1991

Integrating Cognitive Ethology with Cognitive Psychology

Sonja I. Yoerg
University of Massachusetts

Alan Kamil
University of Nebraska - Lincoln, akamil1@unl.edu

Published in COGNITIVE ETHOLOGY: THE MINDS OF OTHER ANIMALS: ESSAYS IN HONOR OF DONALD R. GRIFFIN, ed. Carolyn A. Ristau. Hillsdale, NJ: Lawrence Erlbaum Assoc., 1991. Pp. 273-289.

12 INTEGRATING COGNITIVE ETHOLOGY WITH COGNITIVE PSYCHOLOGY

Sonja I. Yoerg
Alan C. Kamil
University of Massachusetts

ABSTRACT

Cognitive ethology has been defined by Griffin (1978, 1981, 1984) as the study of mental experiences in animals, restricting the domain of the field to phenomena thought to reveal intentionality, awareness, and conscious thinking. We argue that attempts to study these processes, while revealing impressive behavioral complexity, have proven unsuccessful in establishing the importance of mental experiences in determining animal behavior primarily because of the intractability of the problem. We suggest a different approach that draws upon the rich theory and sophisticated methodology of human and animal cognitive psychology while retaining an ecological and evolutionary perspective. Brief accounts of the conceptual underpinnings of cognitive psychology are presented as well as examples of empirical work, including the analysis of imagery in human and nonhuman animals. We hope our broad redefinition of cognitive ethology provides a rigorous framework within which to examine the role of cognition in ecologically relevant behavior.

The term cognitive ethology could have many meanings given the variety of meanings attached to the word cognitive and to the word ethology. Griffin (1978, 1981, 1984) defined cognitive ethology as the "study of the mental experiences of animals". In this paper, we will argue that this definition of cognitive ethology is impractical and unproductive, because nonobservable conscious mental events constitute the very heart of the field. In overemphasizing conscious events and largely ignoring the efforts of cognitive scientists, this definition is unduly restrictive. There is a more suitable definition possible for cognitive ethology, one that involves true integration of the cognitive and ethological approaches and offers hope of eventually understanding the structure, evolution, and function of mind.

When defined in terms of mental events, cognitive ethology has two major flaws. First, it suffers from the absence of theories that make testable predictions. This problem stems partly from the nature of the subject matter that the field has defined as its domain as well as from a reluctance to convert vague and unparsimonious mentalistic accounts of cognitive phenomena into viable hypotheses amenable to empirical test. Second, because of the narrow scope of cognitive ethology, it remains virtually untouched by the theories, data, and methodological developments of human and animal cognitive psychology. This is not healthy. We contend that cognitive ethology can and should be more broadly defined.

In the next section of this paper, we outline the defining characteristics of current cognitive ethology, give its interpretation of the domain of cognitive analyses, and identify some of the problems caused by this definition and interpretation. The field of cognitive psychology is then defined, emphasizing the centrality of the information processing metaphor to both the initial development of the discipline and its current status as a powerful agent in the study of cognitive events. We describe how cognitive processing and organization are examined in nonhuman animals, provide examples, and outline the new trend toward ecologically motivated studies of animal cognition. We argue that cognitive ethology should be this ecological comparative approach to the study of animal cognition.

COGNITIVE ETHOLOGY

According to Griffin (1978, 1981, 1984), the subject matter of cognitive ethology is consciousness, awareness, emotion, intentionality, and conscious thinking in animals; in short, mental experiences. For example, Griffin (1984) states that the challenge of cognitive ethology "is to venture across the species boundary and try to gather satisfactory information about what other species may think or feel" (p. 12). This is a restricted use of the word cognition, which is usually defined as the process or faculty of knowing. Cognitive psychology operates within this broader definition as the study of how knowledge is acquired, processed, and used. Throughout cognitive psychology, the category of cognitive processes includes not only those involved in mental experience but those involved in all mental events regardless of whether the animal itself experiences those events. (An elaboration of the goals of cognitive psychology is given in a subsequent section.)

Certain characteristics of cognitive ethology are consequences of this definition. First, there is an emphasis on continuity with human mental experiences (e.g., Griffin, 1978). This occurs because the best (and perhaps only) source of evidence of consciousness comes from ourselves. The second best source of evidence results from our willingness to generalize from our own experience to those of other humans. And if we are willing to make that generalization among humans, it can be argued that the generalization should be extended to include nonhuman animals as well. For example, most humans would agree that they have had mental images, picture-like experiences in the absence of a concurrent visual stimulus, and assume that this holds for humans in general. Why not, then, grant the likelihood of imagery in other animals? Arguments based on evolutionary continuity are used to support the parsimony of this generalization (e.g., Griffin, 1978).

