

A Cognitive Behaviorist Approach to the Study of Animal Behavior

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ABSTRACT. Traditional psychological approaches to animal learning and behavior have involved either the atheoretical behaviorist approach proposed by B. F. Skinner (1938), in which input–output relations are described in response to environmental manipulations, or the theoretical behaviorist approach offered by C. L. Hull (1943), in which associations mediated by several hypothetical constructs and intervening variables are formed between stimuli and responses. Recently, the application of a cognitive behaviorist approach to animal learning and behavior has been found to have considerable value as a research tool. This perspective has grown out of E. C. Tolman’s cognitive approach to learning in which behavior is mediated by mechanisms that are not directly observable but can be inferred from the results of critical experiments. In the present article, the author presents several examples of the successful application of the cognitive behaviorist approach. In each case, the experiments have been designed to distinguish between more traditional mechanisms and those mediated by hypothesized internal representations. These examples were selected because the evidence suggests that some form of active cognitive organization is needed to account for the behavioral results.

Key words: attention, cognitive behaviorism, cognitive maps, imitation, transitive inference, working memory

BIOLOGISTS AND PSYCHOLOGISTS have approached the study of animal behavior from different perspectives. These differences can be attributed in part to differences in the nature of the questions they ask. The goal of biologists—typically, zoologists and behavioral ecologists—is to understand how animal behavior contributes to survival and reproductive success. The behaviors of primary interest have been those that are genetically predisposed or those that are typical of the species. One would expect the behavior of different species to have varied as they evolved in different environments and under different evolutionary pressures. Thus, the goal of research would be to look for patterns or correlations between environmental pressures and evolved behavior.

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Psychologists, on the other hand, have tended to approach the study of animal behavior primarily from the perspective of the flexibility of the individual animal. The greater part of naturally occurring behavior in most animals, especially for those that live in relatively predictable environments, appears to be predisposed (see Boice, 1973), and it is released by external events (e.g., hormones that are produced in response to seasonal variations in sunlight or temperature). But animals have also evolved to adjust their behavior to environmental variability by reacting to behavioral consequences, and it is this behavioral plasticity that is of primary interest to psychologists. The focus of psychologists on behavioral plasticity can be traced to the remarkable flexibility of human behavior and the attempt to model that behavior in other organisms. However, psychologists differ among themselves in how best to model flexible behavior.

Some psychologists propose that the best they can do with the current understanding of behavior is to describe the conditions under which behavioral consequences can result in changes in the preceding behavior. These behavior analysts (e.g., Skinner, 1938) believe that a full description of the conditions under which behavioral change occurs is needed before one can propose mechanisms to account for that change (Skinner, 1950). They prefer to treat the organism as a “black box” and to study descriptively what happens to an animal’s behavior when certain outcomes are contingent on changes in the pattern of its behavior.

Other psychologists have proposed theories to account for the changes in behavior that take place when hedonic events (e.g., food or shock) follow the behavior. These theorists (e.g., Hull, 1943; Spence, 1937; Thorndike, 1911) have postulated relatively simple mechanisms such as associations, drive, and incentive that interact to account for the flexibility of behavior. Hull, in particular, proposed that if one could specify the parameters of learning, one could make precise predictions of the course of its development.

Tolman (1932) proposed a cognitive approach to learning that exemplifies one exception to the general trend in psychology to either avoid the postulation of internal mechanisms or to propose relatively simple associative mechanisms to account for learning. He allowed for the possibility that learning could be latent and that it involves unobservable stimulus–stimulus associations that may become overt only when a reward is available to provide the organism with a reason to demonstrate what it has learned. He asserted that associations may occur among arbitrary stimuli and when they do, they could result in the formation of a *cognitive map*. He argued further that associations could develop between arbitrary stimuli and biologically important outcomes and that when they do, they could result in a purposeful approach to behavior.

Tolman’s approach was criticized by others (he was seen by some as leaving his rats “buried in thought,” Guthrie, 1952, p. 143). His critics questioned, How, if an animal has a cognitive map, could one distinguish between the behavior produced by such a map and the behavior produced by observable stimulus–response associations? In fact, the predictions that Tolman made in his cognitive approach

are, under most conditions, indistinguishable from the more widely held stimulus–response theories of his time. However, according to Tolman, one can demonstrate these hypothetical unobservable associations by examining the results of critical experiments that distinguished them from more directly observable stimulus–response associations. Tolman’s approach differed from other behaviorist theories (Guthrie, 1935; Hull, 1943) of the time in that it allowed for mechanisms that could not be observed directly and that had to be inferred from the absence of alternative, more directly observable accounts. But it shared with the other theories the identification of environmental and intervening variables, and it was firmly grounded in observable behavior that was obtained from carefully controlled experiments.

Tolman demonstrated his hypothesis—that learning could occur in the absence of reinforced responding—in an experiment in which a rat was free to explore a maze in the absence of external reward. He obtained evidence that the rat had learned the spatial plan of the pathways by means of nonrewarded stimulus–stimulus associations after he demonstrated that when the rat was presented with food that had been placed at a particular location in the maze, it immediately approached that location on the next trial (Tolman & Honzik, 1939).

Tolman’s view—learning can occur in the absence of reinforced responding and that the environment can be represented in the form of a cognitive map—became the foundation of a more general cognitive behaviorist approach to animal learning and not only of the field of comparative cognition. He considered himself a behaviorist, but his was an operational behaviorism in which cognitive processes could play a role, and that was where he differed from the other behaviorists of his time. In fact, one gets the feeling that he developed his formal model, which was based on intervening variables (see, e.g., Hilgard & Bower, 1966), as an afterthought in an effort to gain credibility for his otherwise qualitative cognitive theory at a time when Hull’s formal theory dominated the field of learning (see Staddon, 2001, p. 17).

The cognitive behaviorist approach to animal learning and behavior became more acceptable (e.g., Honig & James, 1971; Hulse, Fowler, & Honig, 1978; Jarrod, 1971) as research in human cognition became more prevalent (e.g., Treisman, 1969; Tulving & Donaldson, 1972). These animal researchers were attracted to this approach because it could be traced to the premise that there was continuity between species—that human capacities may be shared by many other species—and that it was minimally driven by preexisting theory. Furthermore, it became apparent that the investigation of the capacities of animals on the basis of findings from research with humans had general heuristic value because these investigations often generated hypotheses that could be tested with carefully controlled experiments. The cognitive behaviorist approach is generally consistent with what has come to be called the field of comparative cognition or animal cognition (Roberts, 1998; Roitblat, 1987; Shettleworth, 1998). The approach is characterized by the fact that it contrasts the predictions made by cognitive theories

with those made by simpler stimulus–response theories. It differs from Skinner’s functionalism in that it accepts the possibility that there are mental processes that cannot be seen directly. However, unlike other cognitive approaches, it is not tied to a particular theoretical position. Cognitive behaviorists are likely to ask what experimental result would support a particular theory of cognitive functioning. They would likely not prejudge that an animal would not need to have such a cognitive ability, nor would they necessarily be surprised if they could not find any evidence for such an ability. Although cognitive behaviorists are generally interested in theory testing, they are neutral in relation to any particular theory. When the cognitive behaviorist approach is used appropriately, it is much like the theoretical behaviorism proposed by Staddon (2001) in that it is a way to examine presumed cognitive processes with the use of established behavioral procedures and without lapsing into the subjective evaluation of underlying mechanisms.

For the remainder of this article, I describe several examples of the cognitive behaviorist approach on the basis of an extrapolation from human research. I have selected the specific cases because they represent good examples of this approach, because their results are clear, and because, in most cases, they have led to expanded areas of research. They are not meant to be comprehensive, only illustrative. It can be argued in each case that these experiments have led to a better understanding of animal behavior, whether or not support can be found for the hypothesized cognitive capacities.

To demonstrate the usefulness of the cognitive behaviorist approach, I describe examples drawn from a broad range of problems that have been studied in animals. In each case, although we have only a cursory understanding of the cognitive processes that are involved, we are in a better position to explore them in more detail.

Cognitive Maps

Novel paths. As I have noted, one of Tolman’s important contributions to animal learning was the concept of a cognitive map. Tolman (1932) proposed that in a food-motivated learning task, animals learn not only how to get food but also where the food is relative to other locations in the environment. Thus, if a learned path is blocked and a number of other paths are available, a rat will not merely take the path that is most similar to the learned path, but it will likely take the path that leads most directly to the goal (Tolman, Ritchie, & Kalish, 1946). Menzel (1978) reported related evidence that animals develop a representational map of their environment. Menzel found that if a chimpanzee was carried over a circuitous path along which food was hidden at several places, when it was allowed access to the area it could recover all of the food, and do so along a simpler and more efficient path compared with the route along which it was carried.

Chapuis and Varlet (1987) reported perhaps the simplest and most straightforward demonstration of cognitive maps in animals. In this experiment with dogs,

each dog was led on a leash from a starting point along a straight path in a large field with no distinguishing landmarks and was shown a piece of food. The dog was led back to the starting point and from there was led along a second path about 30° from the first path and was shown another piece of food. Again, it was led back to the starting point and then released. If the dog had learned the specific paths that led to food, it should have proceeded along one of the paths and then returned to the starting point before it proceeded along the second path. Instead, when the dog reached the first piece of food, it went directly to the place where the second piece of food was located, without returning to the starting point. These results suggest that the dog had some representation or cognitive map of the field and after it had reached the first goal, it could consult that representation and estimate the direction in which it needed to go to reach the second goal.

