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NUMBER 4
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THE HUMAN BRAIN EVOLVING:

Paleoneurological Studies in Honor of Ralph L. Holloway

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FRONT COVER CAPTIONS

Center: Portrait of Ralph L. Holloway.
Upper left: A modern human brain.
Upper right: Ralph measuring landmarks on an endocast ca. 1976.
Lower right: Homo habilis cranium KNM-ER-1813 from Koobi Fora, Kenya (photo by Holloway).
Lower left: Ralph with an endocast of the Flores "hobbit" cranium.

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CHAPTER 18

The Foundations of Primate Intelligence and Language Skills

Duane M. Rumbaugh, E. Sue Savage-Rumbaugh, James E. King and Jared P. Taglialatela

It must have been an exciting time when hominids found that they had a level of intellectual operations that clearly was giving them an increased advantage in undertaking the unceasing daily challenges of survival–generally in competition with a variety of animals of the savannah and forest, of getting food and water, avoiding becoming a ready meal for carnivores, dying from exposure, and so on. These challenges were only compounded as they migrated to novel environments in the far corners of Europe and Southeast Asia. Most likely a premium came to be placed on tools. Initially, natural items, such as stout portions of branches, could serve as clubs, and broken cobbles might yield knife-sharp edges for skinning and butchering. But tools are consumable and subject to being lost in less-than-well-coordinated running or left at a site because of distractions from salient distal events.

It is not difficult to conjure the premium afforded by invention and symbolic thought. We have the longstanding view that it was the early evolution of bipedalism in hominids that made it possible for later evolution of general intelligence by selection for brain size, and only secondarily by selection for body size. Prior to the emergence of competent bipedalism, intelligence within the primate order appears to have been a generous corollary of body size. Size always has had its perquisites, providing priority access to the resources that afford not only life but the comforts thereof. The factor limiting size was likely the need for ready nourishment, as well as an environment providing accessible food and water for group living. The larger the quadruped ape, the more food and time to eat were required for life. The encephalization process generously gave the great apes' brains larger than justified on the basis of their body size.

The encephalization of the great apes generally makes them superior to the lesser apes and to the monkeys in formal tests of learning (Rumbaugh & Washburn, 2003). Though excellent learners, even the larger monkeys and baboons lack the readiness to become rational learners in comparision to the apes–that is to learn the overarching principles that differentiate classes of visual discrimination problems. Relational learning includes the ability to learn a general rule that defines a correct response for an entire class of problems containing an unlimited number of exemplars, what Harry Harlow (1949) referred to as "learning sets." Monkeys can achieve that capability, but they require far more experience and training than does an ape reared in a similar environment.

Similarly, the larger monkey species can, with extended experience, become quite proficient at transferring learning and consequently benefit from these increased amounts of learning (e.g., knowledge about how to do a task); by contrast the performance of the smaller primate species with smaller brains might become increasingly compromised with additional training on tasks prior to transfer-of-learning tests (Beran, Gibson, & Rumbaugh, 1999). In other words, if one increases the amount of training even slightly prior to transfer-of-training tests, the apes and other large primates do substantially better, though the small primates do worse. We interpret this to mean that whereas all primates' initial learning of discrimination tasks is basically associative, they have a capability for advancement to relational learning—learning of overarching principles to expedite both learning and the transfer of learning to different situations. This advancement to relational learning is a positive function of the species' brain volume.

The Good Fortune of Having the Apes

Although the early hominids are no longer with us, we are fortunate to have the great apes and dozens of feral populations of monkeys and prosimians around the tropical belt of the planet. Rumbaugh and Washburn (2003) have made a recent analysis of experiments that focus upon the intelligence of primates within a comparative framework; the reader is referred to the relevant studies in their book to better understand the bases for the rest of this chapter.

Because of the close genetic relationship between modern humans and the great apes (Gagneux & Varki, 2001), we believe that much can be learned about the origins of intelligence and language through research with the great apes both in the field and laboratory. Furthermore, and more specific to this volume, such research can help us better understand the emergence of intelligence and complex communication processes in the hominids, and ultimately the essence of our own learning and behavior.

