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Squirrel Monkeys, Concepts, and Logic

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The framework of this chapter is a hypothetical scale of comparative animal intelligence that includes measures of the ability to use concepts and logical operations. The scale is hierarchical and equates intelligence with learning ability. The scale is exhaustive, because it includes *all* the basic forms of learning from which *all* other kinds of learning are constructed and because it is applicable to *all* species. The scale can be applied retrospectively or prospectively to any study of animal learning (includes humans) regardless of whether the study was intended to address animal intelligence.

The empirical data to be emphasized here are based on the performances of squirrel monkeys, because most of the research in our laboratory has been done with them. However, we have also used laboratory rats and human subjects, and some of those studies will be mentioned. For an overview of the squirrel monkey's "mind" and a preview of what this chapter will address, the reader is encouraged to read the "Concluding Remarks" at the end before proceeding here.

The Squirrel Monkey

Squirrel monkeys *(Saimiri)* are indigenous to Central and South America. They are relatively small (typically less than 1 kilogram in body weight), largely arboreal, fruit and insect eaters; see figure 4.1. Shown in the inset in figure 4.1 is a sketch of a squirrel monkey's brain. Although the absolute brain weight is small (25–30 grams), the squirrel monkey has a relatively high brain weight to body weight ratio (approximately 1/25 versus the human's 1/50). The squirrel monkey's encephalization quotient (EQ) of 2.8 ranks fourth highest among those of the fifty primate species compiled by Jerison (1973, table 16.3). For comparison, the chimpanzee's EQ is 2.4 and the human's is 7.5. The EQ (for mammals) is an index of an animal's brain in excess of that presumed to be needed to support the

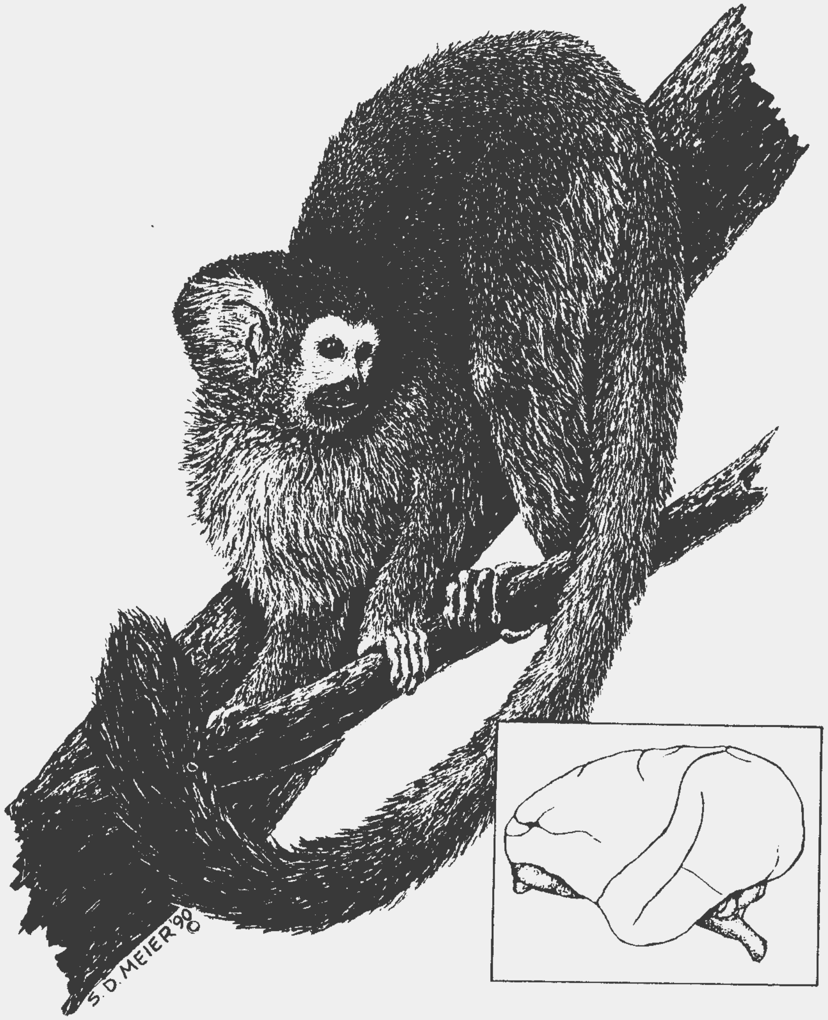

Figure 4.1

A representation of the squirrel monkey and its brain. The author thanks Susan D. Meier for all illustrations in this chapter.

body of a mammel of its size. Therefore, the squirrel monkey's 2.8 suggests that it has nearly three times as much brain as is needed based on this criterion. The "excess" presumably serves intelligence. However, one should not conclude that the squirrel monkey's higher EQ suggests that it is more intelligent than the chimpanzee, because the chimpanzee's "excess" involves an amount of brain that is fifteen to twenty times as large as the squirrel monkey's.

