

Cognitive Ethology: Past, Present and Speculations on the Future¹

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1. Introduction: Defining Cognitive Ethology

The term "cognitive ethology" was introduced by Donald R. Griffin in his book *The Question of Animal Awareness* (1976). He regarded "cognitive ethology" as a study of the mental life of animals particularly as they solve everyday problems in their natural world.

A cognitive ethologist focusses on problems faced in an animal's *natural world*. We should be open to the possibility that the animals are solving more complex problems than have *typically* been set them in the lab. Thus ethological data may reveal more advanced animal cognitive capacities. On the other hand, laboratory study can lead one to search in the wild for cognitive capacities not previously apparent; the various ape and other animal "language" experiments are a case in point (Ristau and Robbins 1982 and Ristau in press). Furthermore, raising the possibility that animals have complex mental processes and are conscious may change the way we explore their behavior.

I see a cognitive ethologist's potential interest in animal capacity as being extraordinarily broad. Because we do not understand how "simpler" processes (attention, discrimination, reinforcement) interface with cognition, a cognitive ethologist should be interested in processes as simple as habituation, found throughout phylogeny, from sea slugs to humans, as well as more advanced reasoning processes.

2. The Past in Cognitive Ethology

The roots of cognitive ethology are evident in Darwin's *The Expression of the Emotions in Man and the Animals* (1872), where he proposed a gradual evolution of mental abilities. His protege, George Romanes, speculated in yet more detail (1882, 1884) about the types and levels of mental abilities characteristic of specific genus and species, but has been harshly criticized for being too accepting of anecdotal information and excessive anthropomorphizing. Yet anthropomorphizing can provide a useful beginning by suggesting potential animal capacities. Since we are mere humans, all we can do in imagining the phenomenological state of a non-human animal mental ability is to anthropomorphize. If we use this heuristic while taking into account the animal's ecological niche and other known capacities and limitations, we could label this cautious approach "animorphizing" or perhaps use Burghardt's term (1991) "critical anthropomorphism."

The classical ethologists, such as Lorenz and Tinbergen, studied the natural behavior of animals in the “wild” (or at least the garden). Of particular concern to them were the animal’s internal motivational states and species specific actions (what has been translated as “instinct.”) There was little focus on cognitive abilities *per se*, although Tinbergen devised elegant field tests of animals’ adaptive behaviors, including the famous experiment revealing the digger wasp’s spatial abilities. By moving a circular array of pine cones which initially surrounded the wasp’s nest, Tinbergen (1951) showed that the wasp found its nest by learning the spatial relationship between the nest and the cones, not merely by associating the nest and cones. The classical ethologists also focussed on *communication*, anticipating contemporary cognitive issues.

Their ideas about communication were integrated with their theories of instinct. As discussed by Beer (1982), the ethologists Lorenz and Tinbergen conceptualized animal social signals as being discrete units. These signals released specific action patterns which were themselves “energized” by the drive states or instincts. But Lorenz also used the concept “*intention movements*” (such as preparing to fly) which might communicate what the animal was likely to do next. This notion of an intention adds a cognitive dimension to a rigid stimulus-response communication system.

An interest in the nature of an animal’s mind is the central focus of Jakob von Uexkull’s concepts of *innenwelt* (“inner world”) and *umwelt* (“outside world”) (introduced about 1905, reported in 1957). von Uexkull’s ideas were based on Kant’s philosophy that we cannot know the outside world veridically. Simply put, an animal, via its unique sensory system, experiences the outside world and creates its own “*innenwelt*.” The organism then “reflects” back this *innenwelt* to create its unique *umwelt*. Besides possible differences in acuity or particular sensory modalities, each *umwelt* could differ in many other aspects such as the salience of stimuli and even the experience of space and time.