Prior to the recent cognitive revolution, psychology was heavily influenced by radical and methodological behaviorism for the majority of the 20th century (Amsel,1989). For this reason alone it is timely that we reexamine the processes of learning and behavior and, in particular, the presumed role of reinforcement in animals' adaptation to their environments. As we do so, we will reconsider how organisms should be viewed and how the processes of learning and behavior that embrace their root sources, from instincts to conditioning, cognition, intelligence and culture, feed into adaptation and behavior. Rumbaugh, King, Beran, Washburn, and Gould (2007) recently have offered a theory of learning and behavior based on salience, not on reinforcement as it is conventionally defined. We will review the basic principles of that theory after we attend more specifically to the various complex learning and problem-solving skills of the great apes, as well as of their capacity to understand symbolism and certain dimensions of language. The capabilities that we will consider entail the emergence of new behaviors and skills that are well beyond behaviors that would be predicted from a behavioristic interpretation of an animal's specific training and/or reinforcement history. For that reason, we term these new behaviors as *emergents*.

A reinterpretation of how organisms should be viewed and of the processes of learning and behavior that embrace their root sources, from instincts to conditioning, cognition, intelligence and culture, has been recently reported by Rumbaugh, King, Beran, Washburn, and Gould (2007). We will review the basic principles of that theory after we attend more specifically to the various complex learning and problem-solving skills of the great apes, as well as of their capacity to understand symbolism and certain dimensions of language. The capabilities that we will consider entail the emergence of new behaviors and skills that are well beyond behaviors that would be predicted from a behavioristic interpretation of an animal's specific training and/or reinforcement history. For that reason, we term these new behaviors as *emergents*.

How Is It That Apes Can Learn Language and Make Tools?

Among the host of delightfully puzzling questions driving the field of primatology today, as it seeks for an ever-objective definition of the ape mind, are those that ask, basically, "In apparent contradiction to the constraints based on the conventional principles of learning and behavior that have been dominant for the past 75 years, why do apes in particular exhibit emergents that take form as creative problem-solving abilities rather than relatively fixed behaviors in response to specific stimuli? What are their parameters? How are these abilities acquired? How do some apes come to learn the semantic meanings of word symbols, to use them in novel social communication, and even to comprehend human language and its elemental syntax? And how do some of them become sufficiently proficient from only observational learning to make tools and start fires based only on observational learning?"

We clearly need a new and comprehensive framework of learning and behavior that embraces unlearned (i.e., instinctive) behaviors constrained by genetics and the remarkable behaviors brought about through conditioning procedures, yet a framework that also provides for creative and inventive behaviors that emerge from time to time, though without a specific history of training that could account for them. These emergent behaviors come as surprises and are seen as something well beyond the domain of reinforcement, of highly specified training procedures (Rumbaugh et al., 2007; Rumbaugh, Savage-Rumbaugh, & Washburn, 1996; Rumbaugh, Washburn, & Hillix, 1996).

Emergents have their roots in unlearned behavior systems as well as in the respondents and operants of conditioned behavior. Yet, they are something identifiably different that strongly suggests high plasticity and intelligence as foundations. Just how emergents are generated by the normal operations of the brain from the experiences that all of life offers is at present imperfectly understood, to say the least. When asked how emergents are formed, one eminent neuroscientist replied, "God only knows." To come to understand the parameters of emergents at any level will take decades of research at all levels, but to understand them better along the way will be reward sufficient to the task. In the meanwhile, primatologists can make valuable contributions in defining the antecedent and subject parameters of emergents and the impacts of emergents upon subsequent behavior, including learning and all other basic processes.

Lana

Let us take a few select examples from our own laboratory research. First, Lana, a female chimpanzee, was taught dozens of word-lexigrams (geometric patterns glossed as words) by basic operant techniques (Rumbaugh, 1977). Specifically, she learned how to organize them into stock sentences required by the computer to operate specific devices that would vend for her a variety of foods, drinks, music, slides, movies, a view out-of-doors, human companionship, grooming play, and so on.

But well beyond that, she was the one, not us, to initiate conversations by using a keyboard in order to get things that she could not otherwise access and to ask for the names of things. On occasion she would direct caregivers' attention to malfunctioning systems. She accurately differentiated sentence stems that correctly began sentences, (that she then would complete to obtain various rewards), from sentence stems that were in error and, hence, were erased as having no value to her. These are only a few of the highly significant behavioral extensions manifested by Lana that had literally no prior history of reward or reinforcement to account for their emergence.

Sherman and Austin

Second, the chimpanzees Sherman and Austin (Savage-Rumbaugh, 1986) demonstrated their capacity for understanding the semantic meanings of the word symbols (i.e., lexigrams) with which they worked each day. Initially they learned to sort lexigrams for three specific foods and three specific tools, drawn from a larger vocabulary of dozens of symbols. After further training, they were able to label just the lexigrams for these foods and tools used in initial training with two new lexigrams, one glossed "food" and the other "tool." Thus, they categorized the lexigrams for the three foods and three tools used in training with two new lexigrams that served to categorize all examples of food or all examples of tools symbolically. In the final test, they made only a single error between them in sorting 16 other food and tool lexigrams for a variety of foods and tools that had been reserved for the final test.