Second, defining cognitive ethology as the study of mental experiences promotes an emphasis on communicative behavior. The reasoning is that because human thought is largely language mediated, then ". . . insofar as animal communication shares basic properties of human language, the employment of versatile communication systems by animals becomes evidence that they have mental experiences and communicate with conscious intent" (Griffin, 1978, p. 528). First, formal and functional similarities between human and nonhuman communication do not demand the operation of conscious processes in both instances. Second, because it is assumed that mental experiences are particularly visible through the window of communication, the relation between communicative behavior and thought, intent, and awareness may be exaggerated. Do words necessarily speak louder than actions?

Collecting Evidence

If we accept for the moment that cognitive ethology is the study of mental experiences, we can then ask how this enterprise is and ought to be conducted. Griffin (1984) has suggested some criteria for inferring conscious thought: (a) "plastic" behavior, (b) modifiable aspects to a complex behavior pattern, and (c) anticipation or intentional planning. The plausibility of these criteria are not at issue. Rather, we need some way to progress from criteria that are suggestive of conscious thought, imagery, or awareness to criteria that are indicative of them. General arguments based on continuity with human mental experiences (given that we have adequate methods for assessing them) can only imply the possibility of the existence of similar attributes in nonhuman species. They cannot establish the continuity. There are certainly enough examples of complex behavior in animals to allow inferences about almost any sort of mental experience to be drawn if the only criteria were the possibility of the existence of such experiences. But if cognitive ethology is to be a science, it must do more than point to interesting cases in which one interpretation of the observed behavior involves conscious thought or intent.

Current cognitive ethology is virtually atheoretical. Without theory, there are no meaningful predictions. Without meaningful predictions (ideally from competing theories) data are difficult, if not impossible, to evaluate. If cognitive ethology is defined as the study of mental events in animals, its theories should consist of possible answers to the question: What should behavior look like if it is influenced by mental experiences? Of course the question asks about behavior and not about mental experiences themselves because we cannot observe mental events directly. It is critical both that the theories make specific predictions and that the postulated mental experiences be distinguishable in their effects from other mental experiences and from internal (and external) events in general. For example, a theory of the effect of visual imagery on orientation to remote food sources would have to do more than predict the use of visual information in finding food. It would have to propose a working definition of what it means to use a visual image and then predict behavioral outcomes that follow from that definition and do not follow from the use of visual information in a form other than an image.

Consider Ristau's (this volume) work on injury feigning in plovers. When an intruder approaches the nest, parent plovers may exhibit a broken-wing display, fluttering along on the ground in a position that gives the appearance of an injured bird. Among other goals, Ristau is interested in determining the extent to which the plover is intentionally leading the intruder away from the nest. That is, does the plover know that feigning injury will lure the intruder away? Does the plover know that it is deceiving the intruder in doing so? The data collected demonstrate that the form of the display is sensitive to the behavior of the intruder; the bird adjusts the direction of the display or its intensity depending on the intruder's response. How do these data bear on the question of intentionality? Although the data do indicate that the function of the behavior is to direct intruders away from the nest, there is nothing that necessitates the invocation of conscious intent as an explanation. Ristau (this volume) has more recently shown that an intruder that threatened a nest earlier evoked a more intense display on subsequent intrusions. This result is also silent on the question of intentionality. It does suggest that the plover remembers individual intruders and can use that memory in determining the strength of subsequent displays—an interesting finding.

In order to assess the role of intentionality in the plover's behavior, a theory must be formulated that specifies behavioral outcomes that would not occur if the plover did not intend to lure the intruder away from the nest. To justify the use of the concept of intentionality, a behavioral equivalence class must be defined, and a prediction about behavior must be made that depends uniquely on the awareness of the plover of its own behavior. We cannot think of a theory that would make that prediction. That does not mean that we cannot bring ourselves to believe that plovers or any other animal may be capable of intention. It means that we cannot conceive of an experiment that would prove it.

One aspect of cognitive ethology that tends to obscure the absence of theory is the tendency to confuse the thought and words that experimenters use to formulate research questions with the explanations assigned to the resulting data. It is a common if not ubiquitous practice for students of animal behavior to place themselves in the position of an animal confronted with a situation, problem, or task and ask, "What would I do?" Our own phenomenology is clearly a rich source of ideas about what animals might do or how they might do it. Indeed, Tolman, perhaps the first cognitive psychologist, said: "I, in my future work intend to go ahead imagining how, *if I were a rat,* I would behave" (1938, p. 24). There is nothing wrong with asking oneself: "If I were a plover and I were trying to get an intruder away from my nest, how would I behave?" It is, however, wrong to assume that the subjective experience that stimulated an experiment is isomorphic with the experience of the animals in that experiment. The interpretation of data should follow from a careful analysis of the consonance of those data with the predictions of a theory and not with one's own introspections. We may talk or think loosely under some conditions about what our animals might be doing or thinking, but we should be circumspect in our evaluation of the level or complexity of explanation the evidence demands.