Comparative psychologists were more empirically oriented and usually observed animals in laboratory settings or in semi-natural environments. Contributions to cognitive ethology included studies of problem solving, such as behaviors which Wolfgang Köhler (1925) termed “insight learning” by apes. While attempting to reach inaccessible food, the apes seemed to achieve either a sudden understanding of the solution or to engage in cognitive trial and error rather than in actual trial and error. Thus the ape Sultan and some of his compatriots placed boxes atop each other in order to reach inaccessible bananas. Sultan was likewise reported to rise suddenly and put together two sticks in order to get a banana otherwise out of reach. These experiments are not without their critics; the pair of sticks had only one hole in which the other could be placed; a stick with several holes, only one of which affords a solution would have been a better test. So would additional reports of that solution discovered independently by more apes.

The possibility of numerical ability was explored by Otto Koehler (1956) using ravens and other birds. He investigated what he termed *unnamed numbers* as an example of counting-like ability. For example, using an array of dots, a bird would be instructed as to the number of pieces of meat to take from a tray. Linking such visual signals with serial behavior need not imply counting, since pigeons readily learn to peck two in reference to three spots (Seibt 1982). More convincing evidence for an abstract counting-like ability would require the bird to generalize to different contexts, preferably not involving food pieces at all. These beginnings are being developed today in studies of a parrot (Pepperberg, 1991) and apes (Boyson, Matsuzawa, Premack, and Rumbaugh as discussed in Ristau and Robbins 1982 and Ristau in press).

A totally different tack was undertaken by Tolman (1932) who was interested in the behavioral indices of mental states. In particular, he was concerned with “descriptive properties” of behavior to indicate that it is *purposive*. He suggested the following: 1) a tendency to seek the easiest route to a goal (But, notes Bennett (1976), that

presupposes we can *identify* the goals) 2) The behavior “seems to have the character of getting to... a specific goal object of goal situation.” (But he doesn’t specify those characteristics.) 3) The behavior manifests *persistence* in getting to the goal. (This could be interpreted as overcoming obstacles or delays in achieving the goal state.) A related contemporary concern is with naturalizing intentionality.

3. More Recent Past and Present Work in Cognitive Ethology

Since I have defined cognitive ethology very broadly, I include the research of experimenters who probably would not consider themselves as cognitive ethologists. Due to space limitations, I cannot review the literature, but am choosing instead to highlight a few experiments and approaches which raise particularly interesting questions.

A. Cognitive Abilities of Animals

1. Non-social Capacities

Some specific non-social skills (which, of course, could also be used socially) include categorical discrimination, concept formation, spatial knowledge, numerosity, problem solving and tool use. Some experiments have used operant conditioning methods to explore the kinds of groupings or categories animals are capable of learning. In such tasks, the animals typically group a large number of exemplars and then generalize to novel instances. These studies often tend to carry a particular weight in the field of experimental psychology, because the researchers have come from a strict behavioristic tradition. Although these studies often do *not* focus on the ease of learning various groupings or categories, such information could be most useful. We might thereby learn possible species’ predispositions to use certain groupings, in turn suggesting possible innate biases or constraints on their cognitive capacities.

For example, Herrnstein and his colleagues (Cerella 1979, Herrnstein and de Villiers 1980, Herrnstein et al 1976, Morgan et al 1976) asked whether pigeons could learn natural, man-made, or even arbitrary categories. Pigeons were trained to peck for food reward at various slides including: trees/non-trees, water/non-water, people/non-people, scenes with a particular person/scenes with other people or no people, the letter “A” in various fonts/other letters, fish/non-fish (a natural category but not one within the usual experience of a pigeon) and a random selection of fish and non-fish/another random selection of fish and non-fish (an arbitrary category).

As judged by their differential pecking rates to the classes of slides and by appropriate generalization to novel slides, the pigeons could make all these discriminations, even those for unnatural (manmade) objects and arbitrary sets. But the arbitrary groupings took by far the longest to learn. Hence, though pigeons are capable of memorizing many specific exemplars, they find it easier to learn groupings which have similar characteristics. This ability to categorize need not imply much understanding about the nature of the categories, however. Another puzzle concerns the effect of experience on these discrimination tasks, since they were solved both by laboratory reared pigeons and by homing pigeons with “worldy” experience.