Lists versus maps. Suzuki, Augerinos, and Black (1980) reported further support for the development of a cognitive map. They hypothesized that rather than forming a cognitive map, animals might develop lists of places to which to go and of places to which they had already been. In their experiment, rats were initially trained on an eight-arm maze with highly distinctive movable cues at the end of each arm. On test trials, the rats were forced to enter three arms (the rest were blocked) and were then confined to the center platform for 2.5 min before they were allowed to complete the trial. In one condition, all the cues were rotated around the maze during the retention interval so that they maintained their relative positions (i.e., the configuration of cues remained the same). In a second condition, the cues were moved randomly during the retention interval so that their relative position was not maintained. In a control condition, the cues remained in the positions they were in at the start of the trial.

If the rats had developed a cognitive map, the position of the arms they had already entered should have provided the subjects in the rotation condition with sufficient information about the orientation of the map for them to be able to complete the maze with few reentry errors. But in the random-move condition, a cognitive map would have been of little use and a greater number of reentry errors should have occurred. If, however, the rats had learned a list of the arms they had already entered and a list of those they had not yet entered, then they should have done well in completing the trial with either kind of transformation because the relative location of the arms should have been of little importance. Suzuki et al. (1980) found that the performance of the rats on the rotated transformation was similar to that of the rats in the control condition, whereas the rats in the random-move condition made a large number of reentry errors. Thus, the relative location of the arms appears to have provided an important cue. This finding supports the hypothesis that rats develop a cognitive map when they perform such tasks. The research suggests further that postulation of the development of a cognitive map encourages researchers to design experiments that can distinguish between representations and alternative hypotheses such as stimulus–response associations or

lists of experienced and unexperienced items (such as the arms in the aforementioned example).

Perception/Attention

When researchers ask if animals have the ability to attend selectively to certain aspects of their environment while they attend less to other aspects, they use the term attend in the sense of the internal filtering of certain elements of the environment or the focus on others, rather than in a peripheral, receptor-orienting sense. Thus, if animals can selectively attend, then it implies that they are active and not passive processors of information.

Researchers have approached selective attention in animals in three different ways, depending on the nature of the original question. When attention appears in the context of an animal foraging for food, it takes the form of a central representation of the food item for which the animal is searching (i.e., a search image). Alternatively, one can ask whether an organism can attend to the dimension that is defined by the discriminative stimuli as well as to the acquisition of specific response attachments (e.g., approach black, avoid white). Researchers believe that this form of attention is a gradual process and that it may take many trials to acquire. Finally, when attention in animals is viewed as a model of human selective attention, the question is whether there is a limit to the amount of stimulus input that can be processed by an animal in a brief period (i.e., whether, as with humans, there is a limit to the amount of information that can be processed simultaneously).

Search image. Tinbergen (1960) was the first to report that birds that fed on two different species of moths would often overrepresent in their diet the species that occurred more frequently (i.e., they ate more of them than one would expect given the frequency of the prey in the environment). Later in the season when the frequencies of the two species were reversed, he again found that the species that occurred more frequently was overrepresented in the birds' diets. Tinbergen proposed that the birds must have formed a search image (i.e., that they selectively attended to a central representation) of the more frequently occurring species. This correlational finding was later confirmed by laboratory research (Pietrewitz & Kamil, 1979; Reid & Shettleworth, 1992) and was shown to occur even with arbitrary, symbolic targets such as letters of the alphabet (Blough, 1991). This evidence that animals can form search images implies that they can expect to encounter a particular food item and that such an expectancy can be as specific as the small visual differences between closely related species of moth.

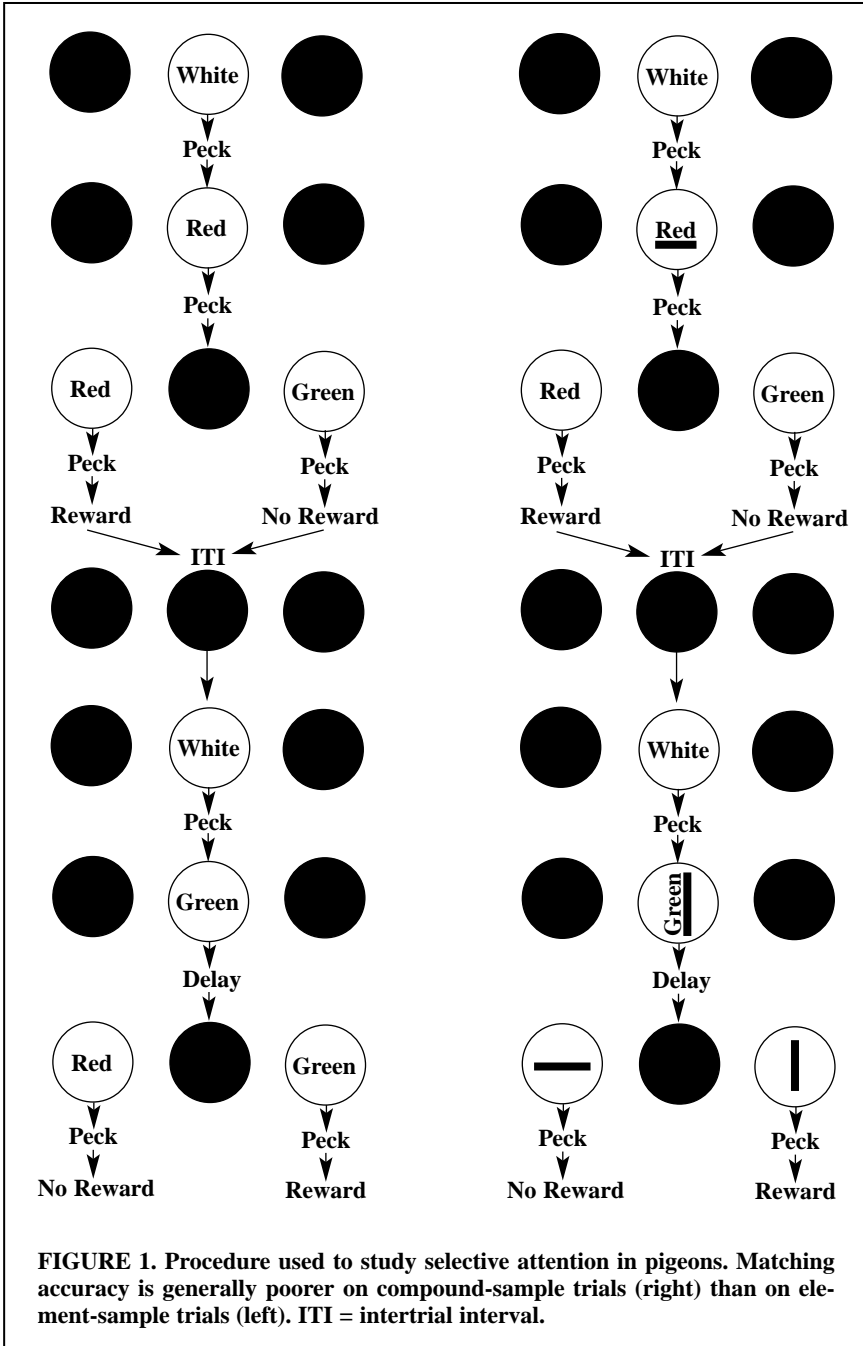
The function of the search image is presumably to make cryptic prey easier to detect and thus provide more food for the predator. This hypothesis has been supported by laboratory research in which evidence of the formation of a search image has been found only when the prey are relatively difficult to detect (Bond, 1983).

Gradually acquired dimensional attention. Researchers studied a different form of selective attention in response to the hypothesis that animals could not selectively attend but instead formed associations between all aspects of the stimulus environment and their consequences and not just with the relevant aspects (e.g., Spence, 1936). Thus, researchers asked if reinforcement associated with one value of a stimulus dimension but not another (e.g., black positive, white negative) would cause animals to attend to that dimension more than they would attend to others (e.g., spatial location, left vs. right; see Mackintosh, 1965). The evidence has not always been consistent, but in general animals appear to be able to learn selectively about relevant stimulus dimensions (Riley, 1968). For example, over-training appears to increase attention to the dimension that is defined by the discriminative stimuli, which facilitates reversal learning (Mackintosh). Similarly, training on a simultaneous discrimination can facilitate the acquisition of a successive discrimination that involves the same stimulus dimension, compared with prior training on a simultaneous discrimination that involves a different stimulus dimension (Lawrence, 1949, 1950).

If these experiments are to be put in the context of research with humans, then this approach to selective attention can be thought of as a test of incidental learning because learning about the relevant dimension is not necessary for task performance. The fact that incidental learning may be sensitive to the particular training conditions (e.g., the salience of the training dimension) may account for the failure to find evidence for this kind of attention in some experiments (see, e.g., Singer, Zentall, & Riley, 1969).

Shared attention. A different model of selective attention in humans is presented in research in which, over the course of training, the participants understand that attention to more than one dimension is a requirement of the task and in which the stimulus processing time is restricted. Such research has shown that humans do not process all aspects of the environment equally but are forced to attend selectively (e.g., Lindsay, 1970).

Similar results have been found when animal researchers have attempted to develop analogous procedures in which attention must be divided between two aspects of a stimulus that is presented briefly (Maki & Leuin, 1972; Riley & Leith, 1976). For example, pigeons have been trained on a matching task in which an initial stimulus (sample) indicates which of two test stimuli (or comparisons) is correct. They are trained with hues (e.g., if red choose red and if green choose green) and line orientations (if vertical choose vertical and if horizontal choose horizontal). When they are presented with compound samples (e.g., a horizontal line on a red background) and the comparisons are either hues or lines (see Figure 1), matching accuracy is poorer than when the samples are a single hue or line element. This effect, known as the element superiority effect, has been attributed to the limited processing capacity of the pigeon. Riley and Roitblat (1978) hypothesized that pigeons can process the informa-



tion in an element sample better than they can in the two elements of a compound sample.

