

# Vertebrate Intelligence: A Review of the Laboratory Research

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This chapter appeared in:

R.J. Hoage and Larry Goldman, Editors  
Animal Intelligence: Insights into the  
Animal Mind  
Washington: Smithsonian Institution Press  
1986

Are dogs smarter than cats? Are pigs smarter than horses? Are dolphins smarter than apes? Questions like these have been asked for centuries, but regrettably, I will not be able to answer them. What I will try to do instead is explain why such questions have not been answered despite many attempts to do so and suggest some ways in which such questions might be answered. In the course of doing this, however, I will be describing some interesting intellectual achievements of a variety of vertebrate species.

## **The Concept of Intelligence**

Intelligence is a fictitious entity. It has no physical existence. No structure in the brain or elsewhere corresponds to it. No standard definition of intelligence exists, and the concept means different things to different people. As a subject for scientific study, therefore, there are certainly easier topics to tackle. But, if we want to know about the intelligence of nonhuman animals, we must first try to agree on a definition of intelligence, or at least on a framework within which to consider it. And if we wish to compare the intelligence of different animals, we must find a scale of measurement or "common denominator" that is suitable for comparing species as diverse as those that inhabit the Earth.

Some have argued that this cannot be done, that there is no common denominator because species vary too widely. Such people are likely to view intelligence as an abstraction that represents how well

each species adapts and survives in its environment. According to this view, there are many kinds of intelligence, and it is not meaningful to compare them. One cannot refute this viewpoint; one can only decide whether to accept, reject, or be willing to compromise its premises. If one prefers to accept its premises without compromising, then we may as well admit that the cockroach is as intelligent as the human and let it go at that. However, if we are willing to compromise, then we may persist with the notion that a common denominator can be found with which to compare animal intelligence.

Intelligence, as I see it, is closely related to adaptability and survival. Some aspects of intelligence are genetically determined, while other aspects involve learning. Some species' survival depends primarily, if not exclusively, on genetically determined behavior, but other species depend to varying degrees on what and how well they learn. Comparing the inherited components of intelligence does not seem to be appropriate, or, at least at this time, there does not appear to be a meaningful basis for comparison. Comparing learning abilities, however, is reasonable and feasible, provided we do not mismeasure them—and the possibility for mismeasurement is considerable. For the remainder of this paper, intelligence will be treated as being equivalent to *learning ability*, and differences in intelligence will be regarded as differences in learning ability. This is not to deny that there are components of intelligence other than learning ability, but rather to simply acknowledge that, at present, there is no way to measure and compare these other components.

### **The Mismeasure of Learning Ability**

Learning ability is usually determined in the laboratory by training an animal to perform some task and keeping a record of the number of trials required to master the task (usually referred to as the number of "trials to criterion") as well as the number of errors made during the process of learning the task. It is important to emphasize that such scores are measures of performance, and that a distinction must be made between learning and performance.

While learning ability certainly affects performance, other factors also influence performance but bear little relation to learning ability or intelligence. This point is especially relevant in a com-

parison of species. For example, as Carl Gans (this volume) explains, sensory abilities of species are rarely equivalent: some animals see color while others do not, some animals have senses of smell or hearing superior to others, and so on. Such sensory differences might give one animal an advantage over another in the performance of a task without reflecting a difference in learning ability. Animals also differ in their motor abilities, that is, their abilities to make the response that the learning task requires. Again, such motor differences might affect performance without reflecting a difference in intelligence. A third factor is motivational differences: one animal may be motivated to perform well while another animal may be less motivated. And these do not exhaust the variables that, alone or in combination, might affect performance and therefore *contaminate* or *confound* the assessment of learning ability or intelligence.

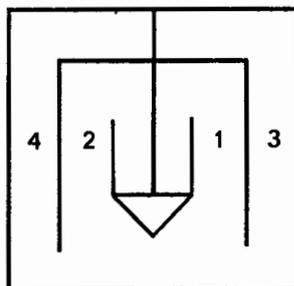
Because performance differences may be influenced by such variables, the general view in recent years has been that quantitative differences such as the number of trials to criterion, or the number of errors made, should not be used to compare intelligence between species. A better approach is to ask whether an animal can learn a task when conditions are suitable—for example, when the task is appropriate in terms of the animal's sensory and motor abilities, and when the animal is properly motivated. If the animal *can* master such a task, then the ability to learn that task is within the animal's intellectual capacity. To compare species, one should use a series of tasks that examine different capacities. If the series of tasks represents a meaningful hierarchy of abilities, then it might be possible that the subject that succeeds further up the hierarchy is more intelligent.