How does the pigeon conceptualize this kind of discrimination? What techniques could permit us to begin to answer that question? Herrnstein (1992, personal communication) tried looking at the concordance between the choices made for the positive exemplars in the tree vs. non-tree discrimination and also at the concordance for the negative instances. Note that the negative exemplars for tree included certain somewhat indeterminate instances such as a stalk of celery. There was a smaller concordance for the positive instances, suggesting a smaller subjective space than there was for the negative instances. In other words, it is not likely that the pigeon is

understanding the negative case as “not-tree,” i.e. by searching in vain for a tree and then rejecting that example. Possibly the pigeon is learning sub-groupings as negative instances. Even the positive instances need not be conceptualized as “tree,” but rather as instances of “leafiness” or “trunkness.”

In a development from this work, Wasserman et al (1988) had pigeons pecking four different keys, grouping together novel instances of natural categories such as cats or flowers, but also functional categories such as automobiles or chairs, a task one cannot readily imagine to figure in the evolutionary history of the bird. In fact it is difficult to accept that it is the functional category “chair” that the pigeon is learning, particularly because the pigeons could not reasonably have seen people sitting in a very wide variety of chairs. Presumably there are certain geometric features of chairs that are being learned. In truth we do not know how the pigeon is making the discrimination.

Clearly experience plays a critical role in the kinds of discriminations an organism is prone to make, but in ways not immediately obvious. Very limited experience can limit a subject’s ability to generalize, e.g. to recognize that an inverted triangle has the same shape as an upright triangle. However inexperience with a diverse set of exemplars can also bias the animal towards more inclusive categorization. Humphrey (1983), for example, describes spontaneous categorization by rhesus monkeys according to species after viewing real pigs, goats and dogs out of their window. In the experiment, monkeys pressed a button to advance a carousel slide projector. The duration of viewing between slide changes was evidence of the monkey’s interest in a particular slide. Naturally, repetition of photos of the same animal (even from a different view) led to habituation of interest and shorter viewing times. Humphrey found that a transition between species (from a series of pigs to a series of dogs) led to a robust renewal of interest for the monkeys who had earlier watched barnyard events. The “indoor monkeys” seemed not to discriminate species, not having the opportunity to form relevant categories. The method shows promise for comparative studies of spontaneous categorization.

2. Cognitive Social Capacities

Many intra and interspecific social abilities of animals appear to require fairly advanced cognitive abilities. Predator-prey behaviors have received particular recent study, including cooperative hunting by lions and by hawks (Bednarz 1988), vigilance behavior (Jamieson and Bekof 1993), communication (see subheading under that topic), particularly the use of alarm calls by vervet monkeys (Cheney and Seyfarth 1990), and “injury-feigning” behavior by certain birds such as plovers (Ristau 1991). The possibility of purposiveness, deception and intentionality are suggested by some of these behaviors.

These issues arise in my own studies of the use of broken-wing displays (BWD), often termed “injury feigning,” by a group of shorebirds, the plovers (Ristau 1991). Plovers are very well camouflaged birds which lay eggs in a well camouflaged, but otherwise unprotected, nest on the ground. When a predator or other intruder approaches the vicinity of the eggs or young, one or both parents are likely to make a variety of distraction displays, among them the very conspicuous broken wing display. While making a BWD, the bird drags one or both wings along the ground, sometimes simultaneously vocalizing a raucous call, thereby sounding and looking (at least to human observers) like an injured bird. However, the parent bird does not always make a BWD in these circumstances. In one series of experiments with piping plovers, BWDs were made in only 40% of direct approaches to the nest by a human. In many of the approaches, the bird(s) instead acted cryptically, not vocalizing at all, often keeping low to the ground or pausing in hollows, often merely observing the intruder. It was thus extremely difficult to detect these sand colored “blobs” against a sand-colored background. Furthermore, other related species, for example, killdeer, have been reported to behave differently depending upon the type of intruder. To

grazing animals, such as cows, which do not prey upon eggs or chicks, but could accidentally trample the eggs, the killdeer sits tight on the nest, suddenly flying into the face of the advancing cow, causing it to veer away.