Although other accounts of the element superiority effect have been offered, further research has shown that these alternative hypotheses do not adequately account for the effect (see Zentall & Riley, 2000). Instead, the research suggests that pigeons, much like humans, cannot process color and line orientation as efficiently (i.e., as accurately given the same sample exposure time) as they can process one dimension alone. Thus, there appears to be some degree of central selectivity of stimulus input by pigeons—and likely by other animals as well. And, as important, the shared-attention hypothesis encouraged the generation of alternative accounts that forced the refinement of experiments and led to the current conclusion.

Working Memory

Early research on animal memory focused on the limits of the abilities of different species to remember an event over time (Hunter, 1913). Later research questioned whether some of these findings could be explained in terms of external mediators, such as the maintenance of body as orientation when the required memory involved spatial location (Maier, 1929) or in terms of secondary reinforcers in the form of differential goal box cues (Grice, 1948). More recently, animal-memory researchers have borrowed the notion of working memory from human research (Honig, 1978). The idea that memory for recent events might be maintained in an active working state has led researchers to ask whether animals can exert control over what they remember. There is evidence that when pigeons acquire delayed matching (see the left panel of Figure 1) in which the sample is turned off for a period of time before the comparisons are presented, the birds may, during the retention interval, spontaneously develop (without direct training or even encouragement to do so) sample-specific behavior that appears to help them bridge the delay (Zentall, Hogan, Howard, & Moore, 1978). Such overt mediating behavior may serve the same function as rehearsal does for humans, but it may not require the involvement of a central cognitive process. That is, idiosyncratic sample-specific delay behavior may develop adventitiously, and this behavior may be maintained because it results in improved delayed matching accuracy.

Directed forgetting. Perhaps more impressive is the finding that pigeons can exert some control over what they remember without evidence of overt mediating behavior (Grant, 1981). In research on control over memory in humans, the participants are instructed to remember certain items and to forget others. MacLeod (1975) presented participants with a list of words, one at a time, and they were told that some of the words would be followed by the instruction to “forget” and that those could be forgotten; whereas others would be followed by the instruction to “remember” and that they should not be forgotten. The participants were

then tested for their memory for the “forget” and “remember” words. They showed a deficit in remembering the words they had been instructed to forget, compared with the words that they had been instructed to remember.

One of the greatest challenges for animal researchers is to find an appropriate substitute for the instructions that are given to humans (see Zentall, 1970, 1997). Instructions are most obviously needed in tasks such as directed forgetting in which subjects have to learn to expect that memory will be required on some trials but not on others. Grant (1981) used a variation of matching-to-sample to develop an analogous task to establish if pigeons could be directed to forget. On some trials, the sample was followed by a cue that indicated that the trial was over and that there would be no memory test (i.e., the cue was an instruction to forget). On other trials, the sample was followed by a different cue that indicated that there would be a test (i.e., the cue was an instruction to remember). On occasional probe trials, a forget cue was followed by a test trial (the sample was followed by a forget cue and then by comparison stimuli; see Figure 2), and on those trials, Grant found a substantial decrement in matching accuracy.

Maki (1981) questioned whether the tasks were analogous because for the pigeons, the forget cue signaled not only that memory would not be required but also that food would not be available (Roper & Zentall, 1993). However, other designs that provide a better model for the tasks that were used in research with humans, demonstrated similar directed-forgetting results (Roper, Kaiser, & Zentall, 1995; Zentall, Roper, & Sherburne, 1995). For example, Roper et al. found clear evidence for directed forgetting. They used a training task in which forget cues and remember cues were equally often associated with reinforcement but in which not having to remember one sample did not eliminate the memory load; it merely instructed the pigeon to remember something else. Thus, it appears that memory in pigeons is not a completely passive process; it can be affected by the expectation that memory retrieval will not be required.

The hypothesis that animals may have active control of their memory processes led researchers not only to test that ability, but also to the development of tasks that better represent the demands of comparable procedures used to assess intentional forgetting in humans. Thus, the cognitive behaviorist approach has implications for the study of similarities in the general abilities of species and for the development of animal models of human cognition, even though its presumed purpose is that it promotes a better understanding of animal behavior.

The differential outcomes effect. Another cognitive approach to the study of memory in animals is to ask if animals can anticipate the outcome of their behavior and if that outcome anticipation can be used as a discriminative stimulus to facilitate choice accuracy. Several traditional theories of learning view the role of hedonic outcomes as affecting the learning process only indirectly by strengthening or weakening the association between the preceding stimulus and response (Hull, 1943; Thorndike, 1911). However, Tolman (1932) argued that outcome

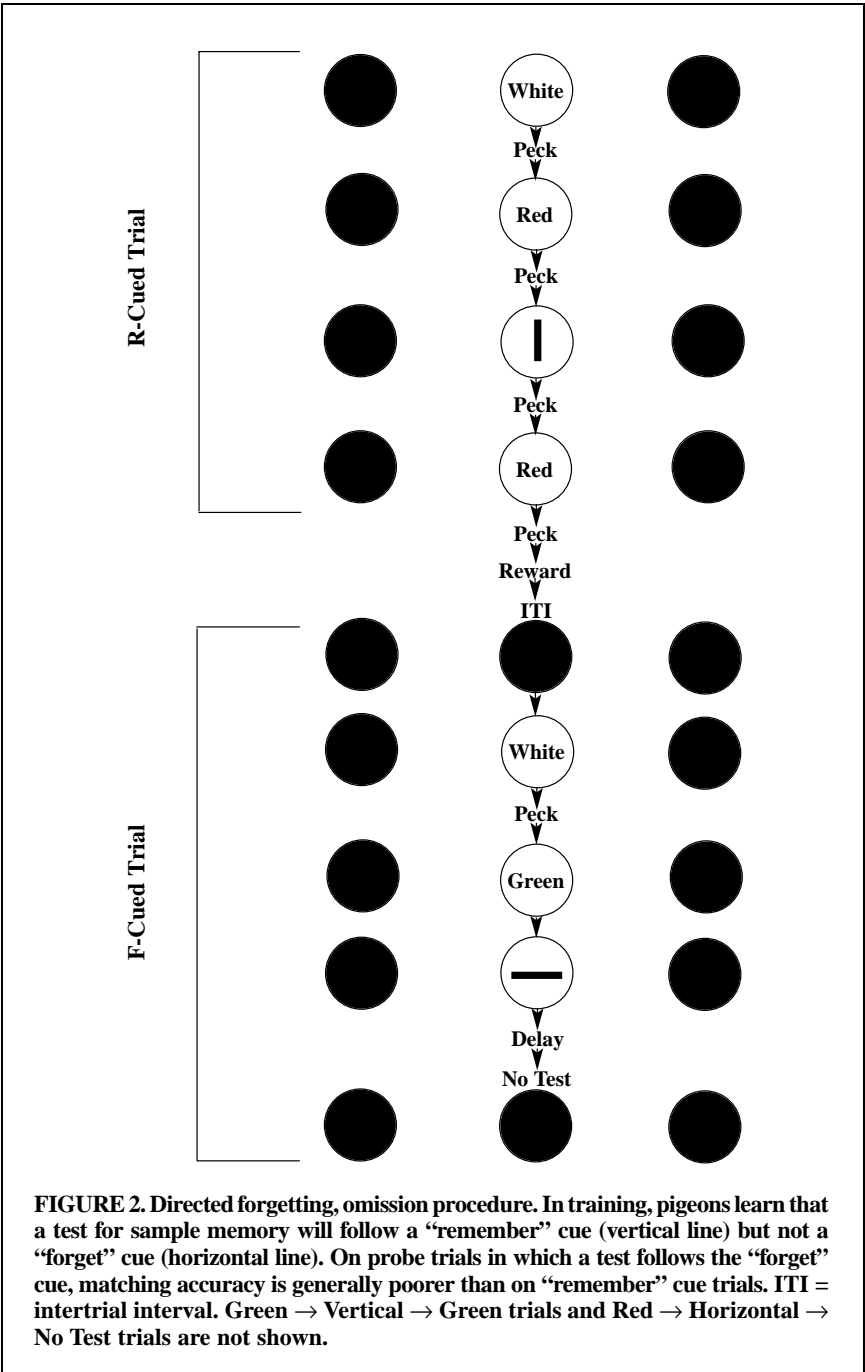


FIGURE 2. Directed forgetting, omission procedure. In training, pigeons learn that a test for sample memory will follow a “remember” cue (vertical line) but not a “forget” cue (horizontal line). On probe trials in which a test follows the “forget” cue, matching accuracy is generally poorer than on “remember” cue trials. ITI = intertrial interval. Green → Vertical → Green trials and Red → Horizontal → No Test trials are not shown.

expectations were an integral part of what was learned (i.e., stimulus–outcome or stimulus–stimulus learning). Crespi (1942) provided early evidence in support of Tolman's position. He found that rats that were shifted from a large to a small magnitude of reward not only ran more slowly to the smaller reward but also ran more slowly than did a control group of rats that had run to the smaller magnitude of reward from the start. This incentive-contrast effect suggests that the expectation of a large reward resulted in relative contrast (a reaction that is analogous to human disappointment) when the rats encountered the smaller reward.

Research by Trapold (1970) indicated that outcome expectations can form an integral part of learning and can act as cues to facilitate it. He found that rats acquired a two-alternative conditional discrimination more quickly when the correct choice of one comparison alternative was followed by one outcome (e.g., food) and the correct choice of the other comparison alternative was followed by a different outcome (water) than they did when either outcome was equally likely to follow either correct comparison choice. These results suggest that outcome expectancies can enhance comparison–stimulus discriminability.

Later research demonstrated that animals could actually use outcome expectancies as the sole basis for comparison choice (see, e.g., Peterson, 1984). Peterson trained pigeons to match hue samples (red and green) to line comparisons (vertical and horizontal) with the use of a differential outcomes procedure (Outcome A might be food, and Outcome B might be the absence of food; see Figure 3). In the second phase of the experiment, the pigeons are trained on a simple successive discrimination in which one shape stimulus (circle or triangle) is associated with food whereas the other shape is associated with the absence of food. Finally, when the shape stimuli replace the hues in the matching task, the pigeons tend to choose the comparison associated with the expected outcome. Thus, in the absence of explicit training with the shapes as samples, the pigeons use the expected outcome after the shape stimulus as the basis for choosing between the comparisons.

