

Sameness-difference judgments in *Saimiri sciureus* based on volumetric cues

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The rationale was to apply Piaget's theory and methods to the study of the phylogenetic development of cognitive abilities. It was asked whether squirrel monkeys have the prerequisite skills for conservation of quantity, and, specifically, whether they might respond differentially to equivalent and unequal volumetric cues. All monkeys responded significantly and differentially to pairs of identical objects or pairs of objects similar only in volume vs. pairs of objects which differed in volume. It was concluded that squirrel monkeys have the prerequisite skills for the conservation of quantity. Discussion included methodological problems associated with demonstrating conservation in nonhumans as well as the potential usefulness of Piaget's theory for phylogenetic studies of intelligence.

The present work was planned in the context of Piaget's theory (e.g., 1970) of development, particularly as applied to cognitive development. Although Piaget's theory appears, generally, to be regarded as a theory of child development, Piaget apparently regards his work as developing a biologically based theory of epistemology. The present study is an effort to apply Piaget's theory to the phylogenetic study of cognitive development. Piaget distinguishes three periods of cognitive development in humans: the sensorimotor, the representative intelligence, and the propositional or formal operations period.

The sensorimotor period may be characterized as one where movements are coordinated with changing perceptions to give rise to the notion that objects have permanence. The representative intelligence period is characterized as one "... in which actions become interiorized thought operations and which, when fully coordinated, are structured in the form of reversible systems of logical operations," (p. 160; Inhelder, Bovet, Sinclair, & Smock, 1966). The formal operation period "...is characterized by hypothetico-deductive strategy and the potential for utilizing all possible transformations of classes and relations," (p. 160; Inhelder et al, 1966). Jolley's review (1972) of the nonhuman primate literature suggests that adult primates function at some subperiod of the representative intelligence period.

There have been few nonhuman animal studies which were addressed specifically to Piagetian concepts. However, the Piagetian notion of object permanence, which represents the culmination of the sensorimotor period, has been demonstrated to develop partially in cats (*Felis domestica*, Gruber, Girgus, & Banuazzi, 1971) and fully in squirrel monkeys (*Saimiri sciureus*, Vaughter, Smotherman, & Ordy, 1972) and rhesus monkeys (*Macaca mulatta*, Wise, Wise, & Zimmerman, 1974). Fundamental to the next period of cognitive development is the concept of conservation of quantity,

and it was to this concept that the present study was directed.

However, analyses of conservation have raised many questions regarding both its basic nature and the appropriate kinds of evidence for its presence (e.g., Brainerd, 1973; Gelman, 1972; Halford, 1970; Klahr & Wallace, 1973; Piaget, 1968; Wallach, 1969; and several chapters by various authors in Sigel & Hooper, 1968). Until certain ones of these questions are resolved, it would be inappropriate to suggest that the present work will be able to say anything conclusive about conservation, as Piaget intended it, in nonhumans. On the other hand, it may be suggested that the present study examined skills which are essential to the demonstration of conservation. Perhaps the most important of these prerequisite skills is the ability to discriminate and respond differentially to the samenesses and differences among quantitative aspects of stimuli. The present work examined the squirrel monkey's ability to identify the sameness of or the difference between two objects where the only systematic cue was volume (or some derivative thereof, such as surface area, etc.).

METHODS

Subjects

Four wildborn, adult male squirrel monkeys (*Saimiri sciureus*) were used. All four monkeys had previous experience (details supplied upon request) in the Wisconsin General Test Apparatus (WGTA), but the experience did not include any of the tasks used in the present work. All subjects were housed in individual cages in the University of Georgia primate colony in a temperature (24°C-27°C) and humidity controlled (50%-70%) area. Daily light-dark cycles (12 h light and 12 h dark) were maintained. Testing was conducted during the light cycle. Once daily feeding took place immediately after test sessions. The standard diet of Purina Monkey Chow (25% protein) was supplemented with fresh fruit.

Apparatus, General Procedures, and Preparatory Training

The animals were trained and tested in a modified WGTA, which was fitted with a white stimulus tray containing two foodwells (19 mm in diam, 5 mm deep, 225 mm apart).