It is informative to consider an analogous problem in behavioral ecology. Optimal foraging models assume that foraging animals have been selected to maximize some quantity related to fitness, usually intake rate. These models, therefore, describe a method of calculating rate of intake as a function of various environmental and behavioral parameters such as prey value and handling time. The calculations often entail high-level mathematics, and some computer simulations require significant processing time on powerful machines. But one cannot contend, when the predictions of an optimal foraging model are confirmed, that the forager calculates optima the way the model does; evidence for how information is processed necessitates a different sort of theory. Cognitive ethologists must maintain the distinction between the tactics of the theoretician and those of the animal.

AN ALTERNATIVE APPROACH TO COGNITIVE ETHOLOGY

We have been very critical of cognitive ethology as defined in terms of mental experience. One aspect of cognitive ethology, however, has had a positive impact. Animal behaviorists—ethologists, behavioral ecologists, and comparative psychologists—all face a substantial challenge illuminated by Griffin (1978, 1981) and others: the complexity of animal behavior. The development of cognitive ethology has helped emphasize that animals routinely engage in behavior more complex than most ethologists or psychologists would have thought plausible as is amply demonstrated in other chapters of this volume. The discovery of this complexity suggests that there ought to be a field called cognitive ethology, but it should not be loosely slung in a net of mentalistic verbiage. Rather, it should be defined as the rigorous, wholly scientific study of cognition in an ethological and ecological context.

Many phenomena show that cognitive processes such as learning, attention, categorization, recognition, and memory can play important roles in the lives of animals in the field (Kamil, 1988; Yoerg, in prep). As we have discussed extensively elsewhere (Kamil, 1988; Kamil & Yoerg, 1982; Yoerg, in prep), evidence for the importance of behavioral complexity has come from psychology, ethology, and behavioral ecology. How do we integrate these different approaches to the study of behavior? In the remainder of this paper, we develop the idea of a cognitive ethology that combines the best of cognitive science with the best of ethology.

COGNITION

The history of the study of cognition is not a simple one. Its initial development cannot be attributed to the work of one, two, or even a few people. Furthermore, the study of cognition was, and continues to be, influenced by many fields. (For historical accounts see Gardner, 1985; Knapp, 1986). Most scholars agree, however, that Neisser's (1967) book *Cognitive psychology* was a seminal work, the first to establish the use of the term that serves as its title. Neisser (1967) states that:

> Cognition refers to all the processes by which the sensory input is transformed, reduced, elaborated, stored, recovered, and used. It is concerned with these processes even when they operate in the absence of relevant stimulation, as in images and hallucinations. Such terms as sensation, perception, imagery, retention, recall, problem-solving and thinking, among many others, refer to the hypothetical stages or aspects of cognition. (p. 4)

More recent definitions are essentially similar to this.

The development of cognitive psychology was tremendously influenced by, if not wholly dependent on, the advent of the communication and information sciences (Lachman, Lachman, & Butterfield, 1979). Abstraction about the nature of man-made physical systems was borrowed from communications engineering and information theory and applied to the study of human mental states and processes: Environmental stimuli became inputs of information, responses (behavior) became the system's output. Conceptualizations about what might intervene between input and output were formulated in the same language using terms such as channel capacity, serial and parallel processing, and coding to refer to how information travelled through and was transformed by the human mind.

Palmer and Kimchi (1986) identify and discuss at length the fundamental assumptions of this information processing approach to the study of cognition. We will outline only the essential points here. First, mental events are functionally analogous to informational events, which consist of an input, an operation performed on that input, and a resulting output. The temporal order among components of informational events specifies the characteristics of information flow through the system. Information in this system is embodied in states called representations; the operations that are performed on that information are embodied in changes of state called processes. The task of the cognitive psychologist from an information processing perspective is to determine the nature and organization of the processes which transform, encode, represent, and use information from the external (or internal) world to produce behavior.

The domain of cognitive psychology can be divided into two interrelated areas: (a) the nature of the representation of information (cognitive content) and (b) the nature of the processing (cognitive structure and function). One question about representation concerns coding: What are the rules that relate the features of the stimulus input to the features of the representation of the information in that input? For example, in remembering someone's face, what is the relation between the contents of memory and the real face? When we form a concept do we represent distinct features, an ideal standard, or an array of exemplars from our experience (Smith & Medin, 1986)?