It often appears that the BWD is not merely a reflexive response or fixed action pattern to a type of predator, but that the plovers are engaging in purposive behavior, that is, they are trying to lead an intruder/predator away from the nest. What constitutes evidence for such a hypothesis? After reviewing literature by Tolman (1932), thoughts of philosophers of mind, and workers in Artificial Intelligence (see Ristau 1991 for further discussion), I propose the following as suggestive criteria for purposive behavior by the plovers: 1) The direction in which a bird moves while making a BWD should usually be appropriate for leading the intruder away from the nest. 2) The displaying bird should monitor the intruder to permit the bird to determine whether the intruder is following. 3) If the intruder is not following the displaying bird, the bird should modify its behavior so as to better achieve the putative goal of leading the intruder away from the nest. By applying these criteria to the bird's behavior, I gathered evidence that supported an interpretation of purposive behavior as opposed to randomly directed displays or rigidly fixed patterns of behaving. (See Ristau 1991).

Using intrusions by humans, we found that in almost all cases, directions of display *were* appropriate to lead an intruder further away from nest/young. If the bird is displaying in order to attract the intruder's attention, we would expect the bird to be selective about *where* it displays, making BWDs where the intruder will see them. In fact in 44 of the 45 cases studied in detail, the bird displayed in the front visual field of the observer and not behind her. Further supporting the purposive interpretation is the fact that the bird does not begin displaying wherever it is located as it first detects an intruder, but instead flies or walks to another location and then begins to display. In all the cases of flying, the bird's new location was closer to the intruder than it had been before the flight and in almost all cases, the bird was also closer to the center of the intruder's visual field than it had been. This is not the behavior of a bird attempting to escape from the intruder, but, rather, the bird appears to be attempting to gain the attention of the potential predator.

Monitoring of the intruder is strongly suggested by observations, photographs and videotapes showing that as a bird is making a BWD, it often turns its head sharply back over its shoulder, its eye toward the intruder. The change in head and eye orientation strongly suggests monitoring of the intruder. Finally we noted that adjustments were made by the bird to an intruder not following the bird's display. The bird, in more than half of such instances for which data were available, stopped its display and reapproached the intruder by either flying or walking. In most of the other cases, the bird either continued to make a BWD or increased the intensity of its display by flapping its wings more vigorously and/or increasing the intensity of its raucous vocalizing. In only 1/6 of the cases did the bird cease to attempt to "lure away" the intruder.

In summary the plovers in this study appear to be employing purposive behavior during "injury feigning" since they (a) *moved* to an optimal location before beginning a display (b) *monitored* the intruder and (c) *modified* their behavior in response to changes in the intruder's direction of motion. I do not suggest that plovers show the fully conscious, very flexible and highly cognitive behavior we humans sometimes exhibit. Presumably there is a continuum between that and reflexive, but goal oriented behaviors. Part of our future task as psychologists, ethologists, and philosophers is to better delineate that long continuum between reflexive behavior and human planning capacities (see Bennett 1976).

3. The nature of communication

A. Natural animal communication systems

Current research has developed beyond both the rigid stimulus-response model of classical ethology and the notion that at least some animal communication is merely a byproduct of an internal state, what Griffin (1992) has termed the Groan of Pain interpretation. Some central issues now concern *what* is being communicated. W. J. Smith (1977) emphasizes the distinction between the message sent by the signaller and the meaning taken by the recipient. Context, including sex, social status and knowledge held by the recipient all have an impact such that the same signal can have very different meanings. For example, a male bird's song both *attracts* an unattached female and *deters* a male. Smith has abstracted a set of behavioral referents which, he suggests, constitute the set of messages used in all animal communication; for the most part, they refer to likely behaviors on the signaller contingent upon responses by the recipient. Recently (1991) he has added the possibility that some signals might (also) have external referents or what some have termed "semantic" referents. The field experiments of Cheney and Seyfarth (1990) provide evidence for semantic reference in the vervet monkeys' use of alarm calls (apparently) to signify different predatory species that prey upon the monkeys.