Table 1
Volume Measurements in Milliliters of the Five Categories
Used in the Generation of the Volume Problems

Object Descriptions	Categories				
	Smallest	Next	Median	Next	Largest
Hemielipsoid	16	28	48	76	116
Hemisphere	15	26	44	72	112
Half-Barrel	10	21	40	74	128
Hexagonal	12	26	48	74	120
Cylindrical	18	26	48	74	114

Discriminanda were selected from gray wooden blocks and colored plastic toys. General procedures for all problems were: (a) currants were used for reinforcement, (b) the intertrial intervals were 30 sec, (c) response intervals were 10 sec, and (d) no more than 40 trials were presented per day in all phases of pretraining and testing. Training and testing were done in the same room in which the monkeys were housed. They were visually screened from the other monkeys and only a 25-W bulb mounted in the top center of the WGTA illuminated the room during testing.

The stimuli were 25 plastic toys which consisted of five forms and multiple variations of the other visual properties. The stimuli were divided into five volumetric categories (see Table 1). As may be seen, objects within a category vary slightly with respect to volume. A validation study using 12 humans was done to see whether they would sort the objects into the five categories shown in Table 1 (further details supplied upon request). One subject erred once. He reversed placement of the 74-ml pink hexagonal object and the 112-ml dark blue hemisphere. He attributed his confusion to the color differences, but in may be noted also that the hexagonal object was taller than the hemisphere.

Volume pretraining. Randomly, one of the foodwells was baited and covered with an inverted 250-ml black plastic beaker, and the remaining foodwell was covered with an inverted 50-ml black plastic beaker. The large beaker was always reinforced (100%), and the small beaker was never reinforced. Training was continued until the monkey responded correctly 9 times in 10 consecutive trials.

Volume difference 1. Randomly, one of the foodwells was baited and covered with a large plastic toy randomly selected from either the largest or median category of objects, and the remaining foodwell was covered with a small plastic toy randomly selected from either the median or smallest category of objects. The two objects were never selected from the same size category. The larger object was always reinforced. Testing was continued until the monkey reached a 90% criterion of 36 correct responses in 40 consecutive trials.

Volume difference 2. Randomly, one of the foodwells was baited and covered with an object randomly selected from any of the categories but the smallest, and the remaining foodwell was covered with an object which had been randomly selected from any category but the largest. The two objects were never selected from the same size category. The larger object was always reinforced. Testing was continued until the monkey reached a 90% criterion of 36 correct responses in 40 consecutive trials.

Volume difference 3. To insure that the monkey was not using the height of the larger object as a cue, the height of the larger object in this series was controlled such that a larger volume object was always selected so that it was shorter than or the same height as the smaller volume object. Randomly, one of the foodwells was baited and covered with an object randomly selected from any of the categories but the smallest; the remaining foodwell was covered with an object which had been randomly selected with the restriction of the height variable

from any category but the largest. The larger object was always reinforced. Testing was continued until the monkey reached a 90% criterion of 36 correct responses in 40 consecutive trials.

Volume difference 2 retest. To insure that the monkey was not now using the width of the larger volume object as a cue, the volume difference 2 task was repeated. Testing continued until the monkey correctly responded 9 times in 10 consecutive trials.

Sameness-Difference Tests

Pretraining. Randomly, the foodwell to the monkey's left was covered with either a gray balsa wood cross (70 mm vertical x 60 mm horizontal x 25 mm thick) or a gray balsa wood block (45 x 45 x 25 mm); the remaining foodwell was covered with a gray balsa wood block (same dimensions as above). When the stimulus objects differed, the foodwell to the left of the monkey was reinforced. When identical objects were presented, the foodwell to the right of the monkey was reinforced. Training was continued until the monkey responded correctly 9 times in 10 consecutive trials.