Issues of representation and coding are linked with those of processing and organization. Early views of cognitive processing (e.g., Broadbent, 1958) accepted a linear view of information flow in which information was transformed in a series of discrete stages beginning with sensation and ending with long-term memory and/or output to effectors. Emphasis was given to the temporal dimensions of the system with little attention to content or the kinds of processing involved. More recent models attempt to accomodate the wealth of empirical data that suggest less linear, more complex flow dynamics. For example, cognitive psychologists now distinguish between bottom-up (sensory-driven) and top-down (concept-driven) processes. In bottom-up processing, the form of the input determines the nature and extent of the processing—the animal is a relatively passive receiver of information. In top-down processing, the evaluation of sensory input depends on previous experience, expectations, and the current context. Most cognitive activity seems to involve the simultaneous interaction of both top-down and bottom-up processing (e.g., Neisser, 1976). For example, perception is usually conceived of as a bottom-up process in that we appear to perceive directly what exists in the world. But expectations can affect perception drastically: Many apparent road kills are really paperbags or pieces of tire. Similarly, remembering would appear to be a top-down process because it requires and depends on past experience. However, the features of the cues used to guide recall are critical to its efficiency. Other questions about the functional organization of cognition include whether component operations of processes are carried out serially or in parallel (e.g., Sternberg, 1966), and whether processing is modular and content-specific (e.g., Fodor, 1983), or more global and content-independent (Anderson, 1983).

The Role of Computer Science

The information processing approach to the study of cognition is, of course, allied with computer science which represents the most advanced information science. However, the influence of concepts and methodology from computer science is not uniform throughout cognitive psychology. Two major positions can be identified: (a) adherence to "weak artificial intelligence (AI)" and (b) adherence to "strong AI" (Searle, 1980). Believers in weak AI consider the computer only a powerful ally in attempts to understand cognitive processing, especially when modelling cognitive functions. Believers in strong AI contend that a computer with the right programs has a mind and cognitive states; hence, the programs are explanations of the cognitive phenomena. Not even a belief in weak AI is demanded by the information processing approach (Palmer & Kimchi, 1986).

The point of drawing these distinctions in attempting to characterize cognitive psychology is to ensure that information processing is not falsely rejected as a plausible way to address questions of import to cognitive ethologists. Griffin (1984) states that an information processing approach leads to viewing the human mind "as nothing more than a computer system" (p. iv). As a consequence, according to Griffin, the possibility of consciousness in animals is rejected, and a major portion of psychological function is disregarded. This rejection of the information processing approach is an error for several reasons.

First, many cognitive psychologists hold that the computer is limited in its ability to mimic human cognitive processing—conscious or unconscious. Second, a belief in strong AI does not deny the reality of consciousness;

consciousness is one cognitive phenomenon of many that might be an emergent property of a properly programmed computer. A human mind, in the strong AI view, would be nothing less (or more) than a computer program. Third, not all information processing models are computer-based. In new parallel distributed processing (PDP) models (e.g., Rumelhart & McClelland, 1986), neural networks are the conceptual analogue. Information is represented as the state of activation of a large network of simple units. PDP models can account for many perceptual phenomena and are now being applied to the domains of memory and language learning.

Nonconscious Cognitive Processing

Perhaps one result of cognitive ethology's distance from cognitive psychology has been the concentration on conscious processes. Cognitive psychology has clearly demonstrated that many crucial aspects of human cognition are not conscious. This is hardly a new development. Freud's most lasting contribution to psychology was probably his discovery of the importance of nonconscious influences on behavior.

There are many examples of important nonconscious phenomena in human cognitive processing. Consider the process of skill learning. Early on, conscious attention to the components of a skill such as driving a car is possible and may even necessary to the acquisition of the skill. After extended practice, however, the process becomes inaccessible to consciousness and attempts to attend to the process may interfere with its execution, as with skilled musicians and typists (Kihlstrom, 1987). The changes in the accessibility of the processes underlying skilled behavior are thought to be concomitant with changes in the representation of the knowledge acquired. Highly skilled abilities may require little or no attention and therefore do not necessarily compete with other processes for limited attentional resources—hence our ability to drive a car and carry on a conversation simultaneously. Such processes are called automatic and operate with little monitoring. Automatic processes sacrifice modifiability for speed and reduced attentional demands.

Many different kinds of studies have shown that information from the external environment can be processed, and thereby affect other concurrent processing, without awareness. For example, in the shadowing task, subjects are required to repeat words that are presented only in one ear (the target ear), while other words are presented in the other ear. Lewis (1970) showed that the presentation in the nontarget ear of synonyms of the words being repeated caused a delay in the repetition. The subjects could not, however, report any of the words presented in the nontarget ear though these words had apparently been processed sufficiently to allow semantic comparison. Similarly, MacKay (1973) presented ambiguous sentences in one ear (e.g., Three men sat on the board) and a single word (e.g., executives or workers) in the other ear. Again, even though the subjects could not remember the words that were presented in the nontarget ear, they interpreted the ambiguous sentences as if they did.