Squirrel monkey taxonomy is controversial. As recently as 1968 there was thought to be only one species, *Saimiri sciureus* (Cooper 1968). More recently, Hershkovitz (1984) has proposed four species, but Thorington (1985), although discounting some of the distinctions used by Hershkovitz, identified only two species. Prior to 1984, most research reports including ours identified the species as *Saimiri sciureus.* As nearly as we can determine retrospectively, the data reported in the present chapter were obtained from the subspecies, *Saimiri sciureus sciureus* and *Saimiri sciureus boliviensus* (following Thorington). We have enough data on both to suggest that they do not differ in their abilities to use concepts and logic.

Comparative Assessments of Intelligence

There have been many approaches to the study of comparative intelligence (see Thomas 1980, 1986) and most are based on measures of learning ability. One of two general approaches has been to base comparisons of intelligence on *quantitative differences* in performance, such as how many trials to learn a task, how many errors committed while learning the task, and so forth. The principal problem with this approach is that *performance* on such measures might differ, not as a function of learning ability but as a function of contextual variables such as sensory capacity, motor skill, motivation, and so on. Some investigators who have used quantitative measures have attempted to control for the effects of contextual variables, but ultimately one can never be sure that they have been adequately controlled (e.g., even if a monkey eats its peanut rewards as quickly and frequently as a cat eats its liver rewards, they may not, in fact, be equally motivated to eat them).

An alternative approach has been to investigate *qualitative differences.* In this case, one might look for different strategies that animals use in solving a common task or for processes that some animals can use but other animals, apparently, cannot. If one had a hierarchy of processes, then one might rank animals along that hierarchy in terms of the processes that they can use. Space precludes reviewing approaches that have been taken

Table 4.1. Gagne's Hierarchy of Learning 1970 and Thomas's Synthesis based on Bourne 1970, Gagne 1970, and Thomas 1980, 1987. See text for explication.

Gagne's Hierarchy	*Thomas's Synthesis*
1. Signal learning (Pavlovian Conditioning)	1. Habituation-sensitization
2. Stimulus-response learning	2. Signal learning
3. Chaining (chains of SR units)	3. Stimulus-response learning
4. Verbal associations	4. Chaining
5. Discrimination learning	5. Concurrent discriminations
6. Concept learning	6. Class concepts: Absolute and relative
7. Rule learning	7. Relational concepts I: Conjunctive, disjunctive conditional concepts
8. Problem solving	8. Relational concepts II: Biconditional concepts

to assess qualitative differences (but see Thomas, 1980 and 1986) except for the two hierarchies of learning-intelligence that are shown in table 4.1. However, for rhetorical purposes if no other, none of the other approaches has the power or precision of Thomas's synthesis shown in table 4.1.

Also included in table 4.1 is Gagne's (1970) learning hierarchy, because it provided the foundation for the synthesis. Gagne, an educational psychologist, was interested primarily in human learning, and some of his levels and examples did not adapt well to testing nonhuman animals. The detailed explanations for the changes and additions to Gagne's hierarchy may be seen in Thomas (1980), but some important general points are as follows:

1. It is hierarchical because lower levels are prerequisites to higher levels.
2. Except for two significant additions, the scale is a synthesis of Gagne's (1970) hierarchy and a concept learning hierarchy described, for example, by Bourne (1970).
3. Thomas (1980) added habituation as the new level 1 and later (1987) added sensitization, a complementary learning process at level 1. Both are generally recognized as being simpler forms of learning than Gagne's level 1, signal learning.
4. Thomas (1980) substituted Bourne's (1970) three-level concept learning hierarchy for Gagne's levels 6–8, because Gagne's explications were too human-oriented and because the processes represented in Gagne's levels 6–8 can be reduced to the structures in levels 6–8 in the synthesis.
5. Thomas (1980) added the distinction between absolute and relative class concepts at level 6 (more on this later).
6. Gagne's level 4, verbal associations, was omitted, because it was limited to human memorization of verbal chains and because Gagne considered it to be a parallel process to chaining.
7. The difference at level 5 is merely to provide a more descriptive name.
8. Although the learning-intelligence processes constitute a hierarchy, this does *not* mean that an animal's use of the processes is serial. It is most likely that the processes within an animal's capacity are used in parallel; that is, the intelligent use of the processes to solve problems may involve using processes from more than one level concurrently. Of course, a given animal's parallel or serial use of the processes will be limited to those processes within its capacity.