SD-test 1. Using the pool of plastic toys as stimuli, on half of the trials identical objects were presented and on the remaining trials different objects were presented. The order of identical or different trials was randomly determined. Identical objects were randomly chosen from either the smallest, median, or largest categories. When different objects were used, the larger of the two was randomly selected from either the median or largest category, and it always covered the foodwell to the left of the monkey. The smaller object was randomly selected from either the smallest or median category. When different objects were presented they were never chosen from the same size category. When identical objects were presented, the foodwell to the right of the monkey was reinforced. When different objects were presented, the foodwell to the left of the monkey was reinforced. Testing was continued until the monkey responded correctly 9 times in 10 consecutive trials.

SD test 2. To insure that the monkey was using volume as the cue, for this task objects that were equivalent in volume but different in shape and hue were used in addition to identical and different objects. On half of the trials equal volume objects were used, and on the remaining trials different volume objects were presented. On half the trials where equal volume objects were used, they were equal in volume but varied in shape and hue as previously stated, and on the other half of the trials the objects were identical. The equal volume objects were selected randomly from any of the five size categories. When different volume objects were used, the larger object was chosen randomly from any but the smallest category; it always covered the foodwell to the left of the monkey. The smaller object was randomly selected from any but the largest category. When identical or equal volume objects were presented, the foodwell to the right of the monkey was reinforced. When different volume objects were presented, the foodwell to the left of the monkey was reinforced. Testing was continued until the monkey responded correctly 9 times in 10 consecutive trials.

SD test 3. To insure that the monkey was not using either the width or height of the larger volume object when different volume objects were presented, the height of half of the different volume objects was controlled as in the third volume difference task. On half the trials equal volume objects were presented; on the remaining trials different volume objects were presented. On half of the trials in which equal volume objects were presented, they were identical objects, and on the remaining trials, objects equal only in volume were presented. The equal volume objects were selected randomly from any of the five size categories. In the trials in which the height of the larger objects was not controlled, the larger object was randomly selected from either the median or larger category; the smaller object was chosen from either the smallest or median category. In the trials in which the height of the larger objects was

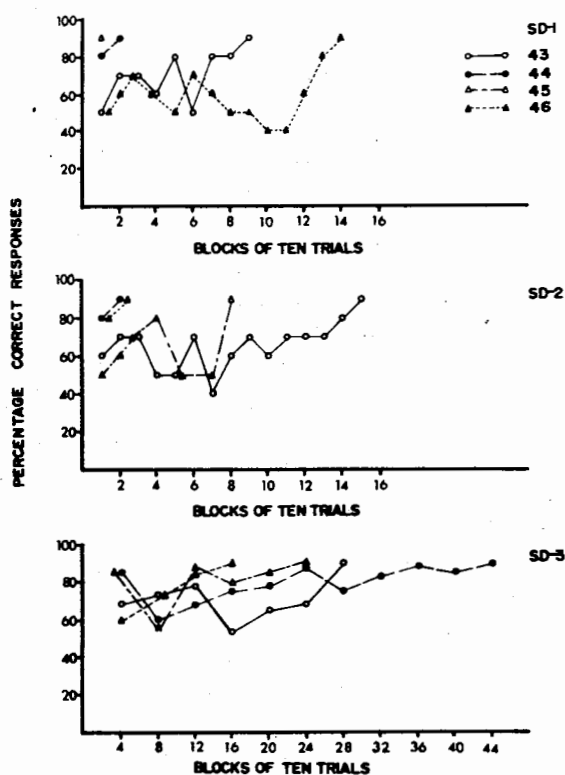


Figure 1. Percentages of correct responses on the three sameness-difference problems as a function of successive blocks of trials.

controlled, the larger object was randomly chosen from any but the smallest category and the smaller object was chosen randomly from any but the largest category. When equal volume objects were presented, the foodwell to the right of the monkey was reinforced. When different volume objects were presented, the foodwell to the left of the monkey was reinforced. Testing was continued until the monkey reached a 90% criterion of 36 correct responses in 40 consecutive trials.

RESULTS AND DISCUSSION

All monkeys reached the 90% criterion on all tasks. Trials to criterion for each monkey on each task may be seen in Table 1. Figure 1 shows acquisition curves for each monkey on each of the sameness-difference (SD) tasks. As may be seen, there was typically an extensive range in the number of trials to criterion on each of the problems, but no monkey appeared to perform clearly superiorly to the other monkeys.