Because of the interaction between unconscious and conscious processes and the importance of each in the performance of many behaviors (simple and complex), it is imprudent to restrict the domain of cognitive ethology to conscious processes alone. If we are to develop a truly comprehensive account of the minds of animals, we cannot turn our attention (pun intended) away from any classes of cognitive events.

AN EXAMPLE OF STUDIES OF ANIMAL COGNITION

One consequence of the broad and intense development of human cognitive psychology was a revival of interest in animal cognition during the 1970s (e.g., Hulse, Fowler, & Honig, 1978). For the 30 years prior to this, the field of animal learning within psychology was almost completely dominated by the radical behaviorist tradition. The strength of that tradition is now much reduced, with most students of animal learning and behavior adopting the cognitive approach that has its historical roots in Tolman's brand of cognitive psychology (Riley, Brown, & Yoerg, 1986). The goals of the study of animal cognition are similar to those of human cognitive psychology: to understand what occurs in the temporal gap between environmental events and behavior. Because a review of the field is beyond the scope of this chapter, we will only provide one example of animal cognitive psychology. Our primary goal is to illustrate how methods borrowed directly from cognitive psychology are powerful tools for examining mental events in nonhuman animals. Two symposium volumes provide other examples (Hulse, Fowler, & Honig, 1978; Roitblat, Bever, & Terrace, 1984).

Sternberg (1966, 1969) developed a procedure for studying memory retrieval processes in humans which has proved invaluable. The essence of this procedure is that the human subjects are shown word lists of various lengths and then asked whether or not a particular word appeared on the list. Sands and Wright (1980, 1982) adopted this procedure for use with rhesus monkeys. The monkey sat before a screen on which it was shown a series of distinct color slides; this was the list of items to be remembered. The length of the list varied from one to six items. A single probe slide was then presented. By moving a lever to the left or right, the monkey indicated whether the probe slide matched a slide in the original list or was different from all the slides in that list. The primary dependent measure was reaction time—the latency to make the same/different choice.

When the probe item matched an item on the original list, reaction times increased with list length. Specifically, the addition of one more list item increased the latency to make the same response by about 13 msec. This finding supports the notion of memory scanning: The probe item was compared to each list item held in memory sequentially. Consequently, longer lists yielded longer reaction times. When the probe item did not match any of the list items, reaction times were slower than on same trials, though the slope of the function relating reaction time to list length was similar. This result constitutes additional support for the hypothesis of a serial memory scan because, on the average, it should take longer to find that no item on the list matches the probe than to find a match.

Furthermore, Sands and Wright (1980, 1982) found evidence for an effect of the serial position of the probe item in the original list; probe items that matched list items presented first (the primacy effect) or last (the recency effect) in the sequence were remembered better than those presented in the middle. All the results described have also been obtained with humans (Sternberg, 1966).

The data generated by this simple task have illuminated one aspect of cognitive processing in rhesus monkeys and humans: that the retrieval of an item in memory, in this situation, is a systematic serial process. The processes responsible for the serial position effects are not completely understood, but any model of this type of memory must account for them.

THE ANALYSIS OF IMAGERY IN HUMANS AND ANIMALS

Cognitive ethology has not yet had a strong impact on the study of animal behavior. This is not because questions of animal cognition are not relevant to attempts to understand the role of behavior in adaptation; the analysis of the relations among behavior, cognition, ecology, and evolution is not only a legitimate area of study but a necessary one (Yoerg, in prep). Rather, cognitive ethology, when defined as the study of mental experience, has suffered from confining itself to the most intractable issues of cognition—consciousness, intentionality, and emotion. The difficulty of studying these concepts is, of course, not sufficient reason to abandon them, but the standards of what constitutes convincing evidence still apply. The purpose of this section is to explore how one phenomenon of interest—imagery—to current cognitive ethology has been studied within human and animal cognitive psychology. Whether other concepts such as conscious intent or awareness can be similarly analyzed is not at all clear and awaits future attempts.

Human Imagery

Images are perception-like experiences. The study of imagery is the elucidation of the processes that underly their formation, transformation, and use. Although introspective evidence for imagery is abundant, its status as a theoretical construct is uncertain. The source of this uncertainty is the difficulty in specifying the nature of the image: What is the relation between the part of the physical world being imagined and the image? What sort of representation is an image? Some argue that images are epiphenomenal or nonfunctional, but as Pylyshyn (1981) correctly indicates, only when we have ascertained what images are will we be in a position to determine if they are epiphenomenal.

