functions of the number of relevant, constant, and ambiguous cues, and the research investigated whether performance was related to the hypothesized difficulty (with Task 1 being easiest and Task 6 most difficult). Tasks 5 and 6 required significantly more trials to criterion than Tasks 1 through 4, and Task 4 required more trials than Tasks 1 and 2. Additionally, response latency was significantly longer on Task 6 than on Tasks 2 and 3, and on Task 5 than on Tasks 2, 3, and 4. Discussion considers differences between humans and squirrel monkeys in the order of difficulty of the six tasks as a function of trichromatic versus protonomalous and dichromatic color vision, and the use of the task hierarchy for ontogenetic and phylogenetic comparisons.

The oddity problem has long been used as a test of conceptual ability in both human and nonhuman animals. It has also been used to study cognitive development in children (e.g., Gollin, Saravo, & Salter, 1967; Lipsett & Serunian, 1963; Sugimura, 1981). Further, both oddity and dimension-abstracted oddity are significant components of the Halstead Category Test (Halstead, 1947), a widely used test in the assessment of human brain damage.

Apparently, Bernstein (1961) was the first to define and use the term *dimension-abstracted oddity* (DAO). Thomas and Frost (1983), suggesting a more general definition than Bernstein's, stated that the difference between oddity and DAO is that the nonodd stimuli in oddity problems are identical, whereas the nonodd stimuli in DAO tasks are not identical but share more properties with each other than they do with the odd stimulus. Dimension-abstracted oddity has also been used to test conceptual ability in human and nonhu-

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man animals (Lubker & Small, 1969; Strong, Drash, & Hedges, 1968; Sugimura, 1981).

The ability to respond to oddity conceptually has been demonstrated in a number of nonhuman primates (e.g., Meyer & Harlow, 1949; Strong & Hedges, 1966; Thomas & Boyd, 1973). Although several studies have attempted and some have reported to show oddity learning with nonprimates (rats: Lashley, 1938, Wodinsky & Bitterman, 1953; canaries: Pastore, 1954, 1955; cats: Warren, 1960; pigeons: Zentall & Hogan, 1974), these studies failed to preclude the possibility of specific stimulus learning. Such learning must be precluded to demonstrate conclusively the use of the oddity concept. A recent study by Lombardi, Fachinelli, and Delius (1984) appears to be the first to show clearly the conceptual use of oddity by pigeons.

Bernstein (1961) was the first to use DAO with nonhuman animals. Specifically, his results showed that some monkeys, *Macaca mulatta* and *Macaca nemestrina,* and apes, *Pan troglodytes* and *Pongo pygmaeus*, are capable of solving DAO problems. Strong et al. (1968) confirmed Bernstein's finding that monkeys and chimpanzees can learn DAO problems. Thomas and Frost (1983) reaffirmed the ability of the squirrel monkey *(Saimiri sciureus)* to use conceptual oddity (e.g., Thomas & Boyd, 1973) and added the squirrel monkey to the list of primates capable of solving DAO tasks.

The dimensions of color, form, and size may be used to construct a hierarchy of six tasks, three oddity and three DAO. These tasks were used by Thomas and Frost (1983) and in the present work, and it will be useful to describe them here. We will not use Thomas and Frost's nomenclature, as it is difficult to follow. (We thank an anonymous reviewer of this article for the nomenclature used here.) The six tasks vary in the number of relevant (R), constant (C), and ambiguous (A) cues, where relevant cues distinguish the odd from the nonodd stimuli, constant cues are shared by both types of stimuli, and ambiguous cues vary for both in a noninformative way. For example, the hypothesized easiest task has three relevant cues, no constant cues, and no ambiguous cues, and may be described as 3R-0C-0A. Similarly, all six tasks are listed as follows in the hypothesized order of easiest to most difficult:

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

In Tasks 4, 5, and 6, the nonodd stimuli are no longer identical; thus, these are the DAO tasks.

Thomas (1980) proposed the hierarchy of difficulty for these tasks on the assumption that a task with three relevant cues is easier than a task with two relevant cues or one relevant cue. Similarily, a task with no ambiguous cues should be easier than a task with one or two ambiguous cues. Because of the possibly offsetting advantages and disadvantages of unequal numbers of relevant and ambiguous cues, there was no clear basis to hypothesize whether the 1R-2C-0A or 2R-0C-1A task should be easier, but Thomas and Frost (1983) guessed that the 1R-2C-0A task might be. Attempts to obtain evidence to validate these hypothesized levels of difficulty have, so far, been limited to Thomas and Frost's study which administered these six tasks in the presumed order of easiest to most difficult (as listed above) to four squirrel monkeys.

Thomas and Frost's (1983) results showed that there were significantly fewer correct responses per session on Task 6 compared with all other tasks. Additionally, there were significantly fewer correct responses per session on Task 5 than on Task 2 and Task 4. These results provide partial support to the levels-of-difficulty hypothesis. However, as noted by Thomas and Frost, only the hypothesized order of easiest-to-most-difficult tasks was administered to the animals; therefore, order effects were not controlled and definite conclusions concerning the order of task difficulty are not possible.