Because the emphasis hereafter is on levels 6–8 only, it may be useful to point out that some species from all classes of vertebrates (except amphibians, which appear not to have been tested) can perform successfully, at least to some degree, at level 5 (see Thomas 1986, table 4).

In principle, one should be able to avoid the conclusion that contextual variables such as sensory and motor capacities or insufficient motivation were responsible for an animal's failure at a given level, because the levels represent processes rather than tasks. The investigator assesses the animal's ability to use a process represented at a given level by adapting the task used to assess the process and by adapting the contextual variables to the animal. Furthermore, the contextual conditions can be moved from level to level, so an animal that succeeds, say, at level 5 but fails at level 6 should do so because of increased cognitive demands and not because of the contextual variables. Of course, it is logically impossible to "prove the null hypothesis," that is, to prove that an animal cannot do something (e.g., perform at level 6), so one can never be absolutely sure that failure means insufficient intelligence. However, the null hypothesis similarly limits what can be done or said with respect to any research question.

Concepts and Logic

There is no standard definition of *concept*, but in animal research it usually means that an animal can apply its knowledge of a given concept to new exemplars of the concept. For example, an animal that has learned the concept of "tree" can respond appropriately to any reasonable example of a tree, including those it has never seen.

Absolute and Relative Class Concepts

"Tree" is an example of an absolute class concept, because the defining properties are inherent in each exemplar, and the animal need not compare exemplars to affirm the one that manifests the concept. Relative class concepts do require the animal to compare the discriminanda being presented to affirm the one that manifests the concept. A well-studied example of a relative class concept is "oddity." Oddity, as it is usually investigated, involves the presentation of at least three objects, two of which are identical or are more similar to each other than they are with the third object. Affirmation of the odd object, which entails the concurrent and complementary process of negation of the non-odd objects, requires the animal to compare all objects to determine which is odd. As suggested, then, the basic logical operations at level 6 are affirmation and its complement, negation.

Relational Concepts

Concepts at levels 7 and 8 involve relational concepts by the definition that they involve relations (a) between class concepts or (b) between class concepts and nonconceptual entities. At level 7, these relations are defined by the involvement of the hierarchically equivalent (in the sense that none is prerequisite to another) logical operations conjunction, disjunction, conditional, and their respective complements. Level 8 is defined by the biconditional and its complement, exclusive disjunction; these are at a higher level, because they have the conditional and its complement, exclusion, as prerequisite operations. Most of the human and all of the animal research has emphasized the basic as opposed to the complementary

operations, and the discussion hereafter will emphasize the basic ones. Bourne's findings (1970) suggest that in terms of empirical difficulty as reflected in human performances, the order from easiest to most difficult is conjunction, disjunction, conditional, and biconditional.

One way to view concepts is that class concepts provide the "elements" of conceptual knowledge and relational concepts are the "compounds" of conceptual knowledge. The logical operations at levels 7 and 8 determine how the elements are related to form the compounds. Conceptual knowledge, no matter how complex, may be analyzed in terms of its elements and the logical relations that connect them. This is not a new idea (Boole 1958 [1854]), nor has it gone unquestioned (Gregory 1981, 229). Gregory did not refute Boole in principle, but questioned whether the "mind" in fact works that way. The view taken here is that whether or not the "mind" works that way, it remains a useful analytical approach.

Class Concepts, Rats, Squirrel Monkeys, and Humans

In our laboratory, most of the research involving class concepts has been in conjunction with squirrel monkeys' use of number and with the use of "sameness-difference" concepts by monkeys, rats, and humans. Among types of sameness-difference concepts, we have studied "oddity" concepts most frequently. Other than investigations in these two categories, which will be considered separately later, we have studied the monkeys' abilities to distinguish exemplars of the absolute class concepts (a) "leaf" versus "nonleaf" (Palmer 1987), (b) "mammals" from "nonmammalian animals," and (c) "primates" from "nonprimate mammals" (unpublished). We have also used the class concepts "triangularity" and "heptagonality" and "same" and "different" as elements in a relational concept task that will be described later.