The points presented so far were usually overlooked in early laboratory studies that attempted to compare the intelligence of different species of vertebrates. But even when they were not overlooked, and investigators tried to equate testing conditions, they could never be sure that the testing conditions were, in fact, equal. Among the most interesting of these early studies is one by Harold Fink, which was published as a monograph in 1954 as *Mind and Performance*. I feel apologetic for choosing this study to illustrate the mismeasure of learning abilities because in many ways it was a monumental and heroic effort, and I respect and admire what Dr. Fink attempted to do. Despite the flaws that I will point out in the study, many interesting and useful data are to be derived from it.

Fink constructed what he called the Arrow Maze (figure 1) for the purpose of comparing the learning abilities of reptiles, birds, and mammals. The animals were trained initially to find a food reward at the end of alley 1. When the animal had done 10 successive trials without error, it was then required to learn to find the reward at the end of alley 2. When the criterion of 10 successive errorless trials was reached in alley 2, it was required to learn to go down alley 3. Finally, it was required to learn to go down alley 4. Each animal learned to go to each goal in this same sequence, and a record was kept of the number of trials to criterion and errors on each goal.

Two factors made Fink's study especially interesting. First, he used 50 humans (college students), 9 pigs, 10 dogs, 10 cats, 10 chickens, 20 rats, 1 goat, 1 rabbit, and 45 turtles and tortoises. No other study to my knowledge has compared such a variety of subjects on the same task. Humans were blindfolded and tested on a version of the Arrow Maze that could be traced with a finger, and unlike the animals, they were not given a food reward but were merely told when they made an error or a correct response. The second interesting feature is that Fink acknowledged the need to equate testing conditions for each species and made a considerable effort to do so.

To equate for running speed, Fink measured the running speed of animals from each group by having them run down a straight alley for a food reward. As might be expected, the turtles ran the slowest (5 yards/minute on the average). Using the turtle's running speed as a reference point, Fink determined how much time each species should be allowed to perform each trial. The turtles were allowed 30



**Figure 1** The Arrow Maze was constructed by Fink to compare the learning abilities of reptiles, birds, and mammals. Subjects used in the study included turtles, chickens, rats, dogs, cats, pigs, and college students. (Illustration redrawn by Kathleen Spagnolo from Fink 1954.)

minutes per trial. Most of the animals were allowed from 2 to 5 minutes, with dogs being given the least time at 1.3 minutes. However, while this was an admirable attempt to compensate for different running speeds in evaluating the success of each trial, it created another problem. One of the oldest known principles of learning is that of contiguity, that is, the relationship between two events is more likely to be learned if they occur closely in time or space. The animal that gets to the goal fastest presumably has a time advantage in associating its path to the goal with its discovery of the reward in the goal.

Fink tried to equate motivation by feeding the animal its total daily allotment of food as rewards in the training trials. He adjusted the number of trials per day and the amount of food on each trial based on his impression of how hungry or satiated the animal appeared to be. While this procedure does correct somewhat for differential food requirements, it does not insure equality of motivation. If anything, it may have been counterproductive, because the normal meal patterns of animals vary. Some animals, such as rats, eat small amounts continuously throughout the day, while others eat most of their food at one time, as dogs do, or consume several distinct meals each day, much as humans do. Thus Fink's approach may have approximated the normal feeding pattern of some of his subjects, but it would have been disruptive of others'.

There is also the question of the particular foods given to each species. Naturally, it was necessary to choose appropriate foods for each species, but, as Fink acknowledged, one could not assume that the foods were equally preferred. He also acknowledged the problem of differences in sensory abilities, but he did not even attempt to control for such differences. Thus, on the one hand, Fink viewed the animal's performance, without regard to its physical advantages or disadvantages, as the appropriate test of ability, and on the other hand, he tried to equalize certain factors such as running speed and motivation. In any event, let us see what he found.

Fink used three measures of learning: the number of trials it took to learn the sequence of goals, the number of trials on which an error was made, and the number of alley-entrance errors. Table 1 shows the species in ranked order on the three measures, as well as the overall score based on the average of the other three. Despite the slight variations in rank order, there is about 90 percent agreement among the measures.

**Table 1** Rank Order of Performance in Fink's Arrow Maze

Total Trials	Error Trials	Errors	Overall
Human	Human	Human	Human
Opossum	Opossum	Opossum	Opossum
Pig	Pig	Dog	Pig
Dog	Dog	Pig	Dog
Chick	Eastern Painted Turtle	Goat	Eastern Painted Turtle
Eastern Painted Turtle	Rat	Eastern Painted Turtle	Goat
Rat	Chick	Rat	Chick
Goat	Goat	Rabbit	Rat
Cat	Rabbit	Chick	Rabbit
Rabbit	Cat	Cat	Cat
Other Turtles and Tor- toises	Other Turtles and Tor- toises	Other Turtles and Tor- toises	Other Turtles and Tor- toises

Source: Adapted from Fink's tables II and III, except the Opossum data, which were reported by James (1959).