The principal purpose of the present study was to validate the hypothesized six levels of task difficulty. Each task was administered to one of six groups of human subjects, and each group was trained to a criterion of nine correct responses in 10 successive trials. Response latencies were also recorded, and it was hypothesized that the predicted order of task difficulty would be associated with increasingly longer response latencies.

EXPERIMENT

METHOD

Subjects

Sixty undergraduate college students served as subjects. Subjects were volunteers from the research participant pool of the Department of Psychology at the University of Georgia, and they received class credit for participating in the study. All subjects were treated in accordance with the "Ethical Principles of Psychologists" (American Psychological Association, 1981).

Apparatus

The apparatus consisted of a locally constructed visual display panel (47 × 30 cm) suitable for back-projection of 35-mm slides, a Commodore computer (CBM 2001 Series), and a Kodak Ektagraphic IIIB slide projector. The visual display panel contained nine Plexiglas stimulus-response subpanels (each 12 cm high × 9 cm wide) arranged in rows of three. Each subpanel was connected to individual microswitches to receive independent responses to each of them. The stimuli were photographed such that the three objects constituting an oddity or DAO problem were projected from left to right, one in each of the three panels that formed the middle row of subpanels. The top and bottom rows of subpanels were not used in the present study. The slide projector, the microcomputer, and the visual display panel were jointly operated via a locally constructed interfacing device.

Procedure

The oddity and DAO tasks were constructed and photographed from a pool of approximately 400 wooden and plastic objects that varied in color, form, and size. All tasks were constructed according to the conditions necessary to devise a given type of task (i.e., the number of relevant, constant, and ambiguous cues within a task; see Introduction). The order of the appearance of the relevant cues (color, form, or size) and the position of the odd object (left, center, or right) were determined randomly.

The 60 subjects were randomly assigned to one of the six tasks so that each task was administered to 10 subjects. Subjects were seated in front of the display panel and informed that a horizontal array consisting of three objects would be projected on the display panel in front of them and that they were to press the panel they thought displayed the correct object. Correct choices resulted in the momentary illumination of a green light at the bottom-center of the visual display panel and incorrect responses were noted by the absence of the light. Subjects were told that they would have 20 s to respond. After a correct or incorrect response or if no response was made in 20 s, the slide was terminated. Each trial was followed by 10 s of blank screen (the intertrial interval) before the next stimulus array appeared. Problems for each task were given until a criterion of nine correct responses in 10 consecutive trials was met or until all available problems for a given task had been administered. Correct and incorrect responses as well as response latencies were recorded by the computer.

RESULTS

The results partially confirmed Thomas's (1980) hypothesis that the six oddity and DAO tasks vary in levels of difficulty. A Kruskal-Wallis, one-way analysis of variance by ranks (corrected for tied observations) showed a significant difference among tasks as a function of the number of trials required to meet criterion, $H' = 39.75$, $p < .001$. The median number of trials required to reach criterion on each of the six tasks is shown in Table 1.

Mann-Whitney U tests and the method of adjusted significance levels (Kirk, 1968, p. 495) were used to determine which comparisons among the six tasks showed significant differences. The sixth

Table 1. Median trials to criterion and response latencies on the oddity and DAO tasks

Tasks[a]	Measures	
	Trials to criterion	Response latencies (s)
1. 3R-0C-0A	9.5	4.03
2. 2R-1C-0A	9.0	3.12
3. 1R-2C-0A	9.0	3.22
4. 2R-0C-1A	10.5	4.59
5. 1R-1C-1A	20.0	6.41
6. 1R-0C-2A	23.5	5.46

[a]Tasks 1–3 are oddity and 4–6 are DAO. The letters R, C, and A represent relevant, constant, and ambiguous cues, respectively.

task required significantly more trials to criterion, $p < .001$, than all except the fifth task. Further, the fifth task was significantly more difficult, $p < .001$, than Tasks 1 through 4. Finally, the fourth task approached being significantly more difficult, $p < .08$, than the third task, and was significantly more difficult than the second and first tasks, $p < .025$. Three subjects failed to reach criterion on the sixth task within the 65 trials allowed, and one subject failed to reach criterion on the fifth task. Twenty-two subjects met criterion in the fewest number of trials (9). Five of these 22 were assigned to Task 1; 7 were assigned to Task 2; 8 were given Task 3; and 2 were given Task 4.

To consider the hypothesis that response latencies will increase as a function of hypothesized task difficulty, a Kruskal-Wallis, one-way analysis of variance by ranks was conducted using the median response latencies per trial for each task (Table 1).