Evidence that outcome expectation can be the basis for comparison choice provides important implications for the nature of events that can be held in memory. The traditional view, which has been held since Hunter (1913) reported his important research, is that some explicit mediator (e.g., the animal's behavior) allows the animal to bridge the retention interval. More recently, other researchers have proposed that a representation of the to-be-remembered stimulus might be actively maintained during the retention interval and that the representation can be retrieved at the time of testing (Honig & Thompson, 1982). If the stimulus that is retained in memory is a representation of the event presented prior to the retention interval, then such memory is referred to as retrospective. On the other hand, presentation of an initial event may result in the elicitation of the expectancy of a future event. Memory that consists of a representation of a future event is referred to as prospective. When humans make plans, they base their behavior on the expectation of future events. Thus, evidence that outcome expectations can

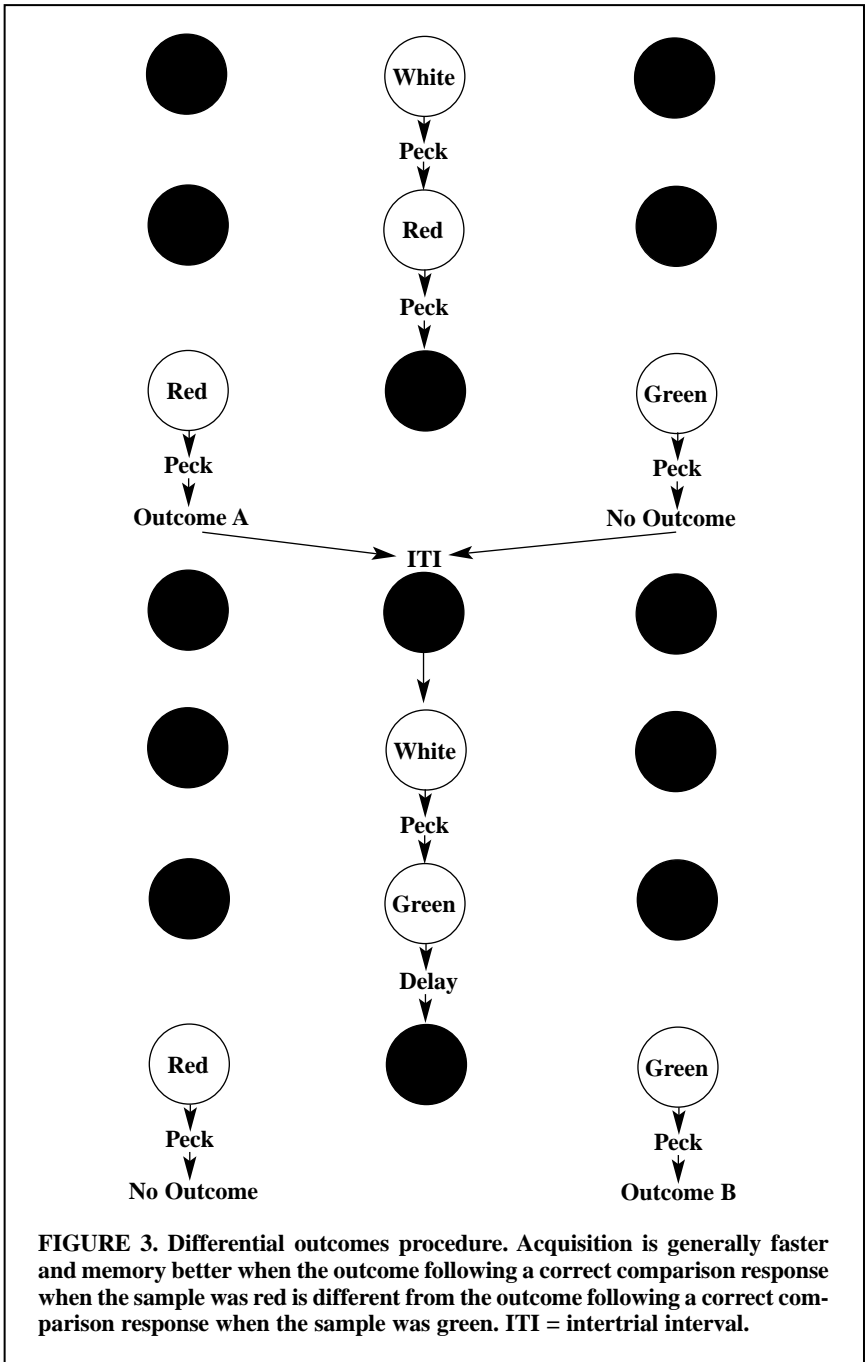


FIGURE 3. Differential outcomes procedure. Acquisition is generally faster and memory better when the outcome following a correct comparison response when the sample was red is different from the outcome following a correct comparison response when the sample was green. ITI = intertrial interval.

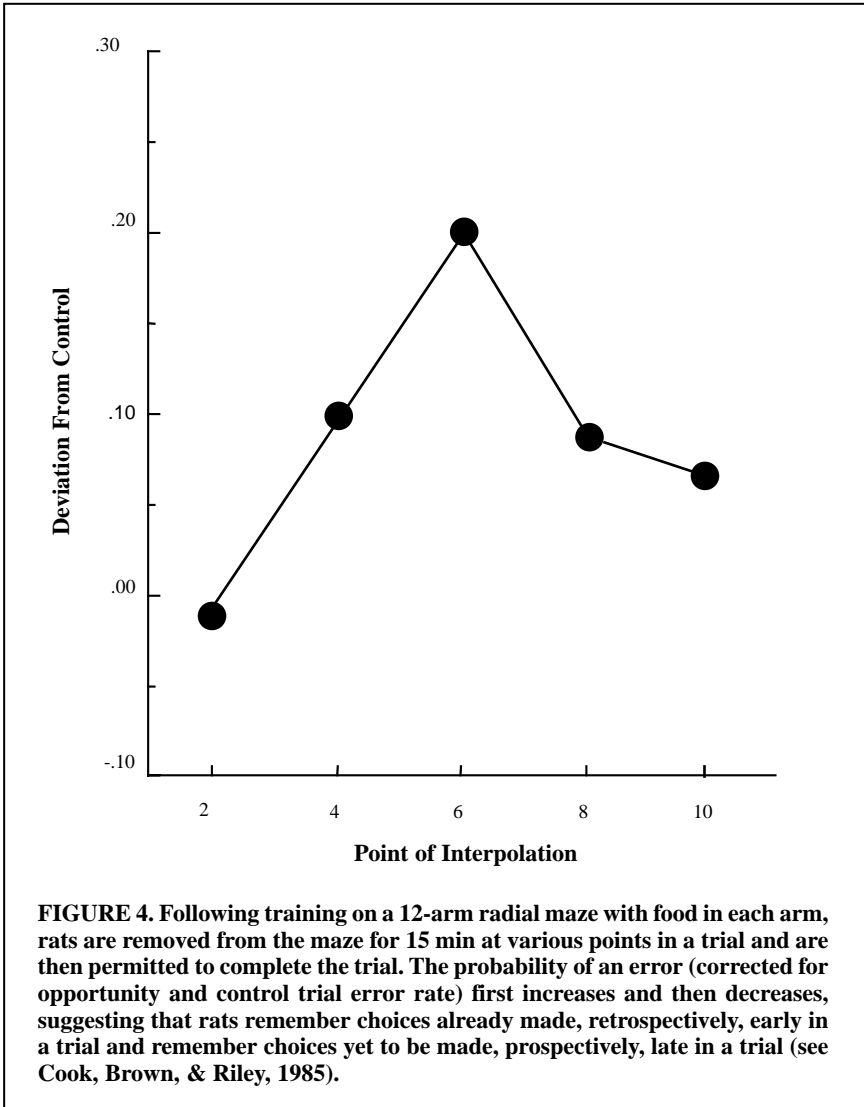
control behavior suggests that pigeons may have a rudimentary ability to plan for the future. However, this flexible, experience-based ability is different from the genetically predisposed, released behavior (e.g., nest building) that may provide the animal with a later benefit (i.e., a place to lay its eggs).

Other examples of prospective memories. Recent evidence suggests that prospective memories can consist also of response intentions and not only of outcomes (Cook, Brown, & Riley, 1985). Cook and his colleagues trained rats to enter each arm on a 12-arm radial maze and to not reenter arms (because once they are entered, the food is eaten and reentries are not rewarded). After the rats had mastered this task, the trials were interrupted by a delay. The point at which the delay was inserted varied from trial to trial. The rats were allowed to complete the trial after the delay. If the rats had retrospectively retained the locations of the arms they had already visited, then the relative number of errors they made after the delay should have increased because the point at which the delay was introduced increased (the greater the number of arms to remember, the higher the probability of an error). Similarly, if the rats had prospectively retained the locations of the arms they had not yet visited, the number of errors they made after the delay should have decreased because the point at which the delay was introduced increased.

Cook et al. (1985) found that the probability of making an error increased as the point at which the delay was introduced increased from 1 arm to 6 arms, but when the delay was introduced after more than 6 arms, the probability of making an error began to decrease (see Figure 4). The decrease in the probability of making an error when the delay was introduced later in the trial suggests that the rats were remembering prospectively the arms that had not yet been chosen. In addition, the overall pattern of error probability suggests that after sufficient experience with the maze, the rats had developed a more complex strategy that combined retrospective memory early in the trial with prospective memory late in the trial and that this effectively reduced the animal's memory load (but see Brown, Wheeler, & Riley, 1989, for an alternative account).

