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The Cognitive Animal

Empirical and Theoretical Perspectives on Animal Cognition

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Since the classic work by Kohler (1925/1976), Yerkes and Yerkes (1929), and Tinklepaugh (1932), researchers have been developing methods to investigate the minds of apes. In this essay, we present a set of principles that we use in guiding our joint and separate research programs that address cognition in great apes. The general questions that guide our research address broad cognitive skills such as symbolic representation and the role of memory in serial processing. We are interested in understanding how apes extract and use information in solving problems. As we attempt to characterize cognition, we develop methods that guide the ape through experimental procedures to reveal the cognitive processes involved in performing a task. We come to our research from different backgrounds, but with similar perspectives and goals. Shumaker is an evolutionary biologist interested in primate behavior and perception. Swartz is an experimental psychologist with a comparative development emphasis.

In light of the evolutionary closeness of humans and the other great apes, one assumption underlying our research is continuity of cognitive ability. Our own experiences, as well as data from the human literature, are useful as a reference point for developing procedures for investigating cognition in great apes. Although this assumption of continuity provides a starting point, we formulate specific research questions and develop methodologies that are appropriate to the behavior of the species being studied. We study these animals because we are interested in understanding them in their own right.

It is a common misperception that the behavior of apes is “analogous to,” “similar to,” “like,” or “equivalent to” young humans or humans with developmental delay. Although we can look at developmental parallels in the achievement of specific cognitive skills in apes and humans, we cannot make statements about overall ability.

Great apes are not the equivalent of preschool-age human children. For example, a $2\frac{1}{2}$ -year-old human and a $2\frac{1}{2}$ -year-old chimpanzee may both show the ability to recognize themselves in a mirror (Amsterdam 1972; Lewis and Brooks-Gunn 1979; Lin et al. 1992), but that does not imply the equivalence of other cognitive skills. Furthermore, Murofushi (1997) reported that an adult female chimpanzee has demonstrated the ability to numerically label random arrays of dots (ranging from one to six) faster than adult humans tested on the identical task. This does not imply that adults of both species share an overall equivalence in cognitive skill. The point is that a discussion of specific abilities generates meaningful comparisons, while a search for overall equivalence is unproductive.

Our empirical methodologies are diverse, depending on the cognitive process under investigation. While we frequently use classical and operant conditioning principles in our research design, the endpoint is not to document these forms of associative learning. Rather, we view these as techniques to initially convey information to the apes about the task at hand. Our intention is to create a situation that allows the ape to demonstrate the ontogeny of a particular cognitive skill or ability.

Our goal is to discover the nature of the internal psychological state and the series of cognitive operations that an animal successively passes through as a solution to a problem is achieved. Not only is it important to devise a task that will allow the ape to demonstrate the “how and why” of the solution, we also may find that some of our preexisting assumptions about the usefulness of a particular task, or the ability of a particular animal, may be challenged. What we may perceive as the most efficient means to elucidate the cognitive processes that lead to a solution may not be optimal, or could be completely in error. Complicating this problem is the inevita-

ble presence of significant behavioral and cognitive differences among individual apes (Boysen 1994). The challenge for the experimenter is to balance task and subject variables in such a way that reliable data are collected and the integrity of the research agenda is maintained.

In our program, we attempt to address these potential complications through a combination of short- and long-term studies. The short-term studies focus on discrete questions based on a well-defined cognitive capacity and have a clearly defined end point. In contrast, the long-term studies have no defined concluding point and are based on a graduated set of cognitive skills. Examples of short-term studies include mirror self-recognition (Swartz and Evans 1991, 1997), observational learning (Shumaker et al. 1998), quantity judgment (Shumaker et al. 2001), two-choice discrimination learning set formation (Shumaker et al. in preparation), and habituation and responses to novelty (Swartz et al. in preparation). Examples of long-term studies include a language acquisition study (Shumaker 1997) and an investigation of serial learning and memory (Swartz et al. in preparation).