In brief, they were very precise in labeling these test lexigrams for foods or tools appropriately with the corresponding general food or tool lexigrams even though the test lexigrams for specific foods and tools had never been previously associated with the general food and tool lexigrams. We conclude that their labeling skills in controlled test must have reflected semantic foundations for their lexigrams. How would they have been able to categorize the test lexigrams so accurately if the lexigrams lacked meaning for them? In other words, the food and tool lexigrams had a general meaning for Sherman and Austin that transcended association with only a few specific lexigrams for particular foods and tools. We hold that the meaningfulness of these test symbols enabled covert representations of their physical referents and that it was those representations that, in turn, enabled Sherman's and Austin's remarkable labeling of them at the time of testing.

In sum, Sherman and Austin demonstrated that, for them, word-lexigrams could acquire symbolic meaning, which is absolutely fundamental to language. Their very limited training with only three food and three tool exemplars led to a generalized competence with 16 other lexigrams in a final test.

Kanzi

Third, Kanzi, a male bonobo, came to comprehend human speech, including both the meanings of individual words and their use in novel sentences of request (Savage-Rumbaugh et al., 1993). He acquired these abilities without any specific training to those ends. Instead, Kanzi was raised in a social environment in which language was used by others in a natural context, similar to that experienced by human children. Indeed, we had thought that no ape had the capacity to acquire these skills. In brief, his brain somehow took the experiences of his daily life and gave them structure and function in new vectors, demonstrating new emergent competencies not at all natural to his species.

Rhesus Monkeys

Fourth, two rhesus monkeys (Rumbaugh & Washburn, 2003) rapidly came to discern which of either member of pairs of numerals, from 0 through 5, was the one designated by experimenters to net the larger number of pellets on any given trial. The trials were massed and the monkeys were not food deprived, so the premium of their receiving, say, four rather than three small food pellets on a given trial seems trivial. Their training was then extended to include numerals 6, 7, 8, and 9. In final test, with seven possible pairings of the entire set of real numerals (i.e., 1-9) reserved for this test, they made only two errors.

In other words, they were able to conclude, on the basis of prior experience with the other numerals that had been used in training, which of two numerals encountered for the first time as a pair in final test would net the larger number of pellets. They did not do this because they were required to do so or even specifically trained to do so. Rather, their remarkably extended competence reflects operations by their brains that took the vast array of other relevant experiences and somehow organized them so as to declare the probable "better" choice of numerals on each novel test trial.

These are only a few of dozens of examples of emergents to which we could refer, yet they are sufficient to define our wonderful quandary: Out of their specific and relatively limited rearing and training histories, *how do primates come to manifest a variety of new abilities and even new competencies heretofore unanticipated and unforeseen—that is, emergents?*

This question cannot be pursued to a satisfactory conclusion within the limits of this chapter. Nonetheless, we shall attempt to define the bases for the questions and, finally, to point to a new perspective of learning and behavior that is more in keeping with our current understanding of behavior of all animal forms than is traditional reinforcement theory. All of this is done to the end that the reader have an enlightened perspective of how the salient events of a challenging social and physical environment fostered larger and larger brains, higher levels of intelligence, and the foundations for creative technologies to emerge. It was likely from this path that a socially complex culture as we know it finally took form. And culture, too, served to provide increasingly stimulating environments within which the hominid infants benefited in their intellectual stimulation and development.

Reinforcement Reconsidered

Although we fully agree that the immediate correlates and consequences of behavior are fundamental to the learning process and acknowledge that the concept of reinforcement has played a very significant role in the history of learning and behavior, it is time that we markedly revise our definitions of the term *reinforcement*, if not abandon it altogether. The reasons for so doing are as follows:

> The term carries excess meaning in that it encourages the beliefs that reinforcers actually strengthen associations between stimuli and specific behaviors and that all behaviors have reinforcement histories.
>
> Its definition has been inherently circular.
>
> It emphasizes behavior in its relation to specific stimuli inordinately and does not encourage consideration of whatever the subject might bring as a sentient and knowledgeable agent-of-action to the determination of its behavior.
>
> It inordinately emphasizes fixedness in behaviors and detracts from our likelihood of observing emergent behaviors–those that are creative, new, efficient, and insightful.
>
> By abandoning the term *reinforcement* and using *reward* in its stead, we continue to acknowledge the importance of consequences of behavior yet recognize that what we have called "reinforcement" is really a resource of value to our subjects and that, in essence, it is equivalent to "pay for work done."