Marler and colleagues (1991) have experimentally explored what they term the "audience effect", namely the impact on some aspect of communication (for example rate of calling) by the presence of different audiences. Insofar as a communicator's signal depends on whether anyone is present and who that is (offspring, conspecific, member of the same or opposite sex), we expect to find differences in signalling, as is observed. The work by Marler and colleagues and Cheney and Seyfarth as well as the studies of interspecific communication by Ristau (1991) and Burghardt (1991) can be considered as beginning explorations of the possibility of intentionality in animal signalling.

B. Artificial animal "language" and cognition projects

Using arbitrary lexicons, several species of apes, sea mammals and birds have been studied to explore communicative and cognitive abilities that are either extant or capable of being developed (reviewed by Ristau and Robbins 1984 and Ristau in press). The research includes work with the great apes, specifically common chimpanzees studied by Boyson, Fouts, Gardner, Premack, Savage-Rumbaugh and Rumbaugh, Terrace, and pygmy or bonobo chimpanzees by Savage-Rumbaugh, gorillas by Patterson, an orangutan by Lyn Miles, dolphins by various researchers, for example, Herman, sea lions by Schusterman, and a parrot by Pepperberg. The field is too extensive and complex to review here, but I will mention a few of the highlights and some intriguing ideas.

Studies with a parrot reveal that after training, the bird can not only respond correctly with verbal labels for numerous objects, colors, shapes and textures, but also engages in a higher level ability. When shown two items and asked "What's same?", the parrot can correctly answer the question, saying "shape", "color" or "matter" (material). The bird can also answer the question, "What's different?". Because there might be more than one attribute which is different, the parrot cannot solve this problem as an "oddy" problem, where there is only one different or "odd" characteristic. The bird must have some comprehension of the meaning of "same" and "different," must compare the specific colors or shapes and then must answer with the category name. Since the task can be performed with novel objects and with novel colors, the bird cannot be memorizing his prior response to particular combinations of shape and color (Pepperberg, 1991).

C. Consciousness: concerns with possibility of self-awareness

To study consciousness, it is most important first to delineate possible levels or types of consciousness, a task for both philosophers and psychologists. Since that is

beyond the scope of this review, I will instead briefly discuss experimental work concerned with one aspect of consciousness, that of self-awareness. Human children up to about the age of 18 months will react "socially" to a mirror, responding to the image as though it were another individual, sometimes looking behind the mirror. Chimpanzees initially behave the same way, making "other-directed" responses, often threatening the image. However, after several days with the mirror, there is an increase in "self-directed" responses. To investigate this phenomenon experimentally, Gallup (1977) anesthetized mirror-"wise" chimpanzees and then marked their eyebrows with a red, apparently odorless dye. Upon awakening, the apes marked with dye began to touch the marked areas while looking in the mirror much more often than did control chimpanzees who had been anesthetized but had no dye, and more often than they had done before being marked. Thus chimpanzees "pass" this test and so do orangutans, but, oddly, gorillas do not. Neither do a host of other species including rhesus monkeys. The "failure" on the test by gorillas seems most peculiar and suggests an artifact in the testing procedure. One possibility is that to primates, a direct gaze is a threat, whose potency may vary from one species to another. A reluctance to stare into the mirror may thus inhibit gorillas (and monkeys?) from attending to the novel face mark. Monkeys have an additional difficulty in that the species tested are unable to use mirror information to direct the motion of an otherwise unseen limb in anything but rote tasks (E. Menzel 1993, personal comm.) Note also that passing the "awareness" test implies only some sense of the self as a body and not necessarily of the self as a mind, or of a self persisting from the past into the future.