Sameness-Difference Concepts

Our interest in sameness-difference concepts was based partly on increasing precision of measurement in the learning-intelligence hierarchy at level 6. It is reasonable to believe that some animals that succeed at level 6 will fail at level 7. How then would we distinguish between species that succeed at level 6 but fail at level 7? Before proceeding to show how the difficulty of tasks at level 6 can be increased systematically, it is noted that it is easy to increase systematically the difficulty of tasks at levels 7 and 8 (see tables 3 and 4 in Thomas 1980).

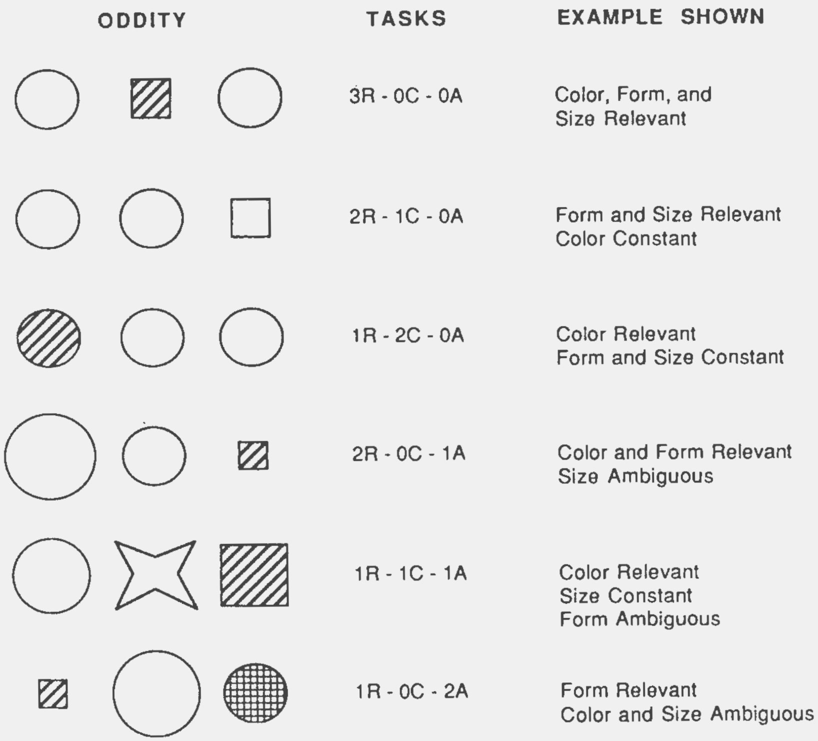

Figure 4.2

A hypothetical hierarchy of oddity tasks from easiest at the top to most difficult at the bottom. Difficulty is presumed to increase as functions of decreasing relevant cues and increasing ambiguous cues. For example, task 3R-0C-0A has three relevant cues, no constant cues, and no ambiguous cues, but task 1R-0C-2A has only one relevant cue and two ambiguous cues. Constant cues are neither informative nor distracting. See text for further explication.

Figures 4.2 and 4.3 show hierarchies of oddity tasks and hierarchies of sameness-difference tasks, respectively. One can construct a hierarchy of hypothetical difficulty by varying systematically (a) the number of relevant cues, that is, cues that enable the animal to differentiate between exemplars of oddity and nonoddity or between pairs of objects that manifest sameness and difference, respectively; (b) the number of constant cues; and (c) the number of ambiguous cues, that is, cues that vary across all objects in a noninformative way.

