# IS THERE AN OPERANT ANALYSIS OF ANIMAL PROBLEM-SOLVING?

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ABSTRACT

In 'An operant analysis of problem-solving', Skinner (1966/1969/1988) develops an account of problem-solving based on the distinction between two different ways in which an organism can learn to adapt to environmental contingencies: (1) *contingency-shaped behavior* in which the behavior of an organism is progressively shaped by repeated exposure to the contingency itself, and (2) *rule-governed behavior* in which a verbally competent human being adapts to a contingency by constructing a verbal formula or *rule* which is said to "specify" the contingency in question. A rule may be constructed, as in the case of contingency-shaped behavior, in the light of repeated exposure to the contingency itself. It may equally well be based on information about the contingency supplied by another speaker, on information derived from a written text, or on an inference from other rules derived from any or all these sources. It is this case where the agent infers a new rule tailor-made for the problem with which he/she is confronted that Skinner has in mind in offering an analysis of problem-solving in these terms.

There is a growing body of empirical evidence (Hayes 1989) which confirms the accuracy of Skinner's description of problem-solving as it occurs in the case of verbally competent human beings. But animals also solve problems; and so do pre-verbal human infants. This kind of problem-solving cannot simply be a matter of contingency-shaping, though previous contingency-shaped behavior is the only resource from which a pre-verbal organism can draw in selecting an appropriate problem-solving strategy. It requires some mechanism like that which Köhler (1925) refers to as "insight" whereby the stimulus class which currently controls a particular response class is somehow stretched so as to include the current stimulus situation.

The case for postulating such a behavior mediating mechanism within the conceptual framework of radical behaviorism is argued by appealing

(a) to the analogy between attending behavior and thinking by talking to oneself, and

(b) to the process whose existence is implied by Skinner's (1938) account of "stimulus class" whereby an organism learns to break up its stimulus environment into stimulus classes "along the natural lines of fracture."

## NATURAL SELECTION REQUIRES VARIATION

The problem I want to address in this paper is one that arises for any application of the principle of 'selectionism' whereby Darwin's theory of evolution by variation and natural selection is taken to apply to any process of evolution or development. The idea that the principle of variation and natural selection has an application to other forms of evolution and development besides that which produces a new species of living organism has been familiar to behavioral psychologists since Thorndike (1898) first applied it to the process of learning by trial and error in his classic study of cats learning to escape from a puzzle box. Needless to say, it is the principle which Skinner (1981) refers to as "selection by consequences."

The problem is that variation and natural selection are two distinct processes of which the second, natural selection, can only operate on variations in a population produced by the first. The causes which produce variation, moreover, are quite different and distinct from those which result in selection. The need to explain initial variation has been dramatically illustrated by the recent much publicized discovery by earth orbiting satellites of ripples in the background radiation which is believed to come from the otherwise uniform primeval soup created by the Big Bang. Without that variation, the process of natural selection, described by Gehrz, Black and Solomon (1984),[1] which eventually produced the stars, galaxies and planets we observe today would have had nothing to work on.

## THE PROBLEM OF THE SOURCES OF VARIATION IN ANIMAL PROBLEM-SOLVING

In Thorndike's original application of the principle to the process of learning, the problem of explaining the initial variation in behavior before the process of selection by consequences gets to work is not seriously addressed. It is assumed that initially the cat in the puzzle box thrashes around in a wholly random way such that its eventual hitting on the successful response is a matter of pure chance.

That this is not an accurate description of the behavior of an animal when confronted with a problem such as this, does not of course, invalidate in any way the conclusions drawn by Thorndike and the whole tradition of research into instrumental/operant learning which he initiated about the process of selection by consequences or effect which operates on the initial population of response variants. But by failing to see the initial variation and its causes as a separate problem from that of explaining the subsequent selection of some variants at the expense of others, Thorndike laid himself open quite unnecessarily to the charge that was subsequently urged against him by Köhler (1925) in his book *The Mentality of Apes,* namely, that of denying the existence and, by implication, the possibility of 'intelligent' problem-solving in the case of animals.