The value of embedding short-term studies in a longitudinal research plan is that these short, well-defined studies can inform us about certain abilities of the animals and hence can indicate whether the methodology developed for the research program is sound. Discovering relatively quickly that a particular ability is demonstrated by our subjects gives us more confidence in our overall design. That is, it gives us confidence that the basic skills required for demonstrating more complex cognitive abilities are present, and that we have developed a methodology that can reveal them. Over time, what we consider to be the more sophisticated task evolves into a set of basic tasks that serve as stepping-stones to more complex cognitive processes.

From the ape's perspective, the advantage to embedding short-term studies in a larger research plan is that the well-defined questions of short-term studies instruct them about the basic

task, with smaller demands and greater opportunity for success. Most of the experimental tasks that we develop to ask cognitive questions of the apes are out of their range of experience and may initially appear confusing. By experiencing success along the way, the ape gradually becomes more sophisticated and better able to perform our experimental tasks. To address more concretely the issues raised here, we turn to some specific examples from our individual and joint research programs that illustrate our perspective.

When a Well-Established Methodology Fails: Mirror Self-Recognition by Gorillas

In 1970, Gallup presented the first observation of mirror self-recognition (MSR) in great apes. Four juvenile chimpanzees (*Pan troglodytes*) were each presented with a total of 80 hours of exposure to a mirror. Initially, each individual responded to the mirror image with social behavior, suggesting that it may have perceived the mirror image as an unfamiliar conspecific. Over the course of the mirror exposure phase of the study, the mirror-directed social behaviors waned, and mirror-guided self-directed behaviors appeared. These behaviors included such things as picking the teeth by using the mirror image to guide the hands, visually inspecting parts of the body that were otherwise visually inaccessible, and blowing bubbles with the mouth while visually inspecting the bubbles in the mirror. The presence of these mirror-guided self-directed behaviors was the first evidence that Gallup presented for MSR.

To obtain a more objective measure of self-recognition, Gallup devised a task that is commonly referred to as the "mark test." He anesthetized each animal and placed a red odorless mark on the forehead and opposite ear, locations that could not be seen by the chimpanzee without the mirror. Each ape was tested individually. When the chimpanzees recovered from the anesthesia, each was observed for a

control period without the mirror present, and the number of mark-directed responses was counted. Only one mark touch occurred during the control period, compared with a total of 27 mark-directed responses across the four chimpanzees when the mirror was present. The finding that each chimpanzee touched the mark on his or her own body rather than attempting to touch the mark on the mirror image provided convincing evidence to support the conclusion that the animals showed MSR.

Over the past 30 years, there has been much controversy about the best methods to use to study MSR, as well as which species do or do not show MSR. The mark test continues to be the task most often used to show MSR (Gallup 1994; Gallup et al. chapter 40 in this volume; Swartz and Evans 1991, 1994), although some researchers have used the presence of self-directed behavior as the criterion for MSR (Povinelli et al. 1993). Important features of the mark test are that the subject be unaware of the placement of the mark, that anesthetized animals be fully conscious during the control period as well as when provided with the mirror, that subjects be provided with sufficient nonmarked mirror exposure prior to conducting the mark test, and that the animals be of the appropriate developmental age when tested [although the developmental course of MSR is not yet understood in any of the great apes; see Swartz (1998)].

To date, despite numerous experimental attempts, MSR has never been clearly demonstrated by monkeys (Anderson 1984; Swartz 1998). MSR appears to be a phenomenon limited to apes, including lesser apes (Ujhelyi et al. 2000). Some, but not all chimpanzees older than $2\frac{1}{2}$ years of age show evidence of MSR using the mark-test criterion (Lin et al. 1992; Swartz and Evans 1991, 1997). Orangutans (*Pongo pygmaeus*) appear to show MSR when tested under conditions similar to those used with chimpanzees (see Swartz et al. 1999). No mark test has been presented to a bonobo (*Pan paniscus*), but they have been reported to show self-directed

behavior when presented with a mirror. While MSR is universally accepted for chimpanzees and orangutans, the presence of this ability in gorillas (*Gorilla gorilla gorilla*) is hotly debated and still unresolved (see Swartz et al. 1999).