For example, it is assumed that having more relevant cues makes a

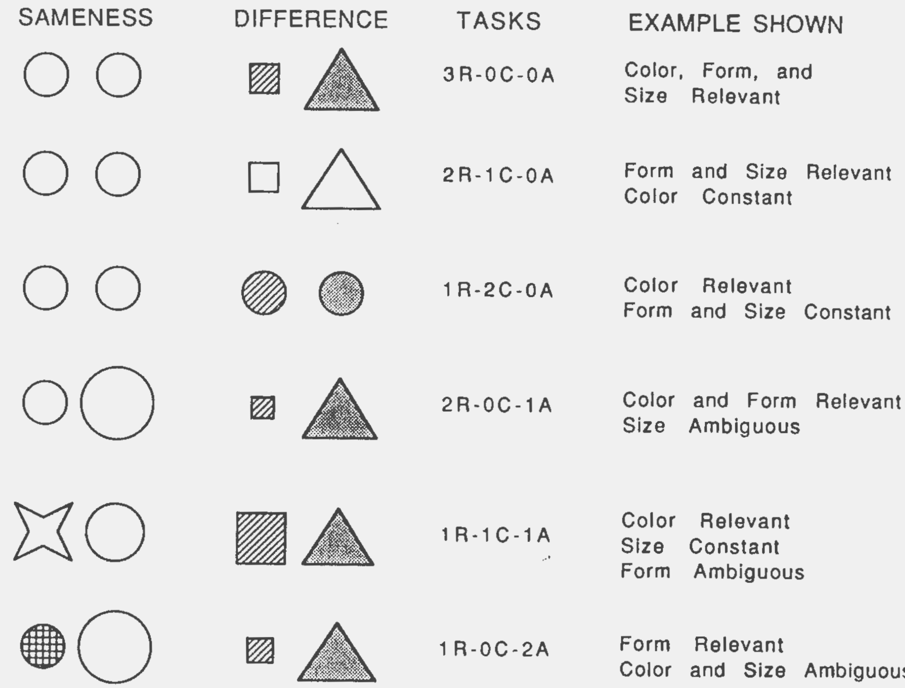

Figure 4.3

A hypothetical hierarchy of sameness-difference tasks from easiest at the top to most difficult at the bottom. See legend for figure 4.2 for further explication.

task easier and that having more ambiguous cues makes a task harder. A goal of the investigations discussed here was to validate the hypothetical order of difficulty. Before considering the findings, however, it is noted that the hypothetical difference in difficulty between task 3 and task 4 is unclear, because task 3 has one less relevant cue than task 4, but task 4 has one more ambiguous cue than task 3. Based on our subjective evaluation, we predicted that task 4 would be more difficult than task 3.

Our first attempt to validate the hypothetical hierarchy of difficulty was with squirrel monkeys (Thomas and Frost 1983). To our surprise, the monkeys found tasks 1 and 2 to be about equally difficult (and relatively easy); but as predicted, they found task 6 to be the most difficult and task 5 to be the next most difficult.

Noble and Thomas (1985) essentially repeated the study using humans.

Generally, the humans found the tasks too easy to show much task differentiation, but as predicted they did find task 6 to be hardest and task 5 to be the next hardest. Unlike the monkeys, there was also some evidence (significantly longer response times and a tendency toward significantly more trials to criterion) that the humans found task 4 to be harder than task 3.

After thinking about the difference in performance between the monkeys and the humans, we realized that the monkeys' difficulty with task 3 could be explained by the well-documented deficiency in color vision of the male squirrel monkeys (which we have used exclusively). Task 3 has only one relevant cue on a given trial and that cue varied randomly from being a color cue, a size cue, or a shape cue. Thus, compared to humans, the squirrel monkey is at a distinct disadvantage on the color-cue trials. Color vision has less effect on task 4, because there will always be in addition either a size or a shape cue to use when the color cue is undiscriminable.

More recently, Steirn and Thomas (1990) also did a study using humans and the oddity hierarchy shown in figure 4.2 as well as the sameness-difference (SD) hierarchy shown here in figure 4.3. We attempted to increase the general difficulty of the tasks in hopes of finding clearer task differentiation by having each subject respond to random problems from three tasks (either 1–3 or 4–6) rather than just from one task, as Noble and Thomas (1985) had done. Steirn and Thomas found about the same results with the oddity hierarchy as Noble and Thomas, but task 4 was found to be significantly more difficult than task 3 in the SD hierarchy. This is of some theoretical interest, because the SD tasks shown in figure 4.3 and the oddity tasks shown in figure 4.2 are constructed similarly, but the SD tasks allow for both absolute and relative class-concept solutions, whereas the oddity tasks allow for only relative class-concept solutions.

As may be seen by comparing figures 4.2 and 4.3, affirmation of the odd object *requires* that the subject compare all three objects regardless of the level in the oddity hierarchy; that is, oddity is a relative property of the three objects and is not an inherent or absolute property of the odd object. However, for the first three levels of the SD tasks where the objects constituting a same pair are identical, one can affirm the same or the different pair, depending on which was designated the correct choice by the experimenter, without comparing the two pairs; that is, "same" or "different" are inherent or absolute properties of the pair of objects, when a pair is viewed as constituting a conceptual entity. On the other hand, because nothing prevents the subject from comparing the same and different pairs and such comparison can facilitate one's choice, a subject might use both the absolute and relative solutions at the first three levels of the SD tasks. Beginning with level 4 of the SD tasks, same and different become relative, because they now represent relative difference or sameness rather than absolute sameness or difference. The need to compare at levels 4–6 in the Steirn and Thomas study was compounded, because the subjects responded to randomly selected exemplars from the three levels and difference exemplars at level 5 are sameness exemplars at level 6.