The view that we are proposing here is as follows: As they adapt to their changing environments, organisms are fundamentally foragers for information. However, the foraging goes far beyond the usual sense of the word. Animals are constantly seeking optimal environments and, most importantly for our theory, relevant information that yields needed resources bountifully and in relatively safe contexts. The search for relevant information and subsequent use of that information in creative and imaginative ways form the basis for emergent behaviors. In contrast, organisms are not entities that have their behaviors comprehensively shaped and reinforced by the consequences of behavior.

A New Perspective

From a variety of perspectives, perhaps no other construct has survived the past century with greater impact than has reinforcement. At the risk of being too simplistic, we would like to say that all perspectives and definitions of reinforcement assume that if reinforcement occurs soon after the occurrence of a behavior, reinforcement can serve to strengthen the probability that this behavior will reoccur, given a repeat of the situation in which it appeared or was elicited. To us, the effect of reinforcement has always implied a certain degree of fixedness, a predictability, a robot-like predictability, that, at face value, are antithetical to creativity, invention, and intelligence generally for which apes are known. In its most basic traditional definition, reinforcement is posited as a theoretical process that strengthens an association, a stimulus, and a response. But now that we have solid evidence of complex cognitive skills and potentials in animals (including of course, humans), the concept of reinforcement is no longer very appropriate except in the context of simple, predictable responses. On the other hand, reinforcements can be important resources for the organism. We propose that the organisms learn predominantly about the resource values of reinforcements.

We are not asserting that the contingencies or aftermaths of behavior have no effect. Instead, we are arguing that the concept of reinforcement should be supplanted with other terms. We suggest the term *outcome*, with *reward* standing for an appetitive outcome, *resource* meaning an outcome garnered by foraging or taking, and *punishment* standing for an aversive outcome.

So, What Is Being Reinforced?

Historical tradition maintains that the manifestation of learning is expected to be the specific behavior that is being reinforced. Now, to illustrate the difficulties encountered in viewing reinforcement of responses as the determinant of both what is learned and what behavior is to be expected, let us consider a complex video-formatted task in which a rhesus monkey was assiduously trained by traditional operant techniques to capture an erratically moving target by using its foot to control a joystick that moved a cursor. Although the monkey was trained to use its foot exclusively (i.e., it was never permitted to use its hand in training), results made it clear that what was learned was something far more comprehensive.

After the monkey mastered the foot task, it was given its first opportunity to use either its hand or foot. It tried to use a foot not at all! Rather, it used its hand exclusively! Even more impressive was the fact that performance was better with a hand than it had ever been with the monkey's foot.

Though reinforced exclusively in training to use its foot, the monkey clearly had learned much, much more: It accrued an apparently comprehensive understanding about the task, namely the relationship between the movement of the joystick and the movement of the cursor on the video screen! Such comprehension in the rhesus is not to be accounted for by the reinforcement of motor responses but rather by the integrative processes of its brain. (See Rumbaugh & Washburn, 2003, for further details.)

Thus, while reinforcement doctrine would lead us to expect that the conditioning of response modes through extensive reinforcement histories will engender responses that are predictable and relatively stereotyped, reinforcements or rewards do not necessarily have such a limited effects! Stated most simply, though an experimenter might condition a specific response to be learned, the subject actually learns not only the relationships between responses but also how to access resources and avoid risks. In terms of the foraging metaphor used earlier, the contingency between stimulus and reward is simply interesting information that is "foraged" in order to be applied within a wider context.

In other words, the brain takes what it obtains from experience and then runs with it, metaphorically, to form new behaviors and new skills. If such were the case with the early hominids, it is clear how they become the dominant force in the world.

Rumbaugh, King, Beran, Washburn, and Gould (2007) have posited that the design of brains serves to bias the selective perception of events in accord with their salience—natural or acquired—and, also, to organize or interrelate them in accord with the ecological resources and needs of the subject so that it adapts and survives. Major principles of that theory now will be considered in relation to the advanced learning and cognition of primates. Because salience of stimuli and events, produced either externally or internally, are basic to the theory, we shall summarize our perspective of salience and its posited role in learning and behavior.