It is important to emphasize that *all* animals eventually succeeded on the task and, therefore, the *ability* to learn the sequence of goals in the Arrow Maze was shown to be within the capacity of all species tested. Whether the ranked orders shown represent differences in intelligence or other kinds of differences simply cannot be determined from such data. In addition to the contaminating influence of sensory, motor, and motivational differences, the animals' ages varied widely. In general, very young animals, even in relative terms, were pitted against young adults or even the relatively elderly (in the case of some of the turtles and tortoises). Once again, the tortoise (or, at least, the Eastern Painted Turtle) has outrun the hare (that is, the young New Zealand white rabbit). Was the tortoise more intelligent, or did its wisdom, experience, and perseverance overcome the impetuosity of youth?

I hope that the point has been made that direct *quantitative* differences such as the number of trials to criterion or the number of

errors made while learning should not be used to compare learning abilities across species. Let us turn now to the question of possible *qualitative* differences in learning.

### **Qualitative Differences in Learning**

#### *Bitterman's Approach*

By qualitative differences in learning, it is usually meant that some animals can perform a task successfully while others cannot, or that different animals perform the task in distinctly different ways. M. E. Bitterman and his co-workers have demonstrated, over many years, a number of qualitative differences in performance on learning tasks by a variety of vertebrates and, sometimes, invertebrates. I will illustrate this with one of his best-known examples. The example involves reversal learning of which two basic types have been used: reversal learning with spatial cues and reversal learning with visual cues.

The basic procedure in reversal learning is for the animal to be rewarded for choosing one alternative (A) rather than another (B) until a preference for A is established. Then the procedure is reversed: B rather than A is rewarded. When a preference for B has been established, A is again rewarded, and so on (Bitterman 1965). Although the different species tested required different experimental environments because of differences in sensory, motor, and motivational characteristics, Bitterman attempted to keep certain basic elements of the test apparatus analogous. With both spatial and visual cues, in each case, the animal was confronted with a pair of translucent plexiglass panels on which various colors and patterns were projected from behind, and it made its choice by pressing against one or the other of the panels in its own way: a fish might strike or bite, a pigeon peck, a monkey push with its hand, and so forth. A correct choice produced a food reward appropriate to each species.

In the spatial reversal learning task, the animal is rewarded for choosing, say, the target on the right rather than the target on the left. After it learns to respond to the target on the right, the procedure is reversed so that it must now choose the target on the left. Typically, about 20 such reversals are made. Bitterman (1965) reported that the monkeys, rats, pigeons, and turtles show progressive

improvement in performance as the reversals continue, but mouth-breeder fish, cockroaches, and earthworms do not. Progressive improvement means that the animal learns to recognize in increasingly fewer trials that a reversal has occurred, and so it tends to learn each successive reversal quicker than the previous one, up to a point of optimal performance. The nonimproving animals learn each reversal as though it were a new task, that is, they take about the same number of trials to learn each reversal.

On the visual reversal task, instead of learning to respond spatially to the left or right, the animal learns to respond to one of two visual cues. For example, it might learn first to respond to a black target, then a white one, then it is reversed back to black, then back to white, and so forth, for about 20 such reversals. Note that the spatial location of the correct target must be changed randomly. This makes the visual reversal task more complicated logically compared to the spatial reversal task, because in the visual task there is one relevant cue, black or white, and also one ambiguous cue, spatial location, while in the spatial task there is one relevant cue and no ambiguous cues. Bitterman's early data showed that the monkey, rat, and pigeon showed progressive improvement on visual reversal learning, as well as spatial, but the turtle did not. His principal point was that while all the animals learned the reversals, only some showed progressive improvement that he interpreted as a qualitative difference in performance.

In Bitterman's early findings (table 2), taxonomic order appeared to be a function of the two types of tasks and whether the animal showed progressive improvement. However, as data continued to be reported it became clear that even reptiles and fish could show some progressive improvement in both types of reversal learning (Bitterman 1975), and so the early suggestion of taxonomic class difference on reversal learning disappeared. Bitterman has examined qualitative differences in a number of categories with a number of different tasks, but the qualitative differences discovered thus far do not constitute an obvious order of learning ability or intelligence.