Two major approaches to the conceptualization of images can be identified: the analogue and the propositional. According to the analogue view, the way in which images can be transformed can be attributed to the medium in which images are represented or to the processes that transform images (e.g., Kosslyn, 1981). That is, the medium of visual image representation is analogous to coordinate space and mimics its properties. According to the propositional view, images are transformed in certain ways because people use their interpretation of the task and tacit knowledge about the physical properties of the world and apply them to images (Pylyshyn, 1981). The phenomena, then, that appear to support a correspondence between imaging and the act of seeing are really only evidence for what subjects believe about physical space and what they perceive is the goal of the task.

Consider the following experiment. Imagine a baseball diamond and focus on homeplate. Now shift your focus to first base. Suppose the latency to make this shift was recorded, for instance, by pushing a button when the instruction to shift was given and pushing it again when you successfully focussed on first base. Now return your focus to homebase and then shift it to left center field. The common finding in this type of experiment is that the latency to make the second shift is greater than the first; indeed, the difference corresponds to the actual difference in physical distance in the scene, assuming it has been accurately imagined. In the mental rotation task (e.g., Shepard & Metzler, 1971), subjects are asked to judge whether a rotated object was the same as a standard form or the mirror image of the form. The latency to make this response depends on the angular disparity between the rotated and standard forms suggesting that the subjects were mentally rotating an image of the form.

Proponents of the analogue account of imagery use such data to identify properties of images, for example, "images have spatial extent" and preserve "relative metric space" (Kosslyn, Pinker, Smith, & Schwartz, 1979, p. 536) and to develop elaborate models of image representation and processing. The correspondence between the time to scan an image and the actual physical distances represented in that image are taken as evidence that images have properties in common with the external world. Proponents of the propositional account dispute this claim; they argue that the empirical evidence suggests only that images represent distances not that images have distances (e.g., Pylyshyn, 1981). The difference is that the laws of the physical world that govern events in the actual scene are not necessarily the laws that govern representations of those events. A model that accounts for the scanning data must indicate why it takes longer to scan representations of greater physical distances. "There is no law of nature that demands that it must take longer to go from *representation* A to *representation* B when A and B merely *represent* locations that are further apart in the world" (Pylyshyn, 1979, p. 562).

Nonhuman Animal Imagery

Our aim in presenting these accounts is some detail (and we have omitted the lion's share of it) is to demonstrate the difficulties inherent in the study of mental experiences. Scores of well-designed experiments have been aimed at clarifying the nature of mental imagery in humans—a phenomenon that (in humans) is generally not disputed, and there is little agreement among researchers about the meaning of the results. We can expect that the study of imagery in nonhuman animals will be fraught with additional difficulties.

Neisworth and Rilling (1987) have developed a procedure that they believe is a first step in the study of imagery in animals. The task requires pigeons to respond appropriately to a moving clock hand that disappears and then reappears. The authors are circumspect in interpreting their findings, claiming only that the pigeon's ability to accurately represent movement may have required imagery. They suggest that additional experiments using a variety of procedures are needed to establish imagery in pigeons.

But their definition of imagery is imprecise: A representation is an image if it contains perceptual information (e.g., size and color) and if it can be transformed similarly to the represented object. They assert that "transformations of a mental representation *require* memory in picturelike form" (Neisworth & Rilling, 1987, p. 203). They do not specify what picturelike means. This is, of course, exactly the focus of the Kosslyn-Pylyshyn debate, and would seem to be less of a logical necessity than a plausible hypothesis. Neisworth and Rilling's (1987) results are intriguing, but whether they constitute even preliminary evidence for imagery in pigeons is unclear and will remain unclear until theories of image representation gain precision.

We do not advocate abandoning such research but, like Neisworth and Rilling (1987), suggest that we proceed extremely cautiously.

It should be noted that the phenomenon of imagery may be more amenable to rigorous analysis than that of consciousness or awareness. Most cognitive psychologists would agree that images are a type of representation, but images and/or representations need not be conscious. However, there is little consensus on what constitutes consciousness or awareness. This is not to say that an information processing approach precludes an analysis of consciousness with the appropriate scientific procedures; indeed, such attempts have been recently made (e.g., Johnson-Laird, 1983; Marcel, 1983a, 1983b).

Finally, these two case histories—serial scanning and imagery—occasion an important methodological cautionary note. In each case, very careful detailed laboratory work was required to establish what we now know about these topics, and we do not know much about the role of consciousness, awareness, or intentions in either case. It seems unlikely that we will make much progress on the complex issues raised by the cognitive approach without some of the research being carried out under highly controlled conditions.

The Ethological Approach to Animal Cognition

The four questions about behavior distinguished by Tinbergen (1963)—mechanism, ontogeny, function, and phylogeny—define the central core of the study of animal behavior. If ethology is the study of animal behavior, then obviously these four questions are the issues ethologists must address. In these terms, cognitive ethology should be the attempt to study the mechanisms, development, functions, and evolutionary history of cognitive processes. This attempt will have to cut across the traditional boundaries between several academic disciplines, primarily psychology and ethology, but also the other cognitive sciences (computer science, linguistics, and anthropology).