Thomas and Noble (1988) investigated rats' ability to use the oddity concept. Rats perform better for odor than for visual discriminanda, so we used three ping-pong balls scented with food flavorings. The procedure was to present a three-ball problem (say, one chocolate versus two banana) for five trials. Three hundred five-trial problems were used. The rats never responded better than chance on trial 1 of a new five-trial problem, indicating they had not learned to use the oddity concept. However, they performed well and better than chance on trials 2–5, indicating they had learned to perform on the basis of "learning set." Learning set may or may not be conceptual (again, a subject too lengthy to discuss; but see Thomas 1989), but it is generally said to depend on learning a rule. The rule may be verbalized "win stay, lose shift," meaning that if you are correct on trial 1, stay with the object (or in the rat's case, the winning odor), but if you lose on trial 1, shift to the other odor.

Finally, before leaving the sameness-difference and oddity tasks, three general observations or suggestions might be useful.

1. Tasks similar to some of those in figures 4.2 and 4.3—but, so far, not the hierarchies per se—are widely used in neurological tests of human brain damage, as well as to assess cognitive development in children.
2. The complexity of hierarchies can be increased by varying properties in addition to color, size, and shape. For example, one could add number to the list of manipulable features. The odd stimulus could be represented by, say, two objects and the non-odd stimuli by two sets of three objects.
3. The highly respected comparative psychologist Henry Nissen often said, "all reasoning reduces to three processes, responsiveness to identity and to difference, and, thirdly, the balance or relative weight given to each of these" (Nissen 1958, 194). The oddity and SD hierarchies represent ways to study Nissen's third process systematically.

Monkeys' Use of Number

Numbers can be studied as absolute class concepts (e.g., responding to "fiveness," "sevenness," "manyness," etc.) or as relative class concepts (e.g., "more," "fewer," "intermediate," etc.). There has long been an interest in animals' use of number, as Wesley's (1961), Davis and Memmot's (1982), Davis and Perusse's (1988), and Thomas and Lorden's (1993) reviews will show. Wesley's and Thomas and Lorden's reviews are more conservative and critical of the literature. For example, unlike the others, Thomas and Lorden considered that, with the possible exception of Boysen and Berntson (1989), no study has shown that animals can count. However, even the Boysen and Berntson study is questionable, because their chimpanzee was trained only to count to four, and the use of number up to and including four is done with precision without counting in human cultures that have not developed the ability to count (see Ifrah 1985).

What, then, can be said about animals' use of number independent of counting? Before attempting to answer this question, it is necessary to mention some of the methodological problems that have to be addressed in any research purporting to show animals' use of number. The typical study has involved animals' abilities to determine the number of objects or discriminanda that are simultaneously present—for example, the number of black-filled circles (or "dots," for short) on a white card. If the dots are uniform in size, as has often been the case, number as a cue is confounded with cumulative area or cumulative brightness difference cues. For example, if four dots occupied 25 percent of a card's area and seven dots occupied 35 percent, the animal might use cumulative area or relative amount of reflected light as its cue to discriminate between the two cards. Another confound is pattern. If the same or too few patterns of dots are used repeatedly, the animal might memorize the patterns and discriminate on that basis. Thomas and Lorden (1993) discuss yet other methodological issues.

Prior to Thomas, Fowlkes, and Vickery's (1980) study, the best controlled studies that also investigated successive number discrimination had been done with chimpanzees (Hayes and Nissen 1971; Dooley and Gill 1977) and had shown only the ability to distinguish 3 versus 4 (hereafter the abbreviated form, e.g. 3:4, will be used). Actually, Dooley and Gill had shown the possible ability to distinguish 9:10, but the discriminanda were Fruit Loops cereal pieces that are uniform in size and, therefore, that confound area with number cues. The 3:4 determination was done in Hayes and Nissen's case with a home-reared chimpanzee. Number was one of many tasks they used concurrently, and they did not try to push the chimpanzee to its limits on any one task. The 3:4 determination by Dooley and Gill was done with metal washers of varying sizes and the study was complicated by other variables (e.g., cuing with lexigrams for "more" and "less") that made it more difficult than a simple number discrimination study. The highest successive pair that they used was 4:5, and the chimpanzee was correct only 60 percent of the time (no better than chance).