Bitterman's approach represents the principal alternative to the traditional approach to the study of animal intelligence, which attempted to scale abilities and rank the animals in intelligence. The traditional approach failed for two reasons. One was that comparative learning abilities were too often mismeasured, as discussed earlier, and the other was that the measurement scales used were too

**Table 2** Progressive Improvement in Reversal Learning

<i>Spatial</i>		<i>Visual</i>
	<i>Yes</i>	
Mammals		Mammals
Birds		Birds
Reptiles		
	<i>No</i>	
Fish		Reptiles
		Fish

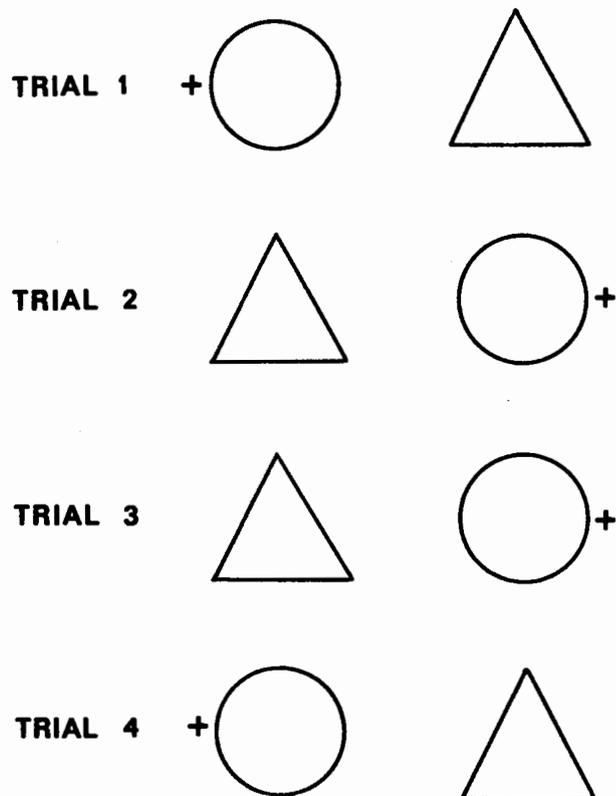
Source: Adapted from Bitterman (1965).

anthropocentric, that is, too often based on conceptions about intelligence in humans. It remains to be seen whether the kinds of abilities and qualitative differences Bitterman has identified can be organized into any meaningful scale, or for that matter, whether there is any value in doing so.

#### *Harlow's Approach*

Harry Harlow, one of the best-known and most innovative students of primate behavior, attempted to measure comparative learning skills in terms of the number of ambiguous cues contained within the learning task (Harlow 1958). Harlow also referred to the ambiguous cues as error factors, which meant that these factors were potential sources of error that the animal had to eliminate in order to learn the correct solution. While Harlow's examples were visually perceived cues, theoretically other sensory modalities could be used, and the task could be administered for each particular species according to its best sensory modality.

The basic learning task in such studies is an object or cue discrimination problem in which two or more objects, shapes such as a triangle and a circle, for example, are placed over the food wells of a test tray. If the subject picked up or pushed aside the correct shape it was rewarded by finding food underneath. Figure 2 shows Harlow's example of a problem with one relevant cue (form) and one ambiguous cue (position). In any single correct trial a response is made not only to the circle, but also to the position it occupies. Because a particular position as well as a particular object is rewarded, the relevant characteristic of the chosen cue is ambiguous. During the many



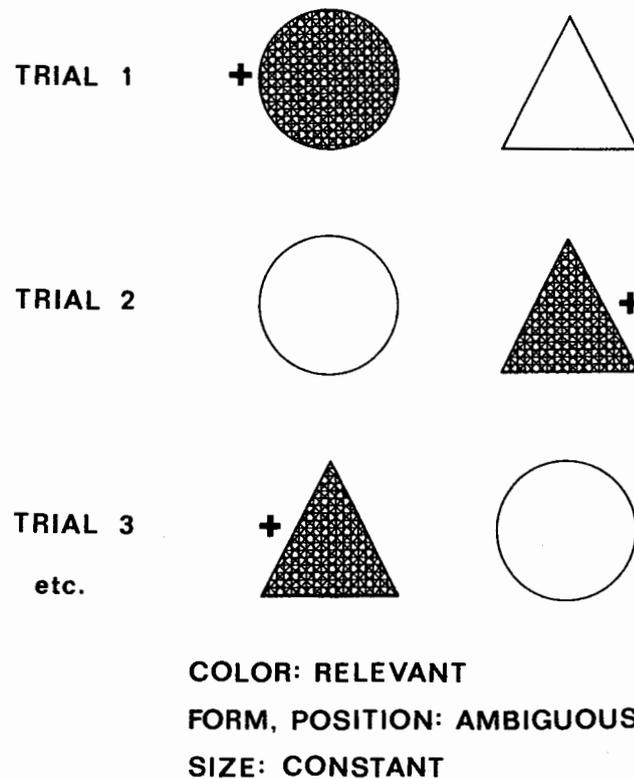
**FORM: RELEVANT**  
**POSITION: AMBIGUOUS**  
**COLOR, SIZE: CONSTANT**

Figure 2 An example of a problem with one ambiguous cue (position) that is unrelated to correctness of choice. Only the choice of the circle instead of the triangle was rewarded, whether it was on the right or the left. (Illustration by Kathleen Spagnolo.)