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[1] I am indebted to Donahoe, Burgos and Palmer (forthcoming) for this reference. The influence of the concept of "selectionism" which is developed in that paper, in Donahoe (1991) and in Palmer and Donahoe (1992) will be apparent throughout this opening section of the present paper.

Consider Köhler's well known example of what he calls "insight learning" in which the chimpanzee Sultan solves the problem of how to reach the bunch of bananas placed too far outside the cage to be reached either by an outstretched arm or by using a single bamboo stick. Reflection tells us that the eventual solution, that of fitting two sticks together to form a stick long enough to reach the bunch, would not have been selected and become part of the animal's repertoire in such situations, had it not in fact been reinforced by achieving the desired result. The fact that the solution was not just hit on by chance does not mean that the principle of selection by consequences ceases to apply.

## 'CONTINGENCY-SHAPED' AND 'RULE-GOVERNED' BEHAVIOR

It is my contention that a similar failure to distinguish between the causes of variation and causes of selection also infects the distinction which Skinner drew in his 'An operant analysis of problem solving' (Skinner 1966/1969/1988) between 'contingency-shaped' and 'rule-governed behavior'. But let me quickly say, before I am misunderstood, that in criticizing that distinction, I am not in any way denying its importance or suggesting that we ought to discard it. On the contrary, I regard the distinction and theory of intuitive knowledge based upon it as possibly the most important contribution ever to our understanding of what is distinctively human about human behavior. Moreover, I have no difficulty with the distinction considered as a contrast between two different ways in which contingencies impinge on human behavior:

(1) in contingency-shaped behavior, through personal experience of the actual contingencies in one's own case,

(2) in rule-governed behavior, through the medium of a verbal specification of the contingency based on either

- (a) personal experience (previous contingency-shaping)
- (b) information supplied through the verbal behavior of others, or
- (c) inference from contingency specifications derived from either or both the previous sources.

The problem with the distinction is that the contingency impinges on a different point in the process of behavioral selection in the two cases. Contingency-shaping is another name for the process which Skinner

(1981) refers to as "selection by consequences." It corresponds to the natural selection part of the variation-natural selection formula. Rules *qua* "contingency-specifying stimuli" are causes of the variation in the behavioral response which is needed if the process of natural selection *alias* contingency-shaping is to have something to work on.

Just as Sultan's behavior in fitting the one stick into the other would not have survived as a component of the animal's repertoire had it not succeeded in enabling it to reach the fruit, so the hypothetical rule postulated by the problem-solver in her attempt to specify the contingency involved will not survive as a member of her repertoire of problem-solving strategies for situations of that kind, unless the behavior it suggests proves to be a successful solution to the problem.

Strictly speaking, rule-governed behavior only applies to the first one or two occasions on which the hypothetical rule suggests itself as a possible solution. Thereafter, if the rule fails to match the contingency which is actually encountered, it is discarded. If, on the other hand, the expectation aroused by the rule is confirmed by experience of the actual contingency, the process of contingency-shaping takes over with the result that the behavior initially evoked by the rule becomes an automatic habitual response to situations of that kind.

## CONTINGENCY INSENSITIVITY IN RULE-INITIATED BEHAVIOR

The suggestion that rules initiate behavior only on the first very few occasions on which they are introduced, and are then rapidly replaced by contingency-shaping, would seem to run counter to the experimental evidence (e.g., Catania, Shimoff and Matthews, 1989) which shows that behavior which was initiated in the first place by a rule supplied either by the experimenter or by the subject is much less sensitive to subsequent changes in the actual contingencies than is comparable animal behavior which has been contingency-shaped from the outset. This insensitivity manifests itself long after the stage is reached when, according to the present hypothesis, the behavior should have become entirely contingency-shaped.

Two possible explanations of this phenomenon suggest themselves. One possibility is that in a social situation such as that constituted by a behavioral experiment with human subjects, the contingencies which shape the behavior which has been initiated by a rule tend to be contingencies of social reinforcement

(evidence of approval or disapproval on the part of the experimenter) rather than the contingencies specified in the rule. This would result in insensitivity to discrepancies between the actual contingency and that specified in the rule, not because the behavior is rule-governed rather than contingency-shaped, but because it is being shaped by contingencies other than that specified in the rule.