Evidence that animals can develop either retrospective representations of past events or prospective representations of future events suggests that they are capable of a simple form of planning. Thus, when the trial is interrupted, not only must the rats remember the arms that they have already visited and those that they have not yet visited, but they must also decide which set of arms they should remember—a decision that is presumably made on the basis of which set of arms involves the smaller memory load.

Such findings are not unique to rats, which are known to be particularly good spatial learners. Zentall, Steirn, and Jackson-Smith (1990) found inverted U-shaped error functions similar to those found with rats when they used an analog of the radial maze in which pigeons had to learn to peck a series of response keys in any order, but in which choice of the same key twice during a trial was not rein-



forced. Thus, this finding appears to have species and methodological generality.

Once again, the results suggest that animals have the ability to form representations or to make simple plans. Furthermore, their performance on the radial-maze task suggests that they are flexible enough to shift between responding on the basis of working memory for places they have already visited and the intention to respond to places they have not yet visited.

Common Representations

When two events are each associated with (or predict that) a response to a third will be reinforced, an emergent relation may develop between them. For example, when a child learns the properties of an object in its environment (e.g., a chair), it may also learn that a word (i.e., “chair”) can come to represent that object. When this happens, typically, the word becomes symbolically substitutable for that object. For example, one can now tell the child, “Put the ball on the chair,” and the command will be understood.

The conceptual interchangeability of objects and the symbols or words that represent them suggest that the two have become commonly represented or that they are functionally equivalent. Animals may be capable of a similar form of symbolic representation even though they do not have natural language. In the following sections, I describe the designs of several experiments that have been conducted to demonstrate the emergent relations that develop between stimuli that have been associated with a common event.

Transfer of training. One can train pigeons in a matching task to associate each of two samples with a common comparison—a task that is sometimes referred to as *many-to-one matching*. For example, a circle comparison is correct when the sample is either a red hue or a vertical line, and a dot comparison is correct when the sample is either a green hue or a horizontal line (see Table 1). One can then ask if the pigeon represents the red hue and the vertical line similarly. To answer that question, one could take a pair of those samples, say red and green hues, and associate them with new comparisons, say blue and white hues, respectively. If, without further training, the pigeons chose the blue hue when the sample was a

TABLE 1
Common-Coding–Three-Phase Transfer Design

Training		
Original	Interim	Transfer test
Red → Circle	Red → Blue	
Vertical → Circle		Vertical → Blue?
Green → Dot	Green → White	
Horizontal → Dot		Horizontal → White?

Note. During original many-to-one training, pigeons are presumed to represent samples associated with the same comparisons similarly. Evidence for such common coding is obtained by training the pigeons on an interim task in which one pair of samples (red and green) are associated with new comparisons (blue and white) and then testing the pigeons for emergent associations between the remaining (vertical and horizontal) samples and the new blue and white comparisons.

vertical line and a white hue when the sample was a horizontal line, then one would have evidence for the common representation of the red hue and the vertical line and the common representation of the green hue and the horizontal line. Urcuioli, Zentall, Jackson-Smith, and Steirn (1989) found significant transfer of training when they conducted such an experiment.

It is important to note that in the aforementioned example, the samples that were associated with a common comparison (i.e., the red hue and the vertical line, as well as the green hue and the horizontal line) were selected to be physically different. One could even argue that those stimuli were less similar to each other than they were to at least one of the stimuli associated with the other comparison (e.g., the vertical line and the horizontal line). Thus, the transfer of training that was found could not be attributable to generalization on the basis of stimulus similarity.

Discriminability of common representations. Further evidence for the common representation of samples associated with the same comparisons comes from convergent results from other experiments. For example, if samples that are associated with a common comparison are commonly represented, one might expect those samples to be more difficult to discriminate from each other than are the samples associated with two different comparisons. Kaiser, Sherburne, Steirn, and Zentall (1997) tested this hypothesis when they trained pigeons on a four-stimulus successive discrimination after training with the many-to-one matching that is described in the aforementioned transfer-of-training experiment. For the consistent group, two presumably commonly represented samples were associated with reinforcement (positive stimuli) and the other two commonly represented samples were not associated with reinforcement (negative stimuli), for example, red+, vertical+, green-, horizontal-. For the inconsistent group, the presumably commonly represented samples were mixed. That is, for each pair, one was positive and the other negative (e.g., red+, vertical-, green-, horizontal+; see Table 2). Kaiser et al. found that pigeons in the consistent group acquired the successive discrimination significantly faster than did pigeons in the inconsistent group. This finding supported the hypothesis that the pigeons commonly represented the samples that were associated with the same comparison.

Partial versus total reversal. In a similar vein, if many-to-one matching results in the development of common representations, it should be more difficult for the subjects to reverse one pair of those associations (e.g., the associations involving the vertical and the horizontal line samples) than it should be to reverse both pairs of associations (i.e., the associations involving both the line samples and the hue samples; see Table 3). According to this hypothesis, the partial reversal should be more difficult because the subjects would have to disrupt the common representations to reassign the line-orientation samples to new comparisons, while they presumably leave the hue-sample associations intact. In the case of the total rever-

TABLE 2
Design of Common-Coding Experiment:
Discriminability of Common Representations

Original training	Simple successive discrimination training	
	Consistent	Inconsistent
Red → Circle	Red+	Red+
Vertical → Circle	Vertical+	Vertical-
Green → Dot	Green-	Green-
Horizontal → Dot	Horizontal-	Horizontal+

Note. Following many-to-one matching training, discriminability of presumably commonly coded stimuli (inconsistent) is compared with discriminability of stimuli presumably coded differently (consistent).

TABLE 3
Design of Common-Coding Experiment:
Partial Versus Total Reversal

Original training	Reversal	
	Partial	Total
Red → Circle	Red → Circle	Red → Dot
Vertical → Circle	Vertical → Dot	Vertical → Dot
Green → Dot	Green → Dot	Green → Circle
Horizontal → Dot	Horizontal → Circle	Horizontal → Circle

Note. Following many-to-one matching training, for one group one member of each pair of presumably commonly coded stimuli is reversed (partial reversal) and for the other group both members of each pair of presumably commonly coded stimuli are reversed (total reversal).

sal, if the hypothesis is correct, the subjects should be able to maintain the common representations and simply assign each of them to the new comparisons. Zentall, Steirn, Sherburne, and Urcuioli (1991) found that, consistent with this hypothesis, the partial reversal was significantly more difficult to acquire than was the complete reversal.

Retention functions. Further support for the common-representation hypothesis comes from research that has examined the retention functions when delays are introduced between the offset of the samples and the onset of the comparisons. First, hue samples are typically more easily remembered than are line-orienta-

tion samples (Farthing, Wagner, Gilmour, & Waxman, 1977; Urcuioli & Zentall, 1986). However, if many-to-one training resulted in the common representation of samples that are associated with the same comparison (e.g., a red hue and a vertical line), one would expect that differences in the rate of forgetting on line-orientation and hue-sample trials should be greatly reduced. Zentall, Urcuioli, Jagielo, and Jackson-Smith (1989) reported an effect that was consistent with this hypothesis.

Interference and facilitation. Zentall, Sherburne, and Urcuioli (1993) reported additional evidence for the common representation of samples that are associated with the same comparison. They used a design similar to that devised by Urcuioli et al. (1989) to train pigeons in many-to-one matching. They trained the pigeons to associate one pair of those samples (e.g., red and green hues) with new comparisons, and after acquisition, they introduced a delay interval between the offset of the sample and the onset of the comparisons. When the remaining samples from original training (i.e., vertical and horizontal lines) were inserted into the retention interval between the offset of the sample and the onset of the comparisons, relative to no interpolated stimulus (see Table 4), Zentall et al. found that there was facilitation of matching when the interpolated stimulus had been associated with the same comparison in original training (e.g., vertical lines following a red sample), whereas interference was found when the interpolated stimulus had been associated with the other comparison in original training (e.g., horizontal lines following a red sample).

TABLE 4
Design of Common-Coding Experiment: Interference and Facilitation

Training		
Original	Interim and delay	Delay testing
Red → Circle	Red → Blue	Red - [Dark(0)] → Blue
Vertical → Circle		Red - [Vert(+)] → Blue
		Red - [Horiz(-)] → Blue
Green → Dot	Green → White	Green - [Dark(0)] → White
Horizontal → Dot		Green - [Horiz(+)] → White
		Green - [Vert(-)] → White

Note. Following many-to-one matching training, and interim training in which one member of each presumably commonly coded pair is associated with a new comparison stimulus, the remaining samples from original training are inserted into the retention interval between the offset of the sample and the onset of the comparisons to assess facilitation (if during original training the inserted stimulus was associated with the same comparison as the sample) and interference (if during original training the inserted stimulus was associated with a comparison different from the sample relative to no inserted stimulus [Dark]).

The experiments that are described in this section on common representations all start with a training phase that involves many-to-one matching. In my attempt to provide a rationale for each experiment, I argued that if samples that are associated with a common comparison were similarly represented, those common representations should have properties that are different from those of the stimulus representations. This strategy has resulted in a series of experiments that involve many-to-one matching and that have provided a body of convergent evidence for the development of common representations.

What Is the Nature of the Common Representation?

The terminology that one uses to describe a phenomenon may influence the kinds of questions one asks about the phenomenon. For example, one can describe the results of many-to-one matching in terms of the emergent relations that develop between samples that are associated with the same comparison. Alternatively, if one considers those samples as being commonly represented one may ask if the nature of the common representation can be specified. A curious finding first reported by Maki and Hegvik (1980) may provide a tool that can be used indirectly to assess the nature of the representation (see also Colwill, 1984; Grant, 1991) even though the direct assessment of the hypothesized common representation is not likely to be possible.