Koko, a gorilla proficient in sign language, has demonstrated clear evidence that she recognizes herself in the mirror (Patterson and Cohn 1994). Of 23 gorillas tested for evidence of MSR (Shillito et al. 1999; see Swartz et al. 1999), only 6 individuals provided any evidence for this ability. Studies have been conducted with 6 orangutans, with 5 demonstrating MSR (see Swartz et al. 1999), and 163 chimpanzees have been tested, with 73 showing MSR (see Swartz et al. 1999). As in other areas of scientific inquiry, such as tool use, chimpanzees are overwhelmingly represented in the literature, making them the de facto standard for comparison (Beck 1982; Swartz et al. 1999). We believe that the use of a “chimpanzee standard” when investigating MSR is an excellent example of faulty expectations on the part of the experimenter. Specifically, all studies investigating MSR in gorillas have defined the phenomenon as it appears in chimpanzees and have limited their methodology to that which has been successful with chimpanzees.

The fact that gorillas have frequently failed the traditional mark test has at least two possible explanations. First, it could be that gorillas are simply incapable of understanding their own reflection in a mirror (Gallup 1994; Shillito et al. 1999). Second, it might be that the mark test is not an effective way to test gorillas and that a reasonable variant of the mark test that is more compatible with gorilla behavior would allow the expression of the capacity.

Koko and the other five gorillas cited in the literature (see Swartz et al. 1999) eliminate the first explanation as a valid possibility. To assess the validity of the second possibility, we modified the traditional mark test and administered this new procedure to Mopie, an adult male gorilla who had previously been reported to fail a traditional mark test (Shillito et al. 1999).

Our modification was designed to increase motivation to attend to the mirror image and to the location of the mark (Swartz and Shumaker in preparation). Mopie was provided with additional mirror exposure beyond what he had had previously (Shillito et al. 1999). Each day before receiving mirror exposure, Mopie was engaged by the experimenter in a trading interaction. The experimenter placed an adhesive-backed, red, 2-cm-diameter paper dot (of the type used to mark file folders) on various parts of Mopie's home enclosure, one at a time. If Mopie peeled the dot from the enclosure and gave it to the experimenter, he received a treat. Placement of dots began on the enclosure, but proceeded to body areas that were clearly visible to Mopie without the use of the mirror. On two or three trials each day that the dots were placed on his body, Mopie was asked to present his head and a dot was placed there above his eyes and removed before the end of the session by the experimenter.

When Mopie was reliably pulling each visible dot from his enclosure or his body and presenting it to the experimenter mark test were begun. One of the dots was left on his head for the mirror exposure period, although as in the previous sessions the experimenter behaved as if it had been removed. On the seventh mark test, Mopie removed the dot from his head, using the mirror to guide his hand. He then immediately presented the dot to the experimenter and received a reward. That mirror-guided dot-directed behavior occurred within two minutes after the mirror was presented. Two unsuccessful mark tests followed and further attempts to replicate this procedure were abandoned because Mopie was aware of the application of the dot, and checked his head by sweeping one hand across his brow (in a motion that was distinctly different from the mirror-guided removal of the dot performed previously) whenever it was touched in the trading session and before a mirror was available.

We then replaced the adhesive dots with the beam from a laser pointer to present a red dot on the enclosure and on Mopie's body. Each time

that he touched the laser spot, Mopie received a reward. Once he was reliably touching each laser spot, we presented a laser spot on his head during mirror exposure. Mopie made no apparent attempt to touch this spot. Given his previous performance with the paper dot, we attempted another slight variation. Instead of shining the laser beam on his head, the dot was placed directly under his chin onto his chest and was invisible except in the mirror reflection. During this presentation, he looked directly at his reflection in the mirror and placed an index finger over the laser dot. He then extended his hand for a reward (Swartz and Shumaker, in preparation).