A Salience Theory of Learning and Behavior

What is salience? We begin with the assumption that consciousness is not necessarily a requisite to perceiving or responding to the salience of events—be they individual units or coupled by parameters outlined below. Notwithstanding, it seems reasonable to assume that organisms attend to stimulus events on the basis of their perceived priority. *Although this might be totally true, to avoid stopping with what is fundamentally a circular definition of salience, let us identify the attributes of objects and events that will declare them as salient.* Salience might be natural, or it might be acquired.

Natural Salience

There are several stimulus events that are inherently salient by reason of the species' genomes. They include ones for which salience is *natural*, such as the following: (a) natural sign-stimuli that are relatively species-specific; (b) intense stimuli (e.g., energies with high decibels, intense illumination and/or pressure levels) that threaten to exceed the sensory thresholds of a given species; (c) biologically predicated need states, as for moisture, nutrients, and an ambient temperature range that varies widely across life forms; (d) novel stimuli; and (e) perceptual integrative/organizing principles as originally defined by Gestalt psychology that serve to group and to otherwise enhance the prospects for an organized percept rather than a random field of stimulation.

These sources of salience are not necessarily dependent upon experience, though they might well be sensitive to requisite stimulation within certain levels of maturation (e.g., within critical age levels). In addition, all unconditional stimuli (of Pavlovian or classical conditioning) that elicit reflexes are inherently salient.

Acquired Salience

Other sources of salience are *accrued*, not necessarily through traditional learning processes but because of what we view as a natural, near-universal principle: Units (stimuli, events, and/or behaviors) that occur reliably in about the same time and space reliably tend to couple, to mix. This is true of most liquids, fumes, and even metals. It clearly is the case in the production of colors and odors. The celebrated neuroscientist Gerald Edelman (2006) has observed that neurons and neural circuits that fire together get wired together] Generally speaking, this mixture is of high probability as a general natural law or principle, echoing the work of D. O. Hebb (1949) and others.

Principles of the Framework

Thus, the first principle of our framework holds that learning is based on the reliable temporal or spatial contiguity of events. Units that co-occur reliably become at least metaphorically coupled or even blended to form an *amalgam*. There are two important corollaries of this principle:

1. In their coupling so as to form an amalgam, the units will mutually share their saliences and their response-eliciting characteristics. Thus, each amalgam will have unique characteristics above and beyond those of the units that have entered into its formation.
2. The merger of two or more units into an amalgam reflects the relative strengths of the individual units.

Consequently, some co-occurring units are coupled naturally because each unit has substantial strength. Thus, the units of lightening and thunder are readily coupled because each unit has substantial strength. It is not necessary that such units in their coupling have inherent sequential organization (e.g., though lightening always precedes thunder, other coupled units might co-occur in any order). That said, if one of two or more co-occurring units differs substantially in its strength from the others, the coupling is more likely if the weaker one(s) precede the stronger ones—as in classical conditioning. Whether units that are relatively weak in strength become coupled if they sequentially follow the units of substantial strength will be determined by the degree to which the salience that inheres in the stronger units obscures or masks the salience that inheres in the weaker units.

Thus we posit that an amalgam of stimulus events will reflect their shared response-eliciting properties as some positive function of the vigor of the responses produced by each stimulus and the relative strengths of their responses when they co-occur in time and/or space. Thus, in classical conditioning, both the conditional stimulus and unconditional stimulus mutually share their response-eliciting properties. It is only because the unconditional stimulus is the stronger of the two that its response-eliciting properties are more strongly manifested with the presentation of the conditional stimulus rather than vice versa. *In other words, the high-strength unconditional stimulus will cause a large change in the response to the conditional stimulus, whereas the low-strength conditional stimulus will have little or essentially no discernable effect on the response to the unconditional stimulus. Nevertheless, there is good reason to hold that the unconditional stimulus accrues an approximation of the relatively minimal response-eliciting property that inheres in the conditional stimulus* (Domjan, 2003).

A second principle of our framework is that species' brains are uniquely designed to process coupled stimulus events, to somehow file and process them to form emergent behaviors and emergent capacities that service the species' adaptation in both familiar and novel challenges. Organisms *detect* coupled events for which their neural systems have been attuned; that is, animals recognize reliable and predictable patterns that might be basic to their adaptation. Either the patterns of events are "out there" in the natural word, or they are reliable consequences of behaviors. They are the regularities if not the invariants of experience across time. The more complex the pattern, the more complex the cognitive system (and the brain) must be to recognize it in detail; notwithstanding, animals learn by detecting predictable temporal or spatial relations if they are extant among co-occurring units that are basic to their adaptation.