succeeding trials, the circle is rewarded on every trial, and each of the two positions, right and left, is rewarded on only half the trials. The inconsistent reward of the ambiguous position leads to its elimination as a reason for making a choice, and the object itself becomes the main choice. The size and color of the objects were held constant, so they were neither relevant nor ambiguous. Figure 3 shows

how the problem that we just saw can be extended to two factors of ambiguity: form and position, with only the choice of color being rewarded. It should be emphasized that there is more than one way to construct a set of problems that vary in the number of ambiguous cues, and if one wanted to compare the performances of animals using ambiguous-cue problems, more than one type should be used before suggesting that an animal might be unable to perform a problem with a particular number of ambiguous cues.

Based on the data available to him, Harlow believed that all vertebrates are probably capable of successfully performing problems with one ambiguous cue. He was unsure whether any nonprimate



**Figure 3** An example of a problem with two ambiguous cues. Here the correct choice is always the darker-colored stimulus, regardless of shape or position. This is a more difficult problem than the one in figure 2 since the correct choice not only varies from right to left, but can also be either a triangle or a circle. (Illustration by Kathleen Spagnolo.)

animal had successfully performed a two-ambiguous-cue problem, but he asserted that no nonprimate animal had successfully performed a three-ambiguous-cue problem, and he noted that Henry Nissen (1951) had shown that a chimpanzee could perform a five-ambiguous-cue problem. In my laboratory, we have studied both college students and squirrel monkeys using problems similar to those used by Harlow, with two and three ambiguous cues. Both the college students and the squirrel monkeys had relative difficulty with the three ambiguous cues as compared to two ambiguous cues, but both performed significantly better than chance on both types of problems. The squirrel monkeys took about 400 trials to criterion per problem, whereas the humans took only about 34 trials on the three-ambiguous-cue problem, but of course, as noted earlier, we would not want to use this difference in the number of trials to suggest that college students are smarter than squirrel monkeys.

It should be noted that in Harlow's approach, as well as the next and last one that will be considered, the testing conditions are suited to the animal. The basic capacities to be investigated in both approaches do not depend on specific experimental tasks. Ideally, the sensory and motor requirements as well as the motivational conditions should be adapted appropriately for each species. Furthermore, the kinds of stimuli, responses, and motivating conditions used at one level should remain basically the same at succeeding levels. If the animal can perform Harlow's one-ambiguous-cue task but not his two-ambiguous-cue task, and if there is no reason to believe that the animal has deteriorated physically or that its motivation has diminished, then a failure at the higher level might reasonably be attributed to a failure in learning or a lack of intellectual capacity, rather than to sensory, motor, or motivational factors.

#### *A Basic Hierarchy of Learning Skills*

The last approach that I will consider involves a basic hierarchy of learning skills (Thomas 1980). By basic, I mean that any learning task may be reduced to or analyzed in terms of the levels of learning to be described here. If an animal is capable of learning, and if it is possible to arrange the conditions so that it will perform in the laboratory, then it should be possible to determine how far up the hierarchy of learning skills the animal is capable of performing. Since for

the purposes of this paper learning is equated with intelligence, how far up the hierarchy the animal is capable of performing can be considered an index of its intelligence.

The hierarchy is essentially a synthesis of a learning hierarchy described by Robert M. Gagne (1970) and concept-learning hierarchy associated with the work of Lyle Bourne (1970) and his colleagues. Table 3 shows the result of that synthesis.