The other possibility which I find more intriguing relies on the suggestion (Rescorla 1991) that the kind of contingency-shaping which occurs in instrumental or operant learning is a matter of learning to *anticipate* or *expect* a certain outcome or consequence, given a certain antecedent stimulus and a behavioral response incipiently evoked by it. On that account of operant learning, it seems entirely plausible to suggest that the contingency-expectation set up in the first place by the verbal formulation of a rule is much more catholic, much less specific than an expectation based solely on previous exposure to an actual contingency. If this is correct, it makes sense that the former, provided the rule is not immediately disconfirmed by the outcome behavior based upon it in the first instance, will be much less likely than the latter to be disconfirmed and consequently modified by subsequent changes in the contingencies.

## THE PROBLEM OF ANIMAL PROBLEM-SOLVING

Despite some uncertainty over insensitivity to contingency-change in the case of behavior that was originally rule-governed or rule-suggested, as I would prefer to say, there seems little doubt that rules have more to do with possible variations in behavior when the organism is confronted by a problem than it has with the process whereby successful variations are selected and the unsuccessful ones are discarded which is what contingency-shaping is all about. If that is correct, we are now confronted by the issue which gives this paper its title, namely, how it comes about that animals who lack the ability to specify a contingency in a linguistic formula or rule can, nevertheless, put together 'intelligent' solutions to problem situations. For, as studies like Köhler's demonstrate, animals too have the ability to think up novel solutions to problems which are adapted to the problem in a way that cannot be simply a matter of chance. Yet we have no reason to think that any animal, with the doubtful exception of apes who have been taught a sign language devised by humans, has the verbal resources which would enable it to construct the kind of contingency-specifying

verbal formula which would qualify as "a rule" in Skinner's sense. But if animals can't think by talking to themselves, may be they can think in ways that don't involve language.

## BEHAVIOR-MEDIATING PRIVATE EVENTS

Because of the anthropomorphic excesses of cognitivism and other forms of mentalism, behaviorists have been traditionally suspicious of theories which postulate private events and give those events a mediating role in the control of behavior. Skinner, of course has always insisted that his radical behaviorism recognizes not only the existence of private events, but unlike methodological behaviorism, the possibility of studying such events by examining the verbal behavior which reports their occurrence in the speaker's own case. Where he shows reluctance is in conceding a mediating role for such events in the control of behavior.

Yet, in his theory of rule-governed behavior, Skinner positively advocates just such a mediating role for the private behavior of sub-vocally talking to oneself. But in that case why should talking to oneself 'under one's breath', be the only form of behavior-mediating private event that the behaviorist recognizes?

## ATTENDING BEHAVIOR COMPARED TO TALKING TO ONESELF

It is true that talking to oneself *can be* a publicly observable event, one which we often observe in others, even if we can't catch the words. But there are other mediating behaviors of a non-verbal kind of which the same is true. A prime example is the behavior of selectively attending to a particular feature of one's total stimulus environment at a particular moment of time:

(1) Like talking to oneself, attending behavior does not change the environment directly.

(2) Like talking to oneself, it modifies the stimulus input which controls the behavior which *does* change the environment.

(3) Just as verbal thinkers have a choice between mumbling out loud and thinking silently, so the attender has a similar choice between moving the head, eyes, nose, mouth or hands in such a way as to bring some environmental feature into the focus of attention and watching, listening, savoring or feeling things that are already in contact with the skin without giving any outward sign of so doing.

(4) In both cases, our evidence for the occurrence of the behavior when its outward manifestations are suppressed are the verbal reports of the human thinker/attender.

There are also some important differences between the two cases:

(1) Talking to oneself involves interposing a self-generated stimulus between the stimulus environment and the process whereby an appropriate environment-changing output is selected; whereas attending behavior simply selects from a total stimulus array at any one time, those features which are to control that selection process. As a consequence it is much less easy to infer the nature of an individual's self-directed talk from the behavior it controls than it is to infer from subsequent behavior what aspects of the stimulus environment an organism has and has not been attending to.

(2) Talking to oneself requires linguistic competence whereas attending behavior does not. This means that whereas talking to oneself is a form of behavior-mediating behavior which is not found in animals, attending behavior is one which undoubtedly is.