Brain Business

We have posited that species' brains or neural systems are attuned to attend to what is basic for their survival and reproduction. As its fundamental model of operation, we posit that the brain produces streams of amalgams as defined above. The brain also functions, perhaps continuously, to relate and interrelate the amalgams into systems that reflect their similarities and their relationships. Metaphorically, we use the term *templates* to label those systems of organized amalgams. We view templates as being either essentially natural or arbitrary. Natural ones are those that reflect the basic adaptation modes and significant processes required of the species. Natural templates receive amalgams that have such fundamental significance to a species' adaptation that rapid learning and adaptation are to be expected. Arbitrary templates are those that are entailed in everything else, such as the complexities of acquiring insights to other-than-natural challenges and of acquiring rules, forming strategies, mastering language, composing music, and inventing. The formation of arbitrary templates might require substantial periods of time, if not years, of experiencing classes of generalized experiences.

In their formation and operation, templates assimilate amalgams that are closely related or similar. When an already existing template cannot accommodate a stream of amalgams being formed as a result of a novel or unexpected pattern of stimulus events, then the assimilation process may adapt by forming a new template to accommodate the novel amalgams. We believe that the tension resulting from the effort to assimilate novel combinations amalgams into new templates may stimulate the formation of emergents as new options that might afford effective and energy-saving adaptations. The flexibility of the template formation process means that the emergent behaviors are emancipated from the constraints of traditional stimulus–response or response–reward mechanisms.

Reinforcement Redefined

The reader will note that reinforcement, according to our frame of reference, does not serve any specific role. Reinforcements obviously have major effects upon behavior due to their strength and response-eliciting properties, either of which might be of natural or acquired origin. In reliable and contiguous association with other stimuli, it shares both its salience and its response-eliciting properties with other current stimuli and behaviors to form amalgams—brain business. Thus, in classical conditioning the unconditional stimulus has natural salience and shares its response-eliciting properties with other stimuli that are contiguous with it, specifically the conditional stimulus. Across trials, the conditional stimulus and the unconditional stimulus form a stream of highly similar amalgams, all sharing a conditional stimulus–unconditioned stimulus temporal contiguity. Hence the conditional stimulus comes to function as though it were the unconditional stimulus, and conditioning is said to have occurred. Since the conditional stimulus is selected by the experimenter because it is weak, nonsalient, and does not elicit strong responses, the unconditional stimulus by itself subsequently shows little readily observable influence after formation of the amalgam between the conditional and unconditional stimulus. Nevertheless, we suspect that subtle influences of a conditional stimulus upon an unconditional stimulus can be detected by appropriate methodology.

We make the following points to clarify further the preceding argument made above. We hold that a process similar to either sensory preconditioning or autoshaping likely prevails in both respondent and operant conditioning situations. Sensory preconditioning enhances the salience of basically neutral stimuli simply by pairing them together temporally with more salient stimuli. In sensory conditioning paradigms, neither of the neutral stimuli would be regarded as an unconditioned stimulus. The less salient of the previously neutral stimuli gains in salience and become functionally equivalent to the more salient stimulus in its role. Thus, if one member of a pair is an unconditional stimulus, then quite likely the other less salient one will assume some of the properties of the unconditional stimulus despite the fact that it originally served as a conditional stimulus in a conditioning procedure.

The phenomena of autoshaping occurs when a neutral stimulus such as a light and a traditional reinforcer such as food are temporally paired. The food presentation is predicted only by the light and is independent of any response that the subject makes (Brown & Jenkins, 1968). After autoshaping, the subject makes responses to the neutral stimulus (e.g. pecking) that were previously make only to the reinforcer. The topography of the conditioned response of pigeons acquired therein (e.g. pecking the light) provides strong support for the frame of reference here advanced—that the functional role of the "reinforcer" is shared with (i.e., becomes elicited by) a visual target or a discriminative stimulus temporally associated with the reinforcer. If the "reinforcer" is grain, the bird pecks at the target as though if it were food; if it is water, the bird pecks as though it were drinking water.

Similarly, pigs described by Breland and Breland (1961) readily learned to pick up wooden nickels and deposit them in a piggy bank for food reward. Across time, however, the nickel-directed depositing behavior became disrupted as the pigs came to root and toss the nickel as though it were food. Thus, the reward came to share its response-eliciting properties with the nickel and resulted in the pigs manifesting their learned rooting and tossing even though it resulted in the absence of food reward.