When comparing the animals over problems, the reader is reminded that different bases for the 90% criterion were used on SD-1 and SD-2 (9/10) as opposed to SD-3 (36/40). This difference was permitted as the first two tasks were viewed essentially as preparatory to the third. In retrospect, this was an unfortunate decision. Despite their reaching the 90% criterion, Grant's (1947) probability tables suggest that the performances of SS 43 and SS 46 on SD-1 and the

performances of SS 43 and SS 45 on SD-2 may have occurred by chance.

However, the performances of all monkeys on SD-3 were significantly better than chance. Using successive correct responses during the criterion block (i.e., where the 36/40 was achieved) and based on the total number of trials taken by the animal to the end of that successful "run," three monkeys had probabilities of $< .005$ and the fourth monkey had a probability of $< .01$ of achieving such runs by chance. Had testing been terminated at the end of the first nonchance run of successive correct responses, SS 43's testing could have been terminated with a run of 13 in 59 trials ($p < .001$), SS 44 with a run of 14 in 29 trials ($p < .001$), SS 45 with a run of 17 in 58 trials ($p < .001$), and SS 46 with a run of 13 in 85 trials ($p < .005$). Additionally, despite the lack of statistically significant performance by SS 46 on SD-1, it may be noted that he had a significant run (8, $p < .05$) while reaching criterion in 12 trials on SD-2; this result suggests immediate transfer of training from SD-1.

GENERAL DISCUSSION

The present work shows that the squirrel monkey is able to detect the sameness of or the difference between two objects when volume (or some derivative thereof such as quantity of substance) provides the only systematic cue. Aside from the relevance of this work to conservation of quantity, it may be useful to compare the sameness-difference paradigm used here with other paradigms which have been used. The characteristics of the sameness-difference paradigm used here are that (a) successive sameness-difference judgments were required, (b) differential responses to both samenesses and differences were required, and (c) volumetric cues were relevant to the acquisition of the reinforcers, whereas differential color and shape cues were present but were ambiguous. Robinson (1955, 1960), who

Table 2
Trials to Criterion on the Volume Discrimination and Sameness-Difference Tasks

Tasks	Subjects			
	SS 43	SS 44	SS 45	SS 46
Volume Differences				
Pretraining (9/10)	18	25	27	10
D1 (36/40)	40	63	60	51
D2 (36/40)	54	67	56	40
D3 (36/40)	103	59	107	149
D2 Retest (9/10)	10	10	10	10
Sameness-Difference				
Pretraining (9/10)	27	95	14	170
S-D 1 (9/10)	89	14	10	153
S-D 2 (9/10)	143	11	70	12
S-D 3 (36/40)	264	424	214	160

Note—Criterion for each task is shown in parentheses.

studied chimpanzees (*Pan troglodytes*), and King (1973), who studied chimpanzees and orangutans (*Pongo pygmaeus*), used a paradigm which may be characterized as requiring (a) simultaneous sameness-difference judgments, (b) a response only to the appropriate sameness cue, either color or form, and (c) color or form as the relevant cue with the other cue appearing differentially but ambiguously. Finally, among possibly other paradigms which might be considered, some of the oddity or matching paradigms require a sameness-difference judgment. With an acceptable paradigm, oddity or matching might be characterized as (a) requiring simultaneous sameness-difference judgments, (b) requiring a response to sameness or difference but not both, and (c) having no ambiguous cues, that is, any cue which distinguishes the odd from the like stimuli is relevant. It may be noted that only those oddity or matching paradigms which provide evidence for conceptual behavior (see Thomas & Boyd, 1973, for related discussion) require sameness-difference judgments.

In detecting the sameness or difference between two objects the subjects may be said to be capable of utilizing the appropriate "estimators" (Gelman, 1972) for this task. Gelman suggested that a distinction should be made between those cognitive processes that may be at work during the assessment of a static presentation and those that may be at work during the assessment of a presentation which involves a transformation of the stimulus objects. She defined those processes that are assumed to function during the solution of a static presentation as estimators and those that are assumed to function during the solution of a transformational presentation as operators. The ability to use the appropriate estimators would seem to be, apart from object permanence, a prerequisite ability of a subject before he might begin to construct the cognitive structure necessary to detect the sameness of or difference between two objects. The ability to use the appropriate estimators for a volume or quantity of substance task may be said to be within the capabilities of the squirrel monkey.