There was a significant difference among the six tasks, $H = 16.88$, $p < .01$. Again, comparisons among the individual tasks were performed using Mann-Whitney U tests and the method of adjusted significance levels. The sixth task resulted in a significantly longer median response latency than the third and second tasks, $p < .01$. Additionally, there was a significantly longer median response latency on the fifth task than on the fourth task, $p < .025$, the third task, and the second task, $p < .01$. Lastly, Task 4 resulted in a significantly longer median response latency, $p < .01$, than Tasks 3 and 2. As regards response latency, note that no attempt was made to influence the subjects' speed of response. Furthermore, the variability in response latency was greatest on Task 1 (ranging from individual medians of 1.95 s to 13.48 s) and least on Task 4 (3.76 s to 5.62 s).

It was decided post hoc to determine whether the type of relevant cue (i.e., color, form, or size) on the initial trial of a task affected the response latencies or the rate at which subjects reached criterion on any of the tasks. A Kruskal-Wallis, one-way analysis of variance by ranks indicated that the type of initial relevant cue did not appear to affect either dependent measure on any of the tasks.

DISCUSSION

The performances of the human subjects here are partially consistent with the hypothesis that the six tasks constitute a hierarchy of difficulty. The three DAO tasks were more difficult than the three oddity tasks. However, the three oddity tasks were too easy for college students, so distinctions among them were not forthcoming. The ability to solve oddity and DAO problems has been shown to increase with chronological age and experience (Lipsett & Serunian, 1963; Strong et al., 1968). Further research, using subjects other than college undergraduates, is needed to assess fully the relative difficulty of the three oddity tasks in the hierarchy.

It was of particular interest in the present study to compare performance on Task 4 with performance on Task 3. As noted earlier, Thomas and Frost (1983) suggested that the relative difficulty of these two tasks was unclear owing to the conflicting differences in difficulty based on the unequal numbers of relevant and ambiguous cues. In the initial formulation of the hypothetical order of difficulty among these tasks, Thomas (1980) judged that the disadvantage of the ambiguous cue in Task 4 would outweigh the advantage of the two relevant cues on Task 4 versus the one relevant cue seen in Task 3. Thomas and Frost (1983) found that two of three squirrel monkeys met criterion on Task 4, whereas none met it on Task 3. Although order of testing may have confounded Thomas and Frost's findings regarding Task 4 versus Task 3, a long-term memory assessment (2.33 years later) involving these same monkeys on these tasks did not confound task order, and the monkeys continued to perform significantly better on Task 4 (Burdyn, Noble, Shreves, & Thomas, 1984).

In the present study, where order effects were not a factor, the difference between Task 3 and Task 4 (as measured by trials to criterion) approached significance, $p < .08$. It should be noted that this is a conservative, adjusted level that was adopted because multiple comparisons were made using the Mann-Whitney U test. Because this difference approached significance and the fourth task resulted in a significantly longer response latency than the third task, the fourth task appears to be slightly more difficult than the third task for humans. Thus, Thomas's (1980) order of difficulty hypothesis received greater confirmation with data from humans than with data from squirrel monkeys.

A possible explanation for the difference in order of difficulty seen between humans (Task 3 being easier than Task 4) and squirrel monkeys (Task 4 being easier than Task 3) may be found in their differences in color vision. Squirrel monkeys are protonomalous trichromats (DeValois & Jacobs, 1968) or dichromats (Jacobs & Blakeslee, 1984), and the humans in the present study were asked not to volunteer unless they had normal color vision. B. E. Mulligan (personal communication, May 23, 1984) constructed probability models for the discriminability of the odd and nonodd stimuli on the basis of color for each of the six oddity and DAO tasks used here. His analysis suggests that normal trichromatic subjects should have an advantage over either protonomalous or dichromatic subjects on both the third and fourth tasks but that trichromatic subjects should be more disrupted by the ambiguous color cues on the fourth task than protonomalous or dichromatic subjects. Further, Mulligan's analysis suggests that if color discriminability were the only factor, the fourth task should have been easier than the third task for both normal trichromatic and protonomalous or dichromatic subjects. Thus, it would appear that the performance of the squirrel monkeys was consistent with Mulligan's predictions for protonomalous or dichromatic subjects and that, as his probability models predicted, the ambiguous cues on the fourth task were slightly disruptive for our presumably normal trichromatic human subjects.

Finally, it will be useful to comment on the value of developing a series of oddity and DAO tasks that vary systematically in difficulty. There is evidence to suggest that human performances on such tasks vary with age (from young children to elderly adults) and experience (e.g., Lubker & Small, 1969; Strong et al., 1968; Sugimura, 1981) and that, generally, DAO tasks are more difficult than oddity tasks for both human and nonhuman primates. Further, as noted earlier, oddity and DAO are heavily involved in the Halstead Category Test, one of the most reliable instruments for detecting human brain damage. In view of the established usefulness of oddity and DAO problems for detecting developmental, experiential, and neurological differences, a systematically developed series of such problems should have increased utility.

The present series was based on the use of color, form, size, and spatial location as factors. Additional factors could be used to increase the number of levels of difficulty. In addition to being useful as tasks with which to make ontogenetic or phylogenetic comparisons, especially among human and nonhuman primates, there is considerable potential for using such tasks with nonhuman primates as models for studying issues pertinent to human development or neurological disorders.

Notes

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