From our frame of reference, a conditional response is a manifestation of the partial functional equivalence of the conditional stimulus and the unconditional stimulus. The response, once conditioned, never completely duplicates the response elicited by the unconditional stimulus because each unit of an amalgam retains in part its own salience and its own response-eliciting characteristics. Functionally, both "reinforcers" and rewards constitute resources relevant to the organism because of its biological and acquired needs. In conditioning contexts, the organism learns about resources that it can obtain and about how to obtain them. Contingent upon the species of subject and its neural system, the conditioning experiences will be processed to the end that the organism is likely to learn primarily about relationships among the units of the task and how to get the valued resource based on those relationships.

Thus we recommend use of the term *reward* instead of *reinforcer* due to the discredited assumption that a reinforcer directly strengthens a specific response or behavior. Rewards play a much more general role in learning and the directions of behavior than traditional rewards. Rewards give the organism a reason to care and learn about the predictable patterning of stimuli and events that we are constantly experiencing.

Early Environment and its Significance

Among the several sterling contributions made by primatologists is the uncontested principle that conditions and experiences present during early development have long-lasting sculpting effects upon the intelligence, emotions, interests, personalities, and morphology of organisms. In the area of primate behavioral development, Mason (2002) saw the emergence of new behaviors and capabilities as a concept that is fundamental to the understanding of behavioral development and that requires new descriptive categories and measurement. The comprehension of human speech and of the meanings of various word-lexigrams by apes without formal training is a prime example.

The Significance of Recent Language Research With Apes

Earlier assumptions comparing the language ability of apes with human standards of speech, especially in phrase and sentence construction, incorrectly led researchers to conclude that apes do not and cannot have language (Rumbaugh & Savage-Rumbaugh, 1994). Extending this logic has brought the equally incorrect converse implication that language is a uniquely human attribute. Contemporary research in ape language, however, has unequivocally demonstrated the capability of apes to acquire the meaning of symbols and to use those symbols with results that demonstrate the fundamental properties of human language.

Specifically, intensive research across the last 30 years has documented that apes can do the following: (a) learn and use symbols to represent objects or events that are not present. This capability is referred to as *displacement* and is a necessary foundation of *semantics*; (b) use learned symbols among themselves and/or with humans to solve problems by exchanging information; (c) readily organize their learned symbols into conceptual categories (e.g., foods, tools, people); (d) acquire language optimally through daily experiences garnered during infancy, not through formal training; (e) comply with basic rules of grammar and comprehend novel sentences that they hear, sentences that have their meanings syntactically embedded; and (f) understand and respond appropriately to sentences that have not be encountered before (Savage-Rumbaugh et al. 1993). This capability, referred to as *generativity* in language comprehension, is probably the most fundamental of all human language capabilities (Corballis, 1992).

In order for apes to display language capabilities, their understanding of those symbols must have become decontextualized. This capability is necessary in order surmount a classic linguistic puzzle identified by the linguist Quine (1960) as the Gavagai problem. The problem arises when a linguist tries to understand the meaning of words spoken by natives in a language totally different from that of the linguist. If, for example, a native points to an elephant and says a word in the native language, the linguist does not know if the word refers to elephants in general, the name of that particular elephant, a particular body part, a mammal, a quadruped, and so one. Quine speculated that if the native language were sufficiently different from that of the linguist, learning the new language might be virtually impossible. The Gavagai problem led Premack (1986) to a pessimistic view toward the possibility of apes ever mastering a language comparable to human language.

Clearly, because of the Gavagai problem, language experience that is based only on exposing an ape to repeated pairings of a symbol with the same particular exemplar will not produce a full understanding of the symbol's meaning. Instead, the ape should be exposed to the symbol in a wide variety of contexts, just as human children are exposed to the word in different types of linguistic, physical and social settings. In other words, the symbol or word must be experienced in a different setting, that is, it must be decontextualized. This approach was followed in the language acquisition of the bonobo Kanzi (Savage-Rumbaugh et al., 1993). Kanzi experienced both lexigrams and spoken English words in many situations similar to those experienced by a human child during the language-formative years. The later evidence that Kanzi could understand these spoken English words when used in novel sentences was compelling evidence that his prior language-related experiences produced a decontextualized understanding of spoken English words.