Typically, if one introduces a delay between the offset of the sample and the onset of the comparisons after matching training with, say, hue samples, the resulting retention functions for trials that involve the two samples tend to be parallel and overlapping. However, Maki and Hegvik (1980) found that when they trained pigeons to match food as one sample and the absence of food as the other, and then inserted delays between the offset of the sample and the onset of the comparisons, the retention functions on food-sample trials were different in slope from the retention functions on absence-of-food trials. As the retention interval increased, the food-sample retention functions were steep, whereas the absence-of-food-sample retention functions were shallow. The fact that matching accuracy on food-sample trials often declined to a level below 50% correct (see Grant, 1991) suggested to researchers that the pigeons had adopted a single-code–default-coding strategy. That is, on food-sample trials, the pigeons coded (or represented) the food sample, and, if they could remember it, they chose the comparison stimulus associated with that sample. On absence-of-food-sample trials, however, no stimulus was coded and the pigeons chose the alternative comparison by default. Thus, as the retention interval increased, when the pigeons forgot the food sample they chose the alternative comparison with increasingly greater probability. On the other hand, on absence-of-food-sample trials, because no stimulus was coded, there was no opportunity for forgetting and matching accuracy remained high.

It is not important for the present purpose to establish whether the pigeons'

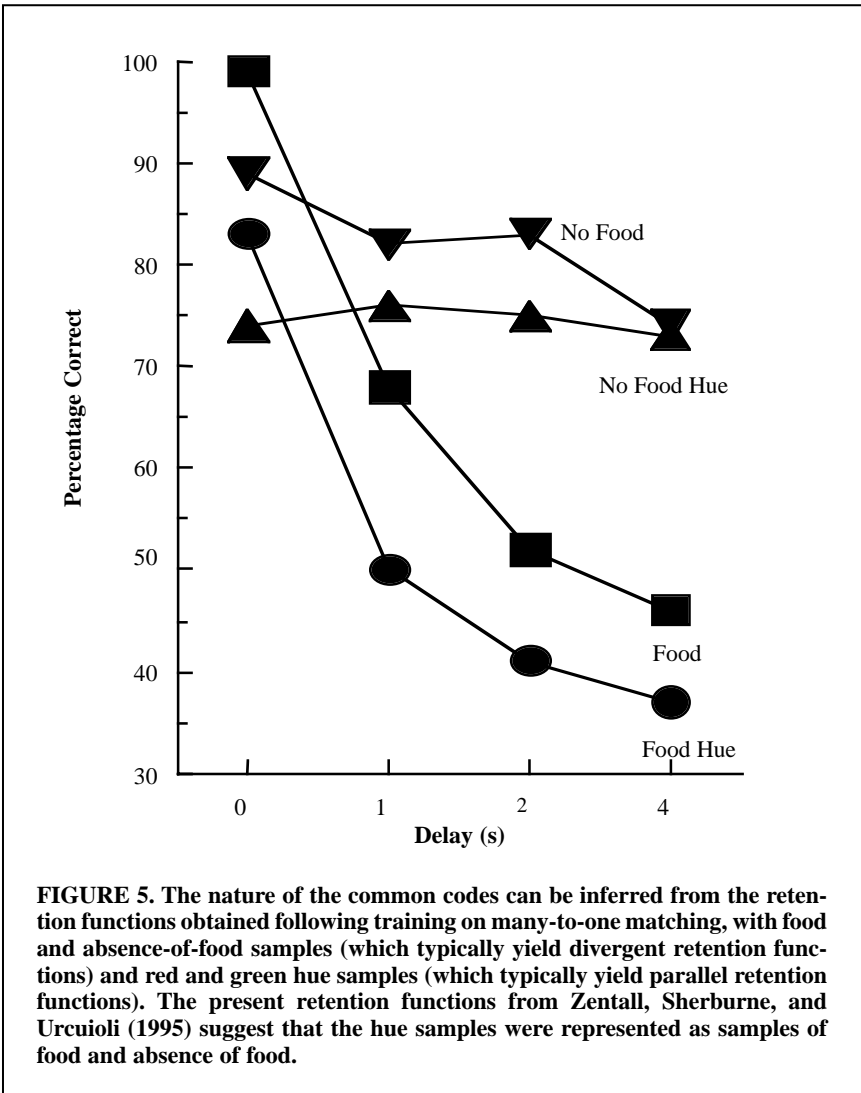
adoption of a single-code–default-coding strategy is necessary to account for the findings of Maki and Hegvik (1980). It is only important that the retention functions for food- and absence-of-food sample trials diverge, whereas the typical retention functions for hue sample trials are parallel and overlapping.

We can now return to the original question. What is the nature of the common representation of samples that are associated with the same comparisons? If pigeons are trained on many-to-one matching with food and the absence of food as one pair of samples and red and green hues as the other pair of samples, one can examine the retention functions for trials involving each pair of samples. If samples that are associated with the same comparison are commonly represented, then the slopes of the retention functions for the trials that involve those samples should be similar. One possibility is that all of the retention functions would be parallel and overlapping because the food- and absence-of-food-sample retention functions would conform to the retention functions for trials that involve the hue samples. Alternatively—and perhaps because of the salience and importance of food for the pigeon—the hue-sample retention functions would conform to the retention functions for trials that involve food and the absence of food as samples, and both pairs of retention functions would be divergent. That is, in fact, what Zentall, Sherburne, and Urcuioli (1995) found (see Figure 5).

Results that are consistent with the common-representation hypothesis have also been found in an experiment in which the presence–absence samples consisted of a nonhedonic event (the presence vs. the absence of a hue) and the other pair of samples consisted of shapes (a small vs. a large circle). The divergent retention functions that were found for trials involving the presence–absence samples were also found for trials involving the shape samples (Neiman & Zentall, 2001), although the retention functions were somewhat different from those reported by Zentall, Sherburne, and Urcuioli (1995) perhaps because of the reduced salience of the presence–absence.

Samples that are associated with a common comparison are not only similarly represented by the pigeon, but each representation appears to take the form of one of the samples. Furthermore, the results of the two experiments that have been described suggest that the representation is based on the more salient (or perhaps the more meaningful) of the two samples.

Results that support the hypothesis that pigeons may commonly represent samples associated with the same comparison also can be viewed as evidence that pigeons can develop symbolic representations that are analogous to the meaning that is ascribed to words in human language. In the case of many-to-one matching by pigeons, it appears that a vertical-line sample can come to represent a red-hue sample, in much the same way that a word can come to represent an object. And just as the word can be substituted for the object in some situations, so too can the vertical-line sample be substituted for the red-hue sample in the transfer of training design.



Transitive Inference

The transitive inference task comes directly from research in which a child is asked, "If Alice is taller than Barbara and Barbara is taller than Carol, who is taller, Alice or Carol?" The rationale for this task is that a correct response to the question should require the child to use Barbara as a mediator to arrive at a logical solution to the problem. This is seen more readily when the problem is presented in its more general form: If $A > B$, and $B > C$, then $A > C$.

Developmental psychologists recognized that there might be a simpler solution to the problem for which a logical solution is not required when it is presented in this form because Alice is taller than someone, but Carol is not (see Bryant & Trabasso, 1971). Thus, this solution does not require the child to use Barbara as a mediator. Researchers have addressed the possibility that children might use this nonmediational solution by adding a term at either end of the chain to make it a 5-term problem: "If Alice is taller than Barbara and Barbara is taller than Carol and Carol is taller than Diane and Diane is taller than Edith, who is taller, Barbara or Diane?" In this case, both Barbara and Diane have been cast in the role of "taller than" in one of the propositions (as well in the other role in one of the propositions). When Bryant and Trabasso tested children on this form of the task, they found clear developmental differences.

A nonverbal analog of the transitive inference task. The verbal nature of the transitive inference task gives it the quality of being a purely relational task. In the aforementioned example, one does not have to know anything about the absolute height of any of the individuals in the problem to arrive a correct solution. This makes it difficult to conceive of a way in which the task could be modified for use with animals. However, McGonigle and Chalmers (1977) reasoned that the propositions that were provided to humans could be translated into simple simultaneous discriminations as long as the absolute value of each of the items in the list was comparable. This could be accomplished by using the 5-term task, by training with four discriminations—for example, A+B-, B+C-, C+D-, D+E- (in each case, + indicates the correct stimulus and - the incorrect stimulus)—and by testing with the BD pair. The rationale is that such training might establish the ordering of stimuli that involve the relation "better than," such that A is better than B, B is better than C, C is better than D, and D is better than E. Furthermore, the B and D stimuli would never have been presented together in training, and each one would have been a positive stimulus in one discrimination (B+C- and D+E-), and a negative stimulus in another (A+B- and C+D-). McGonigle and Chalmers trained monkeys on these simultaneous discriminations and when they tested them with the BD pair, they found that the monkeys showed a significant preference for B over D.

In later research, it was reported that chimpanzees (Gillan, 1981), rats (Davis, 1992), and even pigeons (Fersen, Wynne, Delius, & Staddon, 1991) showed similar transitive choice. Thus, transitive choice has been found in a variety of species. Furthermore, several manipulations of the stimulus pairs support the conclusion that inferences develop, at least in chimpanzees (Gillan). Gillan extended the series by adding a fifth pair of stimuli (i.e., E+F-), and he found that the chimpanzee showed a preference for B over E, and C over E, as well as B over D. But when he created an ambiguous (logically impossible) ordering by training F+A-, he found that the chimpanzee was indifferent when it was tested for those same relations (BE, CE, and BD). Furthermore, the three test preferences returned (i.e., B

over E, C over E, and B over D) when he reversed the last-trained link (i.e., by training A+F-).