To determine the squirrel monkeys' limits for successive number discrimination, Thomas et al. (1980) started with easy ratios (e.g., 2:7) and worked up to the harder ones, and they always reinforced responses to the "fewer." Both monkeys in the study attained the very stringent criterion of forty-five correct in fifty successive trials on a 7:8 discrimination, and one of the two met criterion on the 8:9 discrimination. A related study (Terrell and Thomas 1990)—except that the discriminanda were polygons and the number of sides (or angles) of the polygons provided the number cues—showed two of four monkeys reaching criterion (twenty-seven correct in thirty trials in this case) on 7:8 discriminations; a third monkey's best performance was 6:7, and the fourth monkey's best was 5:7.

Together, these two studies suggest strongly that squirrel monkeys can discriminate seven from eight entities whether connected (polygons) or unconnected (dots). How do they do it? We believe they acquire (via their training) a prototype of each number category (e.g., "twoness," "seven-ness," "eightness") and use such prototypes to discriminate between displays of such numbers of entities. We do not believe they count, because they have not had the prerequisite training. Namely, they have had no opportunity to learn a "tagging" system such as "one," "two," and so on, or to use physical tags (beads, notched sticks), which seem to be required by human members of cultures where counting has not been developed (Ifrah 1985).

Before moving on, two other aspects of our monkey-number research bear mentioning. First, we have also investigated and found that squirrel monkeys can respond to the "intermediate" number of dots (Thomas and Chase 1980), which means that, in a limited sense, they are able to recognize and use ordinal relationships. Second, the Terrell and Thomas study using polygons included a second experiment in which the monkeys were given some trials that had one polygon on each of two cards, some with two polygons on each card, and some with one polygon on one card and two polygons on the other card. In all cases, the monkey was reinforced for responding to the card with the fewer total sides. This meant that on many trials the monkey had to "sum" (in this limited meaning of the term) the sides of *two* polygons to determine which of the cards had the fewer total number of sides.

Given, based on our previous work, that the monkeys' general upper limit was presumed to be about eight and that three is the fewest possible sides for a polygon, we were limited to testing totals of six, seven, and eight sides. Only one monkey met criterion in the "summing" experiment, but the other three had several sessions in which they were performing better than chance. Two final points about number: (1) we believe that the upper limit of eight is determined by (momentary) information-processing capacity as described in Miller's (1956) famous and aptly titled study of human information-processing capacity, "The Magical Number Seven, Plus or Minus Two . . . " and (2) it remains to be seen whether and to what extent squirrel monkeys can learn to count.

Squirrel Monkeys and Relational Concepts

The term "conditional discrimination" has long been used in studies of animal learning to imply that the "if-then" relationship was being investigated. Most of the studies are questionable in terms of whether they involved a *conceptual* use of the if-then relationship on the grounds that it was not applied to new instances in ways that precluded rote memorization of the stimulus-response-reinforcement contingencies. Even so, studies that might qualify as conceptual because new discriminanda were used from trial to trial are also inconclusive in terms of the if-then relationship, because the experimental design did not fully test the truth functions that define the conditional. We will illustrate with a study that we mistakenly, or we should say inconclusively, described as testing the squirrel monkey's use of "conceptual conditional discrimination."

Thomas and Kerr (1976) presented new oddity problems on each trial. When an oddity problem was presented on a white background, the correct (reinforced) choice was the odd object, but when a problem was presented on a black background, responses to either of the non-odd objects were correct. The monkeys met a stringent criterion of successful performance on this task. We described the task as "if white, then odd" and "if black, then non-odd." In our naïveté, we even suggested that it might be evidence for use of the biconditional (e.g., "odd if and only if white"). Later, I realized that the experiment did not incorporate a full test of the conditional, although it could be said to have incorporated the truth functions necessary to show use of the conjunctive (or, in this case, two conjunctives, white *and* odd and black *and* non-odd). Note that the monkeys *might* have responded on the task in a way that is analogous to a human's use of conditional relationships, but conservatively one must say that it shows use of the conjunctive and, *possibly,* the conditional.

Note, also, that it is also unclear when one can attribute the use of the conditional to humans, except those humans who know formal logic or those human subjects in experiments that incorporate all the truth-functional requirements of the conditional (e.g., Bourne 1970). For related discussion concerning humans' use of the conditional in "natural" versus