Making more modest claims, a study by Beninger, Kendall, and Vanderwolf (1974) dealt with the question of whether rats can discriminate their own behaviors. Decades before, the behaviorist Hull had concluded that rats could discriminate between some internal states, e.g. hunger from thirst, because they turned the direction in a maze that led to the need-appropriate reward, either food or water. In Beninger et al's studies, rats were initially rewarded for pressing a lever when a buzzer sounded. Then gradually, a rat was reinforced only for pressing a specific lever (one of four) when it was engaged in a spontaneous behavior such as face washing, walking, rearing and immobility. Thus rats learned to recognize when they were performing one of the four behaviors and to select the appropriate lever in each case.

The data support an interpretation that the rat seems to have some sense of what it is doing, but whether it is by feeling alone (e.g. kinesthesia) or some more global notion such as "Now I am rearing up", we don't know. Stronger substantiation that the rat is aware of what it is doing could be provided by requiring that the rat associate a particular lever with diverse motor sequences having a common function, eg food seeking.

4. Speculations for the Future in Cognitive Ethology

A. Further Exploration into Past and Present areas of Inquiry

B. Avoid "Simplicity Filters" and do not Ignore Few-time Occurrences

Griffin (1976, 1981) has noted how the zealous attempts of many scientists to be parsimonious has led to under reporting or ignoring observations and other data suggestive of thinking by animals or otherwise challenging the established beliefs about animals' cognitive capacities. Sometimes these data are one or few time observations of behavior. Yet, as Griffin notes, these can become valuable starting points for further scientific investigation. To encourage the accumulation of careful, objective reporting of such few time occurrences in the literature is a useful scientific objective.

C. Determining a Biological Basis of Intentionality, of "Belief-desire" Systems; Naturalizing Intentionality

Some of these concerns have begun to be addressed in efforts to build a better theoretical foundation of cognitive ethology (reviewed by Beer, 1991, 1992). There is a

little experimental work addressing this issue, namely Bekoff's studies of play analyzed in intentional terms (discussed in Jamieson and Bekoff, 1993, this symposium) and Ristau's (1991) field experiments with "injury-feigning" displays used in anti-predator behaviors of plovers (previously discussed).

Experimental approaches might also include greater attention to means of revealing an animal's putative goal. For example, one can set *obstacles* such as physical obstructions, delays in presenting a reward, or restricting the animal from starting. Change the putative goal state, perhaps by changing the expected reward or expected behavior of the interactant. How does the animal overcome the obstacles? We may observe behavioral variability or substitution of other behaviors. Does the animal evince "surprise" when the goal object is changed or missing? Some of these techniques have already been used, for instance in an early experiment by Tinkelpaugh (1928). A chimpanzee confronting lettuce in a box wherein it typically found banana exhibited apparent irritation and disappointment and searched the box and environs. Later work with ducklings explored what specific changes in the goal environment disrupted ongoing behavior and evoked looking about the area (Archer, 1974). Similar techniques may be applied to human infants as well.

D. Building Conceptual and Methodological Bridges to Other Disciplines

The discipline of animal learning deals with many of the same phenomena that concern cognitive ethologists, how the animal learns and remembers and solves problems that befall it. The two fields tend to be disparate in training (psychological vs. biological), place of study (lab vs. field) and theoretical orientation; they tend not to read each other's data and perspectives. There is, however, a growing movement within animal learning to consider "real world" uses of perception, learning and memory. Examples include discriminative abilities (see discussion of Herrnstein and colleagues) operant conditioning paradigms as models of foraging strategies and decision making, spatial learning in many species, extensive studies of food caching by birds (reviewed by Shettleworth, 1983; Griffin, 1991) and "constraints on learning" (Garcia et al, 1966; Garcia and Koelling, 1966; review by Rozin and Schull, 1985). In this vein, studies on "natural categories" in pigeon learning could be extended to examine effects of both evolutionary history and individual experience on the ease of forming particular categories. Do herbivores better classify plants and carnivores better categorize certain animal prey? Similar abilities to perform "probability matching" in an operant task could be more tightly related to optimal foraging observations in the field.