I shall pass briefly over the first four levels, because the major vertebrate classes (except amphibians, which apparently have not been tested) have been shown to be capable of performing successfully at the fifth level. Level 1, or habituation, refers to the most basic form of learning, in which an animal learns to ignore a stimulus that has no consequences. That is, it may respond at first when the stimulus is new, but as it learns that the stimulus is neither useful nor harmful, it will learn to ignore it and stop responding. This type of learning is seen in even the simplest invertebrates, as described elsewhere in this volume by Gould and Gould and by Beer. Level 2 is the same as simple classical or Pavlovian conditioning (e.g., a dog begins to salivate at the sound of a bell after the bell is repeatedly paired with food), and level 3 is simple operant conditioning (e.g., a rat presses a lever more frequently when such pressing is followed by a food reward). Level 4 refers to the chaining of simple operant responses, that is, learning more than one simple operant response in a connected sequence (e.g., a rat must press a lever and then climb up a pole before it is given a food reward). The available

**Table 3** A Hierarchy of Intellective (Learning) Abilities

Relational Concepts	Level 8:	Biconditional concepts
		Level 7:
	Conjunctive concepts	
	Disjunctive concepts	
Class Concepts	Level 6:	Affirmative concepts
		Absolute $\wedge$ Relative
	Level 5:	Concurrent discriminations
	Level 4:	Chaining
	Level 3:	Stimulus-Response learning
	Level 2:	Signal learning
Level 1:	Habituation	

data suggest that there are probably no fundamental differences among vertebrates in the ability to perform at the first three levels. One may expect to find differences at level 4, chaining, in terms of the length of the chains that an animal is capable of performing.

The comparison of learning ability at level 5 involves the number of concurrent discriminations an animal can learn, that is, how many simple stimulus-response discriminations it can learn and remember at the same time. For example, an animal might learn that a response to a circle is correct and a response to a square incorrect when they are both presented together. Then while still retaining that discrimination, it learns that when a triangle and oval are presented, the triangle is correct. Then a third discrimination can be added, and so on. These discriminations are considered concurrent if the animal can make the correct choice any time it is presented with any of the pairs of stimuli. Most of the data pertaining to level 5 have come from the work of Bernhard Rensch (1967) and his colleagues, who are interested in the evolution of what they call "brain achievement," which is basically the same as what I have been calling intelligence. Table 4 shows the data reported that are relevant to level 5 in the learning hierarchy. It also illustrates his belief that larger-brained species at comparable taxonomic levels will show greater evidence of brain achievement. Not shown, but interesting to note, is that the octopus, an invertebrate, has performed at level 5 with at least three concurrent discriminations.

Level 6 involves concept learning. Although there is no accepted definition of "concept," it usually refers to some common quality or characteristic shared by a number of specific stimuli that differ on one or more other characteristics. If an animal is capable of discriminating on the basis of concepts, it may be capable of practically an unlimited number of concurrent discriminations. For example, if an animal can use the concept of "tree" and the concept of "person," then it may be able to discriminate between any picture of a tree and any picture of a person. Evidence for an animal's use of a concept should be based on successful performance when new stimuli are used, or when the number of stimuli is so large that it is unlikely that the animal learned to recognize specific stimuli. A subject could learn to respond to tree A as opposed to person B, and then to tree C and not person D, and so forth, by simple concurrent discrimination learning, without ever learning the *concepts* of tree and person. But the animal that has learned the concepts can correctly rec-

**Table 4** Concurrent Discrimination Learning

Animals	Number of Discriminations*
<i>Teleosts (Fish)</i>	
Perch (smaller brained)	4
Trout (larger brained)	6
<i>Amphibians</i>	
Not tested?	?
<i>Reptiles</i>	
Lizard (smaller brained)	2
Lizard (larger brained)	3
Iguana	5
<i>Birds</i>	
Domestic ("dwarf race")	5
Domestic ("giant race")	7
<i>Mammals</i>	
Mouse	7
Rat	8
Zebra	10
Donkey	13
Horse	20
Elephant	20

\*Best as opposed to average performances.  
Source: Rensch (1967).

ognize a new pair, that is, tree Y as a "tree" and person Z as a "person"; the animal that has learned only specific stimuli cannot. This example is especially appropriate, because Richard Herrnstein and his colleagues have shown that pigeons can identify pictures of specific trees and people when presented with hundreds of different slides of each (Herrnstein and Loveland 1964; Herrnstein, Loveland, and Cable 1976; see also Ristau, this volume). Since so many different slides were used, learning of specific stimuli (e.g., 1,200 concurrent discriminations!) was very unlikely.

Natural concepts, such as "trees" or "people," or concepts based on color or form involve the use of what logicians call affirmation and negation. This means that if one knows such a concept one can affirm appropriate examples of it and negate inappropriate examples ("this is a tree" or "that is not a person"). Level 6 concepts involve