Value transfer as an alternative account. Sometimes the value of a cognitive hypothesis, such as transitive inference, is to provoke others to consider alternative accounts of an otherwise poorly understood phenomenon. Fersen et al. (1991), for example, suggested that such a transitive choice may not reflect the development of a true transitive inference because a form of stimulus generalization (or transfer of value) between the positive and negative stimulus in a simultaneous discrimination could provide an alternative account. According to this view, whenever a simultaneous discrimination is acquired, some of the value of the S+ transfers to the S- with which it appeared, even though the two test stimuli are likely to have the same direct value associated with them because each was designated as an S+ and an S-. However, Fersen et al. reasoned that Stimulus A should have had more value to transfer to Stimulus B than Stimulus C had to transfer to Stimulus D because Stimulus A appeared only as an S+, whereas Stimulus C appeared as an S+, in the context of Stimulus D, and as an S- in the context of Stimulus B. Fersen et al. suggested that it was the differential transferred value that accounted for the stimulus preference for B over D on BD test trials.

Zentall and Sherburne (1994) have reported that direct tests of this hypothesis demonstrated that such transfer of value can occur. That is, if pigeons are trained on two simultaneous discriminations in which the two positive stimuli have different values (e.g., $A_{100}B_0$ and $C_{50}D_0$, where the subscript indicates the probability of reinforcement given a response), then on test trials the pigeons reliably prefer B over D. Zentall, Sherburne, Roper, and Kraemer (1996) later reported that the mechanism by which value appears to transfer from the S+ to the S- with which it was presented is likely to be Pavlovian higher order conditioning. That is, after training, the appearance of Stimulus B signals the presence of the higher quality Stimulus A, whereas the appearance of Stimulus D signals the presence of the lower quality Stimulus C.

Transitive inference in the absence of differential value transfer. Weaver, Steirn, and Zentall (1997) argued that such results did not rule out a preference on test trials on the basis of some form of linear ordering of the stimuli (or inference), even though value transfer appears to provide a more parsimonious account of previous findings on transitive inference. In a set of three experiments, Weaver and colleagues presented pigeons with a series of four simultaneous discriminations that maintained the appropriate sequential "better than" relation among them, and at the same time they attempted to eliminate differential value transfer from the stimuli with which the test stimuli were paired in training. To equate the test stimuli for transferred value, they trained the pigeons with the following simultaneous discriminations: $A_{50}B_0$, $B_{100}C_{50}$, $C_{50}D_0$, and $D_{100}E_{50}$. Thus, A and C should have had comparable value to transfer to B and D, respectively. Furthermore, training with

these values should have maintained the $A > B$, $B > C$, $C > D$, $D > E$ relation that is presumed to be needed to obtain a transitive choice. When pigeons that had been trained in this way were given BD test trials, they still showed a significant preference for B over D. Thus, in spite of the presumed nondifferential value transfer to the test stimuli, a significant transitive choice was found.

Regardless of whether further research supports the hypothesis that pigeons can create a relative linear ordering of the value of stimuli following simultaneous discrimination training of the kind described here, the fact that researchers asked if such learning was possible led them to carry out further experiments on transitive choice. And the results of those experiments can be applied to the presumably related phenomenon of value transfer (see Zentall & Clement, 2001), and not only to the original question of transitive inference.

Imitation

The study of imitative learning by animals has been of interest to researchers in part because the mechanism that is thought to be responsible for such learning in humans is one that is supposed to become available to children only as they reach the concrete operational stage of cognitive development (i.e., at 5–7 years). Piaget (1955) asserted that true imitative learning requires that the observer be able to “take the perspective” of the demonstrator. He reasoned that a young child does not yet understand the relation between its own body (especially unseen body parts), and the bodies of others. Thus, according to Piaget, if an adult says, “Do this” while placing his hand on his own head, young children would probably not be able to comply because they do not understand what to do to create the same result. Older children, however, know the relation between unseen body parts and can achieve the goal—a goal that can be described as a body position that would be judged by a third party to be similar to that of the adult.

If perspective taking is a necessary mechanism for the ability to learn through imitation, it is unreasonable to expect that animals (with the exception perhaps of the great apes and also dolphins) will be able show such learning. On the other hand, perspective taking may not be necessary or there may be some precursor of perspective taking that is sufficient to support imitative learning. The defining characteristic of imitation is that the behavior of the demonstrator should determine the behavior of the observer, rather than of other associated variables. In any case, the search for imitative learning is an empirical question that requires the careful exclusion of other forms of social influence and social learning (see Zentall, 2001). Many of these extraneous variables can be identified and their effects either avoided or controlled.

As will become apparent, the question of whether animals are capable of imitative learning has led to the identification of numerous socially mediated mechanisms that can produce behavior change. Thus, the question of imitation by animals has had considerable heuristic value.

Social Influence

Contagion. Certain kinds of species-typical behavior can be released by the presence of another animal of the same species (a conspecific) engaged in that behavior. For example, a sated animal in the presence of food can be induced to eat immediately by the introduction of a hungry conspecific. In humans, yawning and laughing are both behaviors that can be released by the presence of others engaged in either of those activities. Thus, to control for species-typical released contagion, the behavior that one selects to be imitated should be relatively arbitrary.

Social facilitation. The effect on task performance of the mere presence of a conspecific can be either facilitative or detrimental (Zajonc, 1965). Zajonc has suggested under what conditions facilitation should occur, but it is still important to control for whatever effects the presence of a conspecific might have.

Fear or stress induction. When demonstrators acquire or perform tasks that are motivated by attempts to avoid aversive stimulation, they may display behavior that is indicative of pain or fear, and such behavior may induce a similar reaction in the observer. The induced motivational state of the observer may affect the rate at which the observer acquires the avoidance response in a way that would not be considered imitative learning (e.g., Kohn & Dennis, 1972).

Social Learning

Matched dependent behavior (discriminated following). Rats can learn to follow other rats to food (Church, 1957), but such discriminative learning is different from imitation because it is acquired through differential reinforcement of the choices of the observer during the period of observation. Although the demonstrator provides a social stimulus that may release affiliative behavior and facilitate acquisition, one could also train the observer with the use of any salient cue (e.g., a block of wood that the observer would be rewarded for following), and one would not consider such learning to be imitative.

Local enhancement. Learning can be facilitated by the observation of a conspecific performing a response, such as pressing a bar for food, because the demonstrator's behavior causes the bar to move and that draws the observer's attention to the bar. One way to avoid the effects of local enhancement is to use what has been referred to as the *duplicate cage apparatus* (Warden & Jackson, 1935). With this procedure, the demonstrator and the observer both have bars to press, and because the observer's attention is drawn to the demonstrator's bar by the movement, the observer's attention should be drawn away from its own bar and its learning should be retarded. Zentall and Levine (1972) used the duplicate cage apparatus and compared the acquisition of bar pressing by rats that observed

another rat pressing a bar for reward with the bar-press acquisition of rats that observed (a) another rat obtaining reward without having to press a bar, (b) another rat neither pressing a bar nor obtaining reward (a social-facilitation control group), and (c) an empty chamber (a trial-and-error control group).

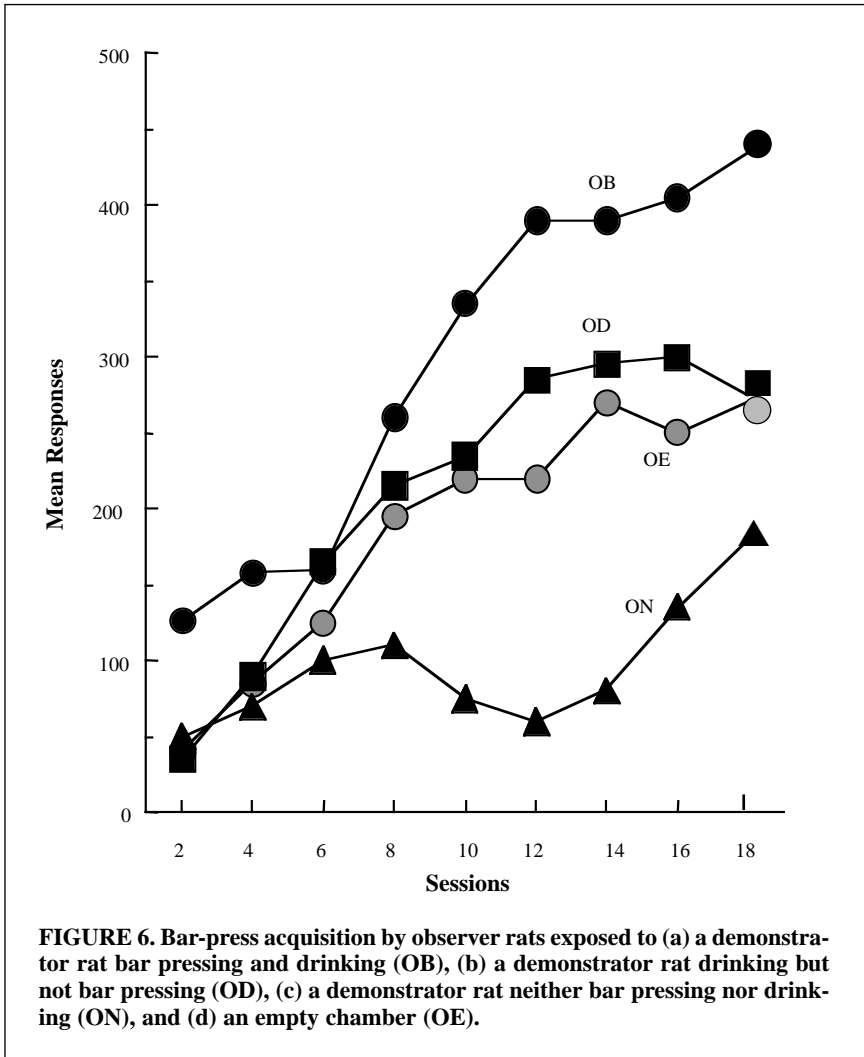
Zentall and Levine (1972) found that rats that observed another rat pressing a bar for reward acquired the bar-pressing response the fastest, and rats that observed another rat neither pressing a bar nor obtaining reward acquired the bar-pressing response the slowest. Those that observed another rat obtaining reward without having to press a bar acquired the bar-pressing response at a rate between the fastest and slowest groups (see Figure 6). However, rats that observed an empty chamber acquired the bar-pressing response faster than did the social-facilitation controls and as fast as the rats that observed the demonstrators drinking water. Apparently, the mere presence of another rat retards acquisition but if that other rat is engaged in a behavior that is relevant to the observer's state of motivation, it is sufficient to overcome the negative effects of the demonstrator's presence.