The ability to recognize samenesses and differences has been discussed as a prerequisite for the ability to conserve. Examples of such discussions are those of Beilin (1964), Klahr & Wallace (1973), and Wallach (1969). The reason that this ability is seen as a prerequisite for conservation is that the subject must be able to identify when a stimulus presentation consists of objects that are perceptually and quantitatively equivalent. This ability may also be said to be within the capabilities of the squirrel monkey, as all four subjects reached a strict criterion for demonstrating the ability to recognize samenesses and differences.

Despite the views which regard sameness-difference judgments as preliminary to conservation, the literature provides a basis for asking whether the successful sameness judgment when the perceptual properties differ

may be evidence for conservation. Consider the following remark by Piaget (1968), which was given in the context of his criticism of an experiment by Mehler and Bever (1968).

...but conservation of equality is not proven by such conservation of inequality. The former can be shown only if two rows of equal numbers are presented and one row is then spread out or crowded; *or at least if two rows of unequal length are presented without modification* (p. 978, italics ours).

Our presentation of two objects equivalent in volume, although perceptually unequal, seems to us to be a direct analogue of the task italicized in the quotation. Beilin (1964, 1966) described a task with equal but spatially noncongruent areas as "an analogue to Piaget's area conservation problem" (p. 208). Beilin referred to such tasks as "quasiconservation" and, later (1968), as "static conservation." Such static tests, however, would be at odds with most theoretical analyses of conservation, and it is not likely that these tasks will be found to be acceptable.

An unresolved issue concerning conservation which is particularly relevant in studies concerning nonhumans is whether the subject's correct judgment (response per se) as opposed to his explanation may provide the necessary evidence for conservation. Brainerd (1973) argued that the subject's judgments provide the necessary and appropriate evidence for conservation. On the other hand, several theoretical analyses of conservation seem to us to have required the subject's verbal explanations (e.g., Gelman, 1972; Halford, 1970; Klahr & Wallace, 1969). Presumably, those who emphasize the need for a subject's explanation of his performance in the typical conservation tasks do so in order to assess that the transformations of the stimuli have been considered in the subject's perceptual judgments. Since a subject might make the correct judgments before and after transformation purely on perceptual bases and given the usual definitions of the various conservations of quantities, explanation or some other pertinent kind of evidence would appear to be necessary. It may be noted, however, that (a) the verbal explanation has been the principal form of supporting evidence and (b) its *necessary* status is by no means clear from the writings of those who have attempted to interpret Piaget precisely on this question (e.g., Elkind, 1968, especially pp. 464-465). Since verbal explanations are unlikely to be obtained from nonhuman subjects, other means of determining that the transformation was considered in the perceptual judgment will have to be developed.

While there are other issues which might be raised, the present report will be concluded with a brief return to the suggestion that Piagetian theory may provide a useful framework for the study of the phylogenetic development of intellectual and cognitive abilities. In this regard, it may be noted that Jerison's (1973) theoretical suggestions concerning the evolution of the

brain and intelligence read at times rather similarly to Piaget's descriptions of the ontogenetic development of cognitive abilities (compare Jerison's speculations on pp. 20-21 to Piaget's discussions of object permanence). Jerison, however, developed his views independently of Piaget and drew his interpretations from natural history, paleontology, comparative anatomy, and sometimes laboratory animal behavior studies. It is evident that Jerison rarely found the latter suitable to his purpose (see p. 419). We suggest that the use of appropriately revised tests of Piagetian concepts together with Piaget's extensive theoretical analyses of the ontogenetic development of cognitive abilities and Jerison's speculations concerning the evolution of cognitive abilities may provide the basis for a fruitful approach to the study of phylogenetic developments in intelligence.

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(Received for publication September 19, 1974.
Revision received June 9, 1975.)