The boundaries between experimental animal psychology and ethology are crumbling. Meaningful integrative theoretical and empirical work has been taking place. For example:

1. Psychological models of timing, particularly the scalar expectancy model (Gibbon, 1977) has been successfully applied to foraging problems (Lucas, 1987), and integration of this mechanistic theory and optimality theory may prove extremely useful;
2. Psychological techniques and theories have been applied to the ecological and ethological concept of the search image resulting in

new insights into the mechanisms underlying the detection of cryptic prey (Getty, Kamil, & Real, 1987);

3. The mechanisms responsible for the recovery of cached food by parids (Shettleworth & Krebs, 1982) and Clark's nutcrackers (Kamil & Balda, 1985) have been studied by biologists and psychologists working collaboratively, and this research is increasing our understanding both of spatial memory and of the ecology of scatter-hoarding (Balda, Bunch, Kamil, Sherry, & Tomback, 1987).

In view of these and other developments, a comprehensive integration of psychological information processing approaches with those of ethology and behavioral ecology is at hand. Explicit detailed knowledge of the history of the advances made and problems encountered by each approach will expedite this integration. The history of the psychological study of animal cognition contains much that is useful to the modern ethologist interested in cognition. A study of this history can lead to the avoidance of errors committed and the acceptance of valuable procedures and concepts (Kamil, 1983).

The core of the matter is as follows: Cognitive organization and processing has an evolutionary history and, it is reasonable to assume, serve adaptive functions. Because behavior is determined by the interaction of environmental (ecological) and cognitive events, an interdisciplinary approach to the study of behavior is demanded, whether the behavior of interest is the result of processing that is simple or complex, conscious or unconscious. This interdisciplinary approach will follow logically from the broad definition of cognitive ethology that we suggest.

ACKNOWLEDGMENTS

Preparation of this chapter was supported by NSF grant BNS-8418721.

REFERENCES

Anderson, J. R. (1983). *The architecture of cognition.* Cambridge, MA: Harvard University Press.

Balda, R. P., Bunch, K. G., Kamil, A. C., Sherry, D. W., & Tomback, D. F. (1987). Cache site memory in birds. In A. C. Kamil, J. R. Krebs, & H. R. Pulliam (Eds.), *Foraging behavior* (pp. 645–666). New York: Plenum.

Broadbent, D. E. (1958). *Perception and communication.* London: Pergamon Press.

Fodor, J. A. (1983). *The Modularity of Mind.* Cambridge, MA: M.I.T/Bradford Press.

Gardner, H. (1985). *The mind's new science: A history of the cognitive revolution.* New York: Basic Books.

Getty, T., Kamil, A. C., & Real, P. G. (1987). Signal detection theory and foraging for cryptic or mimetic prey. In A. C. Kamil, J. R. Krebs, & H. R. Pulliam (Eds.), *Foraging behavior* (pp. 525–548). New York: Plenum.

Gibbon, J. (1977). Scalar expectancy theory and Weber's law in animal timing. *Psychological Review, 84,* 279–325.

Griffin, D. R. (1978). Prospects for a cognitive ethology. *Behavioral and Brain Sciences, 4,* 527–538.

Griffin, D. R. (1981). *The question of animal awareness.* New York: Rockefeller University Press.

Griffin, D. R. (1984). *Animal thinking.* Cambridge, MA: Harvard University Press.

Hulse, S. H., Fowler, H., & Honig, W. K. (1978). *Cognitive processes in animal behavior.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Johnson-Laird, P. N. (1983). *Mental models.* Cambridge: Cambridge University Press.

Kamil, A. C. (1983). Optimal foraging theory and the pscyhology of learning. *American Zoologist, 23,* 291–302.

Kamil, A. C. (1988). A synthetic approach to the study of animal intelligence. *Nebraska Symposium on Motivation.* Vol., 35, 357–308. Linclon: Univ. of Nebraska.

Kamil, A. C., & Balda, R. P. (1985). Cache recovery and spatial memory in Clark's nutcrackers *(Nucifraga columbiana). Journal of Experimental Psychology: Animal Behavior Processes, 11,* 95–111.

Kamil, A. C., & Yoerg, S. I. (1982). Learning and foraging behavior. In P. P. G. Bateson & P. H. Klopfer (Eds.), Perspectives on ethology, vol. 5 (pp. 325–364). New York: Plenum Press.

Kihlstrom, J. F. (1987). The cognitive unconscious. *Science, 237,* 1445–1452.