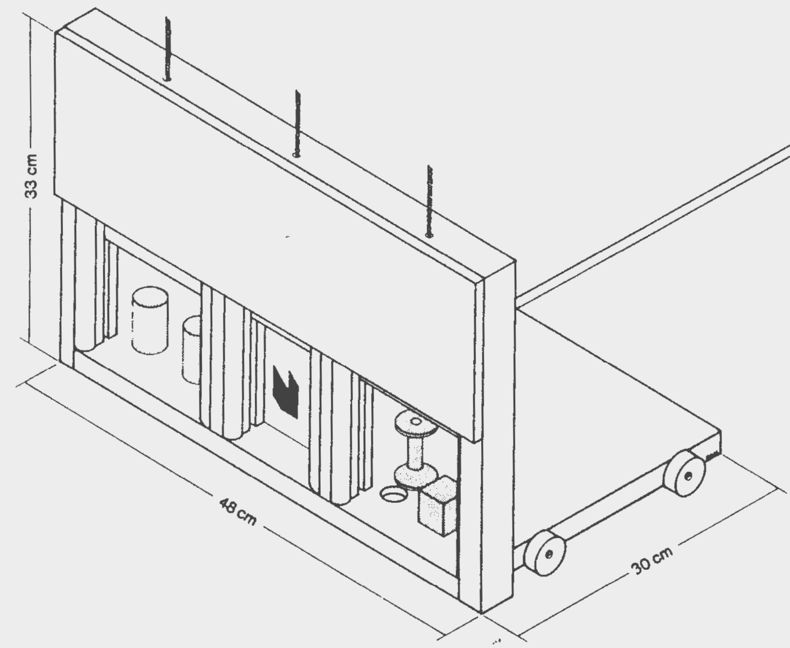

Figure 4.4

Apparatus and representative discriminanda in which a heptagon is the cue to choose the pair of objects that manifests "difference." The spool is displaced to show the food well beneath which the monkey obtains its reward. Randomly interspersed but not depicted are trials in which a triangle is the cue to choose the pair of objects that manifests "same." New triangles and new heptagons as well as new objects are used on each trial to preclude specific memorization. Doors can be separately raised or lowered to preclude the view of the discriminanda. For example, in later trials the triangle or heptagon was presented and withdrawn before the pairs of objects were presented.

"standard" logic, see Braine (1978) and Lehman, Lempert, and Nisbett (1988).

So far, we have not designed a study using monkeys—nor are we aware of anyone else doing so—that would be conclusive regarding the use of the conditional. However, we have used variations on the procedure described with the previous oddity study in several contexts. For example, in the study mentioned earlier that showed squirrel monkeys' ability to respond to displays of dots that were intermediate in number (Thomas and Chase 1980), we used one cue light when the monkey should choose the display with the fewest dots, three lights when it should choose the most dots, and two lights when it should choose the intermediate number of dots. Similarly, Thomas and Ingram (1979) used black, white, and medium-gray backgrounds as the respective cues for monkeys to choose the small, large, or middle-sized object among three objects of different sizes.

The last study that we will describe used conceptual stimuli as cues to choose between other conceptual stimuli. Burdyn and Thomas (1984) used exemplars of "triangularity" as cues to choose a "same" pair of objects and used exemplars of "heptagonality" as cues to choose a "difference" pair of objects (see figure 4.4). The same and difference pairs were similar to those of tasks 1–3 in figure 4.3, and trial-unique pairs of objects were presented *simultaneously* on each trial. The triangles and heptagons were presented *successively,* one triangle or one heptagon per trial, and whether it was a triangle or a heptagon was determined according to a quasi-random order. Not only did the monkeys learn that triangularity cued same and heptagonality cued difference, but they were able to use the triangle or heptagon cues even when they were presented and withdrawn prior to presenting the same and difference pairs. We systematically increased the intervals between withdrawal of the triangle or heptagon cues and presentation of the same and difference pairs of objects. The best monkey's best performance in these terms was to meet a stringent criterion with an interval of sixteen seconds between withdrawal of cue and presentation of choices; the other three monkeys' best performances were eight, four, and two seconds, respectively. This shows that the monkeys were able to use a symbolic process (e.g., a triangle symbolized sameness) in the absence of the symbol, that is, from a memorial representation.

Concluding Remarks

The squirrel monkey is clearly able to use a variety of class concepts involving color, shape, size, number, and multidimensional discriminanda. Its momentary information-processing capacity, based on its ability to distinguish seven entities from eight entities, suggests that it is comparable in this regard to humans (Miller 1956). Its ability to choose the middle-sized object (Thomas and Ingram 1979) and the intermediate-number of entities (Thomas and Chase 1980) shows that it can make ordinal judgments. Its ability to "sum" the number of sides of two polygons (Terrell and Thomas 1990) shows that it can abstract and combine the properties of two discrete entities and use the result to make a relative choice ("fewer"). It can also use conceptual information as a symbolic

memorial representation of other conceptual information. We have only begun to learn about the abilities of this relatively complex "mind," which is commensurate with approximately one ounce of brain tissue.

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