Stimulus enhancement. Galef (1988) noted that experiments that are conducted in the duplicate cage apparatus may rule out local-enhancement effects, but the similarity between the demonstrator's bar and the observer's bar could lead to generalization or stimulus enhancement, which would result in the observer's attention being drawn to its own bar as well. The possibility of facilitation of learning through stimulus enhancement presents a problem for the study of imitation in animals because at a conceptual level it is important that the two bars and the responses to them look alike; otherwise the observer may not understand the relevance of the demonstrator's response.

Emulation of affordances. Finally, there should be a distinction between imitation and the emulation of affordances. *Affordance emulation* refers to the effect that the demonstrated response has on the environment. It refers to learning, but it is learning how things work—unlike local enhancement, which refers to the attention-getting value of the movement observed. For example, Bunyar and Huber (1999) allowed marmosets to observe conspecifics entering a food box through a door that was hinged at the top by pulling it toward themselves or pushing it away from themselves. The observers generally opened the door in the way in which they had seen it demonstrated, but they could have learned through observation of “how the door works” rather than from the demonstrator's movements that were required to open the door.

True Imitation

The two-action method. Dawson and Foss (1965) reported that when they allowed budgerigars (a variety of parakeet) to discover how to remove a cardboard cover from a food container, the birds learned to remove the cover in different ways,



either by pushing or flipping the card with their beaks or by pulling the card with their claws. Of greater interest, each observer removed the card in the way in which it had seen its demonstrator do it. These results, as with those of Bunyar and Huber (1999), can be accounted for in terms of affordance emulation because the cards moved in different ways for each of the three different behaviors. However, a variation of this procedure in which the two responses have the same effect on the environment cannot be explained in this way (Zentall, Sutton, & Sherburne, 1996). In this experiment, demonstrator pigeons either stepped on a treadle or pecked at the treadle to obtain a food reward. Observer pigeons that

watched only one response showed a significant tendency to respond in the same way in which they had seen the demonstrator respond. Akins and Zentall (1996) repeated this experiment with the use of Japanese quail, which is a more affiliative species, and they reported even larger imitation effects. Thus, at least pigeons and Japanese quail appear to show clear evidence of imitative learning (see also, Akins & Zentall, 1998; Dorrance & Zentall, 2001).

These experiments cannot help determine whether perspective taking plays a role in birds' ability to learn. However, given the fact that such an ability does not appear in humans until they are about 5 years old, one should consider the possibility that information is transmitted by the demonstrators to observers in ways that we may not be able to specify at this time.

The value of research on imitative learning in animals goes beyond the cognitive implications of imitation. Researchers have identified several mechanisms of social influence and social learning in their attempts to define which processes should not qualify as imitation. These phenomena, which are worthy of examination in their own right, had not been well defined or studied in earlier research. Furthermore, research on imitation in animals has implications for the study of imitative learning by humans. There has been no attempt to separate imitative learning by children from other social influences that are known to affect learning, although it is clear that even very young children are capable of imitating.

Work Ethic

If one can develop an analogy to a cognitive task that has been used with humans and can show similar behavior in animals, then three possible conclusions can be drawn. First, it may be that animals are capable of a greater degree of cognitive behavior than researchers had thought. In the case of research on cognitive maps, it would appear that animals such as rats and dogs have some ability to represent space to the extent that they can take novel paths that lead more directly to reward.

Second, it is possible that the analogy is not a good one. In the case of the analogy to the transitive inference task, it may be that a simple simultaneous discrimination (of the type, red is correct, green is incorrect) is not sufficiently similar to a verbal proposition (of the type Alice is taller than Barbara). Further research may clarify whether the two tasks produce similar results.

Third, it may mean that there is a simpler account of the behavior in humans and that the research with animals may make it more likely that a simpler account is considered. I think that the "work-ethic" effect in animals is such a phenomenon. *Work ethic*, which is sometimes referred to as overjustification of effort (Aronson & Mills, 1959), can be described as the greater value given to a reward when the reward is difficult to obtain. The phenomenon of work ethic is part of a more general phenomenon known as cognitive dissonance (Festinger, 1957), and it has been attributed to the dissonance that arises when an individual works

hard for a reward that may not otherwise be worth the effort. According to this theory, although it would be difficult to deny that the work was done, to resolve the dissonance, it would not be so difficult to subjectively adjust the value of the reward upward. The notion of dissonance between behavior and beliefs and the idea that humans should want to resolve that dissonance appear to require a rather complex human motivational system, one that is mediated by social learning. If humans need to show consistency between their beliefs and their behavior, it is probably because such consistency is valued by others (i.e., it is probably socially rewarded). But it would be hard to imagine such complex socially mediated cognitive behavior in a pigeon.

Clement, Feltus, Kaiser, and Zentall (2000) reported evidence that was consistent with the finding of work ethic. They trained pigeons on a task in which trials started with the presentation of a circle projected on the center response key. On half of the trials, a single peck was sufficient to turn off the circle and project, for example, red and yellow on the side keys. A response to red was reinforced, and a response to yellow was not. On the remaining trials, it took 20 pecks to turn off the circle and to turn on green (correct) and blue (incorrect) side keys. When the pigeons were allowed to choose between red and green after training, they preferred the green. Thus, the pigeons preferred the positive stimulus that followed the greater effort (20 pecks) over the positive stimulus that followed the lesser effort (1 peck). This effect is directly analogous to the overjustification-of-effort effect reported by Aronson and Mills (1959), in which humans were found to give greater value rewards (e.g., membership in a club) when it was harder to qualify for membership than when it was easier to qualify for membership. Or as Groucho Marx is reputed to have said: "I would not want to belong to a club that would have me as a member."

This effect may result from an attempt to resolve the dissonance between beliefs and behavior in humans, but it is unlikely to do so in pigeons. In the case of pigeons, one would first look for a simpler account. There is a substantial body of literature by researchers who have found that behavior is based not only on the absolute value of the outcome obtained but also on the difference between the value of the outcome expected and that of the outcome actually obtained—the so-called contrast effects (Flaherty, 1996). Procedures in which contrast has been reported differ considerably, depending on whether the contrast occurs between phases of the experiment (incentive contrast, Crespi, 1942), between trials within a session (behavioral contrast, Reynolds, 1961), or in anticipation of a change in reinforcement value (anticipatory contrast, Flaherty, 1982). But in each case, the value of the reward is compared with the value of the preceding or expected hedonic state. Thus, in the case of the work-ethic effect found with pigeons, one can propose that the hedonic state of the pigeon immediately before the onset of the discriminative stimuli is poorer when 20 pecks are required than when only 1 peck is required. And it is the contrast between that hedonic state and the expectation of reward when the discriminative stimuli appear, that determines the rel-

ative value of those stimuli. The greater the contrast, the greater the value of the discriminative stimuli (see also Clement & Zentall, 2002).

The possibility that contrast may be responsible for the work-ethic effect does not mean that this effect can be easily dismissed. After all, calling it contrast describes only the effect and places it in the context of other effects that appear to have a relative motivational (incentive) basis. Instead, describing the work-ethic effect as a form of contrast suggests that similar effects that have been found in humans may also be attributable in part to contrast effects. For example, Is it possible that the overjustification of effort that is found in humans is caused by the relatively large shift in value from the negative state engendered by hard work to the positive state elicited by the reward, and not by the resolution of dissonance? A much smaller shift would be expected when the reward is preceded by less work. The results of studies on work ethic in pigeons suggest that it may be useful to reexamine the cognitive dissonance literature for the potential contribution that simpler contrast effects may play.

Conclusions

The examples described in this article were selected in part because of their heuristic value. They represent attempts to assess the cognitive capacities of animals, and they often raised questions that might otherwise not have been raised.

Many topics that have been considered important examples of animal cognition have not been mentioned in this article. Some of these, such as language training, the use of tools, and numerical competence have not been addressed because of the absence of a clear definition of behavior, which, if found, would clearly offer support for the existence the capacity. Others, such as same-difference concept learning, timing, and serial pattern learning, were omitted to keep the length of this article within manageable bounds. The interested reader should consult an excellent book by Roberts (1998) for a discussion of these capacities in animals.

The cognitive behaviorist approach that is used in the research described in this article provides a useful tool for the exploration of animal learning capacity. It is a tool that is less likely to be used by those who take other approaches that have been popular in behavioral research conducted with animals (e.g., Hull, 1943; Skinner, 1938). When researchers are strongly committed to a particular theory (e.g., Hull) there is a tendency to view behavior from that perspective and not to be open to novel findings. Alternatively, the rejection of theory (e.g., Skinner) that occurred in reaction to the proliferation of complex models of learning (e.g., Hull) may not provide sufficient direction for research of the kind discussed here. I believe that the cognitive behaviorist approach that has been promoted in the present article combines a reasonable compromise. On the one hand, it embraces a theoretical approach, but not a particular theory; it allows for the design of more objective experiments; and it does not discourage researchers

from pursuing tangential findings. On the other hand, it adopts a theory-testing stance that provides researchers with the direction they need to describe research questions clearly. The examples provided in the present article demonstrate how useful this cognitive behaviorist approach can be.

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