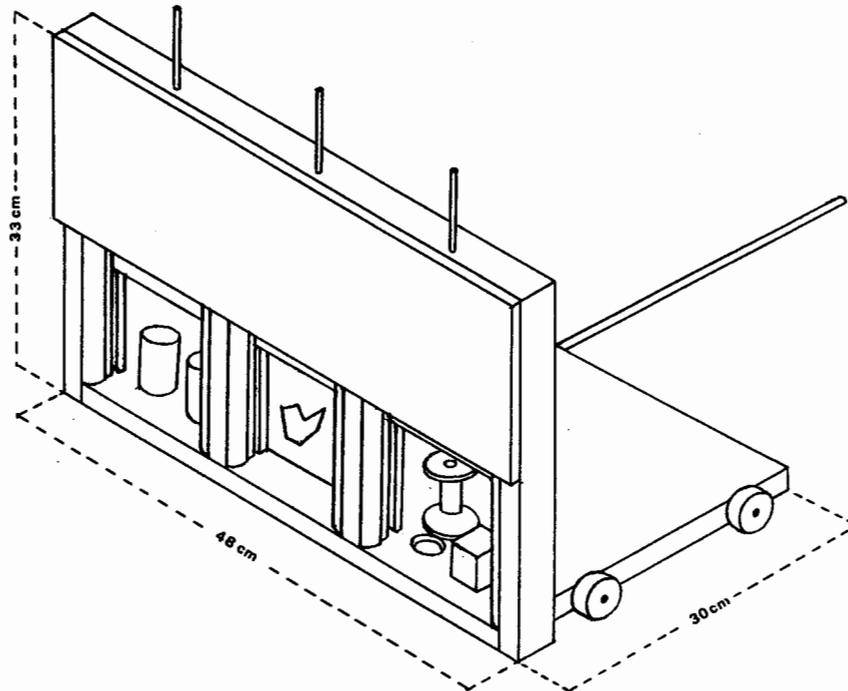
only affirmation and negation, and so these are called affirmative concepts or, synonymously, class concepts. However, there are two distinct kinds of affirmative or class concepts: those involving judgments based on *absolute* stimulus properties, and those involving judgments based on *relative* stimulus properties. The distinction is based on the necessity of comparing stimuli in order to make a correct choice. If you are shown a picture of a tree, you need look no further to affirm that it is a member of the class "tree." However, if you are supposed to affirm the stimulus that manifests the oddity concept (i.e., the one that is different from the rest) or the concept of "larger," you must compare your choices to determine which is the odd stimulus or which is the larger one.

To the best of my knowledge, conclusive demonstrations of the use of class concepts by animals have been limited to pigeons and primates, and pigeons have only been shown to perform absolute class concepts. Some studies in the 1920s and 1930s claimed to have demonstrated form concepts in rats, cats, and dogs, but in almost all cases the possibility of specific stimulus learning cannot be eliminated. There have also been attempts to demonstrate the oddity concept in rats, cats, and pigeons, and some investigators have claimed success. However, based on the most conservative analyses, these studies are also inconclusive on the grounds that specific stimulus learning may have occurred. In my laboratory, Linda Noble and I have been trying for about two years to develop a conclusive demonstration of oddity learning in the rat. We have tried both visual and olfactory experiments, but so far all that we see when the critical tests are administered is chance behavior.

The two highest levels in the learning hierarchy, levels 7 and 8, involve logical operations that define relationships among stimuli, and which may be described as relational concepts. Level 7 involves conjunctive, disjunctive, and conditional operations. Symbolically speaking, concepts involving A *and* B are conjunctive; concepts involving A *or* B are disjunctive. Chimpanzees and squirrel monkeys have been reported to use conjunctive and disjunctive concepts (Premack 1976; Wells and Deffenbacher 1967). Conditional concepts may be viewed symbolically in terms of the phrase, "if A, then B," with the additional requirement that either the antecedent, A, or the consequent, B, or both must be class concepts. A study by Riopelle and Copeland (1954) showed that rhesus monkeys could learn conditional concepts when the antecedent, A, was a class concept. Stephen

Kerr and I (1976) showed that squirrel monkeys could learn conditional concepts when the consequent, B, was conceptual, and Leonard Burdyn and I have recently finished a study in which both A and B were conceptual (Burdyn and Thomas 1984). I will use that study to illustrate the use of conditional concepts.

There were actually two conditional relationships in the Thomas and Burdyn study. Figure 4 illustrates the device that tested the conditional, "if septagonal, then different." On other trials, a triangle might appear in the center door, in which case the conditional was "if triangle, then same." A large number of different triangles and septagons was used in the latter phases of the study, so the concepts "triangularity" and "septagonality" were the relevant cues, rather than specific triangles or septagons. Similarly, the objects



**Figure 4** The Thomas-Burdyn test apparatus. The center window provides the cue indicating which of the two sets of stimuli in the other two windows is correct. The subject must move one of the objects of the correct pair to get the reward hidden beneath it. In the illustration, the spool-shaped member of the "different" pair has been displaced to show the food cup below it. The two cylinders in the other windows represent the "same" pair. (Illustration by Kathleen Spagnolo.)

that represented the concepts "same" and "different" were changed on each trial. In some stages of this study, such as that illustrated in the figure, the cue and the objects were simultaneously present, but in other stages the cue was withdrawn before the objects were presented. This meant that the squirrel monkeys had to remember both the symbol in the center door and what it stood for in order to make the correct choice. We systematically increased the time delays, and the best performance was by a monkey who could perform accurately with delays of up to 16 seconds. When we increased the delay to 32 seconds, the monkey could not learn to respond correctly in the 300 trials allowed.