This slight modification of the traditional mark test provided motivation for the gorilla to find and remove the adhesive dot, or to find and touch the laser spot. Although it may have been the case that some tactile sensation was produced from the adhesive dot, Mopie did not remove the dot from his head until he looked in the mirror. He clearly used the mirror reflection to guide his hand during removal of the dot. Any potential problem in interpretation based on possible tactile cues was eliminated by the use of the laser pointer. We think that this is a clear example of how a traditional test, although powerful with chimpanzees, is not appropriate for gorillas. A modification of the procedure provided the opportunity for the gorilla to demonstrate an ability that was in question.

This example illustrates the value of short-term studies in the context of a long-range research program. Mopie's demonstration of a specific ability, MSR, not only provides strong evidence that he has the ability to perform this task, but also suggests an alternative method for exploring this phenomenon in other gorillas and possibly other species. Knowing that Mopie has the ability to show MSR allows us to develop a long-term study of related but more complex cognitive skills involved in mental state attribution, often termed "theory of mind" (Gallup 1982; Premack and Woodruff 1978).

When Nonexperimental Observations Conflict with Controlled Studies: Observational Learning by Great Apes

Observational learning, also frequently called “social learning,” is the process in which an observer acquires a behavior by watching another individual, referred to as the demonstrator, perform that same behavior (Galef 1988). There are three different forms of observational learning. In order of complexity, they are social facilitation, stimulus enhancement, and imitation. Social facilitation refers to a situation in which a behavior appears to be “contagious.” A flock of birds taking off one by one is an example. Stimulus enhancement describes a change in an observer’s behavior toward some object in the environment as a result of seeing a demonstrator have a positive experience involving that object. If one monkey in a group uses a stick to obtain a favored food that is otherwise out of reach, and another monkey shows greater interest in holding and manipulating sticks as a result, stimulus enhancement would be a likely explanation for his increased attention toward sticks. Stimulus enhancement does not imply that the observer understands the full behavior, but is simply attracted to some object associated with a behavior. Imitation, the most sophisticated form of observational learning, describes a situation where an observer exactly replicates a new or unfamiliar behavior after watching a demonstrator perform that same behavior. A clear act of imitation implies that the observer has the mental ability to understand a situation from the demonstrator’s point of view.

It is generally accepted that a variety of monkey species show evidence for social facilitation and stimulus enhancement, but not for imitation (Nishida 1986; Beck 1980; Visalberghi and Fragazy 1990; Whiten and Ham 1992; Zuberbühler et al. 1996). The forms of observational learning that exist for great apes are less clear. The current debate is focused on whether great apes are

capable of imitation. Observations of wild great apes argue for the existence of all three forms of observational learning (Goodall 1986; Boesch 1991). The behaviors that exist in different groups of wild great apes vary (Boesch 1994; McGrew 1994; Tomasello 1996) and are persistent at the local population level. As individuals move among groups, these behaviors spread rapidly and become fixed within a population (Huffman and Wrangham 1994; Wrangham and Goodall 1989). One likely explanation for this behavioral change is imitation between immigrating demonstrators and observers from the local population. Apes in the wild have also been reported to imitate behaviors that were performed by humans (Russon and Galdikas 1995).

In captivity, imitation has been documented for apes that have been subjects in language research experiments. These imitative acts have been reported to occur spontaneously as well as at the request of the experimenter (Hayes and Hayes 1952; Miles et al. 1996; Gardner and Gardner 1969; Savage-Rumbaugh and Lewin 1994).

However, the results from some captive studies that have been specifically designed to test great ape observational learning abilities conflict with these observations (Tomasello et al. 1987; Nagell et al. 1993; Call and Tomasello 1994, 1995). Much like the previously mentioned studies of MSR, we suggest that these investigations failed to consider the perspective of the apes that served as the subjects.