Investigations into constraints on the ubiquity of "general process" laws of learning were initiated by Garcia, his data suggesting that differences in functional systems, e.g. ingestive vs. escape, were significant for learning processes. He showed that there are differences in the ease of associating particular stimuli and great differences in the time intervals over which associations can readily form. In addition special abilities such as food-caching and song-learning by birds seem to show specialized learning processes which challenge generalized theories. The nature of imitation is another facet of early learning in many "higher" vertebrates which is likely to impact upon a cognitive theory of animal behavior. Current investigations with orangutans (A. Russon, personal comm.) provide evidence for their ability to comprehend the functions of acts such as pouring, and rather than "blindly" imitating particular motor patterns, the apes modify their actions and the vessels as needed to accomplish their "goal." In all the phenomena mentioned, a biological perspective adds an important dimension to future research endeavors.

Developmental psychology faces the same methodological problem as cognitive ethology in that, for the youngest human subjects at least, verbal communication is impossible. Both fields also share recent interest in problems such as deception and

attribution of intention. (See essays by J. Astington, A. Gopnik, J. Perner, D. Premack, H. Wellman and others in Whiten (1991)).

The nature of representation concerns researchers in cognitive ethology, cognitive psychology and artificial intelligence. Experimental approaches to studying one kind of representation, human imagery (e.g. Shepard and Cooper 1982, Kosslyn et al. 1978), can be extended to animal subjects. Another common and controversial concern is whether humans and non-humans are more readily able to solve social problems than logically analogous problems in other domains (Cosmides 1989); Cheney and Seyfarth 1990). In another vein, humans appear to use certain heuristics which can ease the multitudes of daily decisions with potentially overwhelming or sometimes insufficient information. For example, in the "availability" heuristic, the information most readily available to a subject, perhaps because it is familiar or was encountered in a very arousing or graphic way, is given far greater weight in guiding the subject than it should. It is reasonable to suppose that non-human animals have evolved heuristics, perhaps very similar, to aid their decision making. There may have been certain classes of problems which gave rise to developing heuristics and evolutionary forces promoting and inhibiting such development. By formulating heuristics so as to be applicable to non-human animals, we can begin exploring these issues.

Neuropsychology likewise offers important bridges to cognitive ethology, some of them still science fiction-like possibilities. Contemporary neurophysiologists have developed several brain scanning procedures which might provide correlates of conscious experience. Among these are very brief simultaneously oscillating circuits in different parts of the brain, "connecting" the separate analyses occurring in these parts. Another idea entails hierarchically organized "convergence" zones, which neural processes are "viewed" through magnetic resonance imaging (MRI) and radioactive tracing of metabolic activity in brain cells (PET scans). Future experiments might have animals freely moving and behaving in a semi-natural or lab setting while scientists monitor correlates of regional brain activity during either "routinized" or "attentive" occurrences of the same motor sequence.

E. Developing Methodologies

Numerous methods have been suggested throughout this essay. In general, a greater stress on *observation* is needed, in lab as well as in field. A detailed study of the process by which organisms learn a task or solve a problem can reveal differences in the cognitive capacities being utilized. Data could include time and number of trials required to learn a task, kinds of errors and hence possible innate biases, and whether the animal appears to *seek* information, perhaps by slow investigation of the environs. See Bennett (1976) concerning his suggestion that greater tendencies to *seek* information may be associated with organisms capable of higher levels of intentionality.

5. Closing Statement

We must try hard to keep abreast of new findings in other areas, using new data, new methodologies in creative ways. This means including "other" fields in the programs of the conferences we attend, attending meetings "outside" our area and reading about other fields, beginning, if need be, in the popular media. I hope you will join me in this present and future task of exploring cognitive ethology.

Notes

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