King, Rumbaugh, and Savage-Rumbaugh (1999) later noted the similarities between the decontextualized understanding of language-related symbols and the understanding of general personality dimensions including extraversion, conscientiousness, and neuroticism. These dimensions are readily imputed to other individuals as a result of either observing or learning about the responses of an individual in a diverse set of circumstances. Therefore, a personality judgment about someone's degree of extraversion could be viewed as a decontextualized concept extracted from multiple past occurrences of a person's behaving in an extraverted or introverted manner.

The emergence of symbol meaning as well as perception of personality dimensions are both results of inferences about an underlying concept as a result of experiencing multiple instances of multiple exemplars in multiple contexts. Because of the similar logical structure of decontextualized symbols and decontextualized personality constructs, King et al. (1999) suggested that the origins of language in hominids coincided with early intense sociality and increased language use-centered discussion related to personalities of others (see Dunbar, 1996).

The relationship of the exemplars to the symbol meaning or personality perception is far more complex than is the extraction of a set of common elements and lies beyond the scope of this chapter. Yet, symbol meanings and personality perceptions are highly salient parts of our lives. If we return to the previously noted interpretation of salient stimuli as being based on organized aggregations of amalgams into templates, it is clear that the templates for linguistic symbols or personality traits are not a simple sum of all information in the exemplars. Instead, a complex inferential process leading from exemplars to template occurs.

Consequently, on this foundation, current research has accomplished the following broader objectives:

> It has elucidated the evolutionary and ontogenetic roots of language.
>
> It has provided training materials and techniques that greatly benefit children who have language deficiencies because of developmental disabilities.
>
> It has revealed that the basics of language competence probably comprise the abilities (a) to use symbols to represent objects not necessarily present in time or space and (b) to use learned symbols to communicate information that cannot be exchanged via the unlearned modes of communication.
>
> In addition, research into the commonalities of primate language has confirmed similarities among the great apes and humans in the following areas.

Early Environment and the Importance of Logic Structures

Although we know that early environmental stimulation can have generally facilitating effects upon development, research involving apes has confirmed that it is the *logic structure* (recurring patterns of communication, language use, music, and movement) of the early environment that defines the specific dimensions and interests of cognition and competence. A corollary of this important principle is that the specific effects of the logic structure are quite probably related to brain size and complexity. In particular, we can say that early environment is probably much more critical to the cognitive development of children and apes than it is to monkeys and prosimians.

Principles of Continuity

As a result of the research with bonobos, and in particular with Kanzi, the noted comparative psychologist Michael Domjan (2003) concluded that continuities between animals and humans reach far beyond the mere biological: "The language sophistication of Kanzi proves that many important linguistic skills are not uniquely human attributes. Thus, these findings vindicate Darwin's belief, stated in Chapter 6 of the *Origin of Species (1859),* that *Natura non facit saltum* [Nature does not move by leaps but through continuous gradations]" (p. 384).

Neuroanatomical Continuities

One salient feature of how the human brain processes language is the lateralization of this function to one hemisphere. According to the classical model popularized in the second half of the nineteenth century, two cerebral cortical areas larger in the left hemisphere are most commonly associated with language functions. Broca's area is a productive region that encodes vocal signals into meaningful words and sentences; Wernicke's area, a receptive region, processes and integrates auditory sensory information. In other words, Broca's area functions primarily in the planning and execution of speech, whereas Wernicke's area functions to make sense of the speech that a listener perceives.

Human-like neuroanatomical asymmetries have been identified in the posterior temporal lobe and inferior frontal regions in the left hemisphere of the chimpanzee brain, regions considered homologous to Broca's and Wernicke's areas, respectively. Furthermore, asymmetry of the chimpanzee's inferior frontal gyrus, the location of the Broca's area homologue, has been associated with hand use during gestural communication (Taglialatela, et al 2006). These results suggest that both biological and behavioral continuities exist between the communicative systems of the great apes and humans.

Summary

Study of the primate order is very revealing about major trends of evolution to humans. We suspect that the emergence of bipedalism was but one of several major stepping stones, yet with bipedalism came the opportunity for further elaboration of manual dexterity and invention of tools. Intelligence likely was uniquely advanced by selection for dexterity and perceptions of relationships in learning processes. As the processes of learning advanced beyond basic associative problems into realms of learning of relationships there was a tremendous advance that promulgated what we call emergents and have contrasted with the outcome of basic conditioning procedures. Elaboration of the brain, both in size and emphases in organization, facilitated the construction of cultural trends, systems, and institutions.

All of what we know portrays humans as projections of dimensions and of continuities with other forms of primates, not as the creature so apart from the natural world that we are "uniquely unique in being defineable as the totally unique product of nature that we might otherwise want to be."

Notes

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