Level 8 in the hierarchy of learning abilities involves the biconditional, which may be verbalized as "A if and only if B" or as "if A, then B; if B, then A." Apparently, there have been no attempts to study the ability of nonhuman animals to use biconditional concepts. I believe that it is feasible to do so, and my guess is that at least some monkeys and apes will be able to perform successfully.

### **Conclusions**

There is little that we can confidently say at this time about the comparative intelligence of vertebrates. Despite a century of interest in such questions, there are too few data based on a common definition of intelligence or a standard scale of measurement. If it appears that only monkeys and apes were referred to as we considered the highest levels of learning, it must be remembered that, with few exceptions, only monkeys and apes have been studied at these levels. It is best to avoid debates such as the comparative intelligence of the horse versus the pig, or whether your neighbor's cat is smarter than your dog. The answers simply have not yet been found, and the only way that they will be provided unequivocally is by more well-controlled research that is based on an accepted definition of intelligence and a common framework of measurement.

### **Select Bibliography**

Bitterman, M. E. 1965. Phyletic differences in learning. *American Psychologist* 20:396-410.

- . 1975. The comparative analysis of learning. *Science* 183:699–709.
- Bourne, L. E., Jr. 1970. Knowing and using concepts. *Psychological Review* 77:546–56.
- Burdyn, L. E., Jr., and R. K. Thomas. 1984. Conditional discrimination with conceptual, simultaneous, and successive cues in the squirrel monkey, *Saimiri sciureus*. *Journal of Comparative Psychology* 98:405–13.
- Fink, H. K. 1954. *Mind and performance*. New York: Vantage Press.
- Gagne, R. M. 1970. *The conditions of learning*. New York: Holt, Rinehart & Winston.
- Harlow, H. F. 1958. The evolution of learning. In *Behavior and evolution*, ed. A. Roe and G. G. Simpson. New Haven: Yale University Press.
- Herrnstein, R. J., and D. H. Loveland. 1964. Complex visual concept in the pigeon. *Science* 146:549–50.
- Herrnstein, R. J., D. H. Loveland, and C. Cable. 1976. Natural concepts in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes* 2:285–302.
- Heath, P. L. 1967. Concept. *The encyclopedia of philosophy*. Vol. 2. New York: Free Press.
- James, W. T. 1959. Behavior of the opossum in the Fink Arrow Maze. *Journal of Genetic Psychology* 94:199–203.
- Kendler, H. H., and T. S. Kendler. 1975. From discrimination learning to cognitive development: A neobehavioristic odyssey. In *Handbook of learning and cognitive processes*, ed. W. K. Estes. Volume 1. *Introduction to concepts and issues*. New York: John Wiley & Sons.
- Klüver, H. 1933. *Behavior mechanisms in monkeys*. Chicago: University of Chicago Press.
- Nissen, H. W. 1951. Analysis of a complex conditional reaction in chimpanzee. *Journal of Comparative and Physiological Psychology* 44:9–16.
- Premack, D. 1976. *Intelligence in ape and man*. Hillsdale, N.J.: Lawrence, Erlbaum Assoc., Inc.
- Rensch, B. 1976. The evolution of brain achievements. *Evolutionary biology* 1:26–68.
- Riopelle, A. J., and E. L. Copeland. 1954. Discrimination reversal to a sign. *Journal of Experimental Psychology* 48:143–45.
- Rumbaugh, D. M., ed. 1977. *Language learning by a chimpanzee*. New York: Academic Press.

- Thomas, R. K. 1980. Evolution of intelligence: An approach to its assessment. *Brain, Behavior and Evolution* 17:454-72.
- Thomas, R. K., and R. S. Kerr. 1976. Conceptual conditional discrimination in *Saimiri sciureus*. *Animal Learning and Behavior* 4:333-36.
- Warren, J. M. 1960. Reversal learning by paradise fish (*Macropodus opercularis*). *Journal of Comparative and Physiological Psychology* 53:376-78.
- Wells, H., and K. Deffenbacher. 1967. Conjunctive and disjunctive concept learning in humans and squirrel monkeys. *Canadian Journal of Psychology* 21:301-8.