Knapp, T. C. (1986). The emergence of cognitive psychology in the latter half of the twentieth century. In T. J. Knapp & L. C. Robertson (Eds.), *Approaches to cognition: Contrasts and controversies* (pp. 13–35). Hillsdale, NJ: Lawrence Erlbaum Associates.

Kosslyn, S. M. (1981). The medium and the message in mental imagery: A theory. *Psychological Review, 88,* 46–66.

Kosslyn, S. M., Pinker, S., Smith, G. E., & Schwartz, S. P. (1979). On the demystification of mental imagery. *Behavioral and Brain Sciences, 2,* 535–581.

Lachman, R., Lachman, J. L., & Butterfield, E. C. 1979. *Cognitive Psychology and Information Processing: An Introduction.* Hillsdale, NJ: Lawrence Associates.

Lewis, J. L. (1970). Semantic processing of unattended messages using dichotic listening. *Journal Experimental Psychology, 85,* 225–228.

Lucas, J. R. (1987). Foraging time constraints and diet choice. In A. C. Kamil, J. R. Krebs, & H. R. Pulliam (Eds.), *Foraging behavior* (pp. 239–269). New York: Plenum.

MacKay, D. G. (1973). Aspects of the theory of comprehension, memory and attention. *Quarterly Journal of Experimental Psychology, 25,* 22–40.

Marcel, A. J. (1983a). Conscious and unconscious perception: Experiments on visual masking and word recognition. *Cognitive Psychology, 15,* 197–237.

Marcel, A. J. (1983b). Conscious and unconscious perception: An approach to the relation between phenomenal experience and perceptual processes. *Cognitive Psychology, 15,* 238–300.

Neisser, U. (1967). *Cognitive psychology.* New York: Appleton–Century–Crofts.

Neisser, U. (1976). *Cognition and reality.* San Francisco: W. H. Freeman.

Neisworth, J. J., & Rilling, M. E. (1987). A method for studying imagery in animals. *Journal Experimental Psychology: Animal Behavior Processes, 13,* 203–214.

Palmer, S. E., & Kimchi, R. (1986). The information processing approach to cognition. In T. J. Knapp & L. C. Robertson (Eds.), *Approaches to cognition: Contrasts and controversies* (pp. 37–77). Hillsdale, NJ: Lawrence Erlbaum Associates.

Pylyshyn, Z. W. (1979). Imagery theory: Not mysterious—just wrong. *Behavioral and Brain*

Sciences, 2, 561-563.

Pylyshyn, Z. W. (1981). The imagery debate: Analogue media versus tacit knowledge. *Psychological Review, 88,* 16-45.

Riley, D. A., Brown, M. F. & Yoerg, S. I. (1986). Understanding animal cognition. In T. J. Knapp & L. C., Robertson (Eds.), *Approaches to cognition: Contrasts and controversies* (pp. 111-136). Hillsdale, NJ: Lawrence Erlbaum Associates.

Roitblat, H. R., Bever, T. G., & Terrace, H. S. (1984). *Animal cognition.* Hillsdale, NJ: Lawrence Erlbaum Associates.

Rummelhart, D. E., & McClelland, J. L. (1986). *Parallel distributed processing: Explorations in the microstructure of cognition.* Cambridge, MA: M.I.T Press.

Sands, S. F., & Wright, A. A. (1980). Serial probe recognition performance by a rhesus monkey and a human with 10- and 20-item lists. *Journal of Experimental Psychology: Animal Behavior Processes, 6,* 386-396.

Sands, S. F., & Wright, A. A. (1982). Monkey and human pictorial memory scanning. *Science, 216,* 1333-1334.

Searle, J. R. (1980). Minds, brains and programs. *Behavioral and Brain Sciences, 3,* 417-457.

Shepard, R. N., & Metzler, J. (1971). Mental rotation of three-dimensional objects. *Science, 171,* 701-703.

Shettleworth, S. J., & Krebs, J. R. 1982. How marsh tits find their hoards: The roles of site preference and spatial memory. *Journal of Experimental Psychology: Animal Behavior Processes. 8,* 354-375.

Smith, E. E., & Medin, D. L. (1986). *Categories and concepts.* Cambridge, MA: Harvard University Press.

Sternberg, S. (1966). High-speed scanning in human memory. *Science, 153,* 652-654.

Sternberg, S. (1969). Memory scanning: Mental processes revealed by reaction-time experiments. *American Scientist, 57,* 421-457.

Tinbergen, N. (1963). On aims and methods of ethology. *Zeitschrift für Tierpsychologie, 20,* 410-433.

Tolman, E. C. (1938). The determiners of behavior at a choice point. *Psychological Review, 45,* 1-41.

Yoerg, S. I. (in prep). Ecological frames of mind: The role of cognition in behavioral ecology. *Quarterly Review of Biology.*