Nagell et al. (1993) presented 2-year-old humans and chimpanzees of varying ages with a tool task to assess their ability to imitate. Initially, both the human and ape subjects were given the opportunity to observe a human demonstrator use a rake to obtain an out-of-reach food reward. The demonstration was performed without error. When given the chance to try the task themselves, the humans clearly imitated the performance of the demonstrator. The chimpanzees did not imitate, but devised their own suc-

cessful methods to obtain the food with the rake. The authors concluded that the humans clearly imitated, while the chimpanzees focused more on the results of the activity rather than the process that was used to acquire the reward. The same study was carried out with orangutans (Call and Tomasello 1994), yielding similar results, even when the study was modified to include an orangutan demonstrator.

Call and Tomasello (1995) further investigated the observational learning skills of orangutans and human children. Both groups observed a human demonstrator either push, pull, or rotate a rod that was attached to a box. A specific sequence of movements resulted in a food reward being delivered. The human demonstrator knew the sequence in advance and performed it in front of both groups. The humans reliably imitated, while the orangutans did not, even with an orangutan demonstrator. It is interesting that the humans were never tested using an ape demonstrator.

Shumaker et al. (1998) report that under a different methodology orangutans can clearly imitate the behavior of a demonstrator. In this task, three pairs of orangutans were tested on a match-to-sample task of increasing complexity that served as the beginning stage for a long-term study of language acquisition. Each pair had a dominant and subordinate individual. The dominant individual served as the demonstrator while the subordinate had the opportunity to observe all interactions between the experimenter and the demonstrator. In this task the demonstrator in each pair learned to label a specific food with its corresponding abstract symbol. During all phases of the task, the experimenter focused only on the demonstrator and provided no direct instruction, in any form, to the observer.

Three aspects of the results provide support for imitation by the observers. During the course of the study, two of the demonstrators briefly left the testing area on ten separate occasions. Each of these times, their observer immediately approached the testing apparatus and made a

selection from the array of symbols that were present. The observers did not require preliminary training to acquaint them with the “rules” of the task. They approached the experimental apparatus, pointed to a stimulus, and then extended their hand (or lips) toward the experimenter for a reward. The topography of the pointing response provided a second piece of evidence supporting imitation. The demonstrators had been trained to produce a clear pointing response using only one finger, a response form that is not typical of orangutans. None of the observers required training in this form; all responded with the single-finger discrete response they had observed in the demonstrators. Finally, of the ten selections made by the observers, nine were correct. The observers exactly replicated the novel behavior that had been exhibited by their demonstrator partner, clearly satisfying the definition of imitation.

Rather than a lack of ability to imitate, we propose that experimental design figures prominently in the explanation for the difference in results in the studies that have been cited. Nagell et al. (1993) and Call and Tomasello (1994, 1995) only used demonstrators (human or ape) that were competent at the experimental task. Therefore the observers only saw successful performances. In Call and Tomasello’s (1995) study that utilized a vending apparatus operated by pushing, pulling, or rotating, the workings of the box were completely hidden from the ape. In addition, each ape in that study was given between 0.5 and 2.5 hours to interact with the test apparatus prior to actual data collection. During that time, no food reward was possible, even though the ape investigated the apparatus and could move the handle freely. It is entirely possible that during this habituation period the ape learned that no particular action resulted in a food reward.

Shumaker et al. (1998) used a significantly different methodology. Specifically, the demonstrator and observer were both completely naive at the beginning of the study. The observer was therefore able to see both mistakes and correct answers, rather than just accurate performance.

In addition, every aspect of the task was made obvious at all times, and every correct answer was always rewarded. We propose that these methodological differences had a significant impact on the performance of the apes.

In summary, the examples of MSR and observational learning cited in this essay illustrate the major influence that experimenter expectations and inappropriate methodology can have on the conclusions that are formed from otherwise well-executed and reasonable studies. We encourage the notion that whenever possible, experimenters must first consider the perspective of the subjects during the design of an experiment. We also encourage the implementation of short-term, direct studies as a means to assess the appropriateness of a methodology before embarking on long-term investigations. Overall, the natural behavior and inclinations of each species must be fully considered when conceptualizing, designing, and implementing a research program.

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