## CLASSIFYING, CATEGORIZING, CONCEPTUALIZING

Attending, like talking to oneself, is a partially private event whose existence is at least grudgingly accepted by Skinner in the section he devotes to it in *Science and Human Behavior* (Skinner 1953 p.122-124). On the present hypothesis, attending behavior plays an crucial *mediating* role in the process whereby animals and pre-linguistic infants solve problems. But in order to complete the picture, we also need to recognize the existence of another more wholly private form of event whose existence Skinner does not *explicitly* acknowledge, the process whereby stimulus inputs are 'classified', 'categorized' or 'conceptualized' by the organism as a first step in the process whereby an appropriate environment-changing behavioral output is selected.

## STIMULUS CLASSES AND RESPONSE CLASSES

Although verbs such as 'classifying', 'categorizing' and 'conceptualizing' are not to be found in Skinner's writings, there is an important passage in *The Behavior of Organisms* (Skinner 1938) where he addresses

the issue which others talk about when they use such terms. Thus in Chapter One, after outlining his "System of Behavior", he goes on to say

> The preceding system is based upon the assumption that both behavior and environment may be broken into parts which retain their identity throughout an experiment and undergo orderly changes. If this assumption were not in some sense justified, a science of behavior would be impossible. But the analysis of behavior is not an act of arbitrary sub-dividing. We cannot define the concepts of stimulus and response quite as simply as 'parts of behavior and environment' without taking account of the natural lines of fracture along which behavior and environment actually break. (Skinner 1938 p. 33).

On the following page after analyzing the example of the flexion reflex, he says

> It will be seen .... that in stating the flexion reflex as a unit the term 'stimulus' must refer to a *class* of events, the members of which possess some property in common, but otherwise differ rather freely, and the term "response" to a similar class showing a greater freedom of variation but also defined rigorously with respect to one or more properties. The correlation that is called the reflex is a correlation of classes, and the problem of analysis is the problem of finding the right defining properties.
> The level of analysis at which significant classes emerge is not determinable from the mere demonstration of a correlation between stimulus and response but must be arrived at through a study of the dynamic properties of the resulting unit (Skinner 1938 p. 34).

## SKINNER AND THE CLASSIFYING ORGANISM

There are two points I would like to make about these two crucially important passages from *The Behavior of Organisms*. The first point is that although Skinner is talking primarily about the way in which the scientist who is studying behavior must ensure that his or her conceptual scheme follows "the natural lines of fracture along which behavior and environment actually break", his introduction of the concepts of "stimulus class" and "response class" into the analysis of behavior constitutes an implicit recognition that the organism itself is confronted with the problem of carving up the environment along its "natural lines of fracture". In other words, in order to survive and reproduce itself an organism needs a conceptual scheme in the sense of a set of stimulus classes controlling its behavior which correspond to those resemblances and differences between things in its environment which mark off one set of biologically significant contingencies from another. To some extent, no doubt the processes of variation and natural selection which Skinner (1975) refers to as "the contingencies of survival" have ensured that organisms are endowed with such a conceptual scheme by their genetic constitution. Nevertheless, just as the scientist needs to learn or 'abstract' his conceptual scheme from the experimental data, so the behaving organism must learn much of its conceptual scheme through

the process of operant discrimination learning described by Skinner in Chapter Five of *The Behavior of Organisms*.

## STIMULUS CLASSES AS "FAMILY RESEMBLANCE CONCEPTS"

This brings me to my second point concerning the passages from Chapter One of *The Behavior of Organisms*, which is that when Skinner talks about the members of a stimulus class possessing some property in common, he talks as if this common property is some feature common to the stimuli themselves. In fact the common property that needs to unite the members of a stimulus class is the property of reliably signalling the presence of the *same contingency* or set of contingencies. Moreover, one of the effects of the operant discrimination learning procedure which is controlled by the consequences of choosing one stimulus rather than another is that it becomes possible to develop highly disjunctive stimulus classes which correspond to some actual and behaviorally significant feature of the environment, but which *qua* stimuli have the kind of "family resemblance" character that Wittgenstein (1953) speaks of, rather than any common property. This is well illustrated by Figure 1 from Canfield (1941) which shows the external genitalia

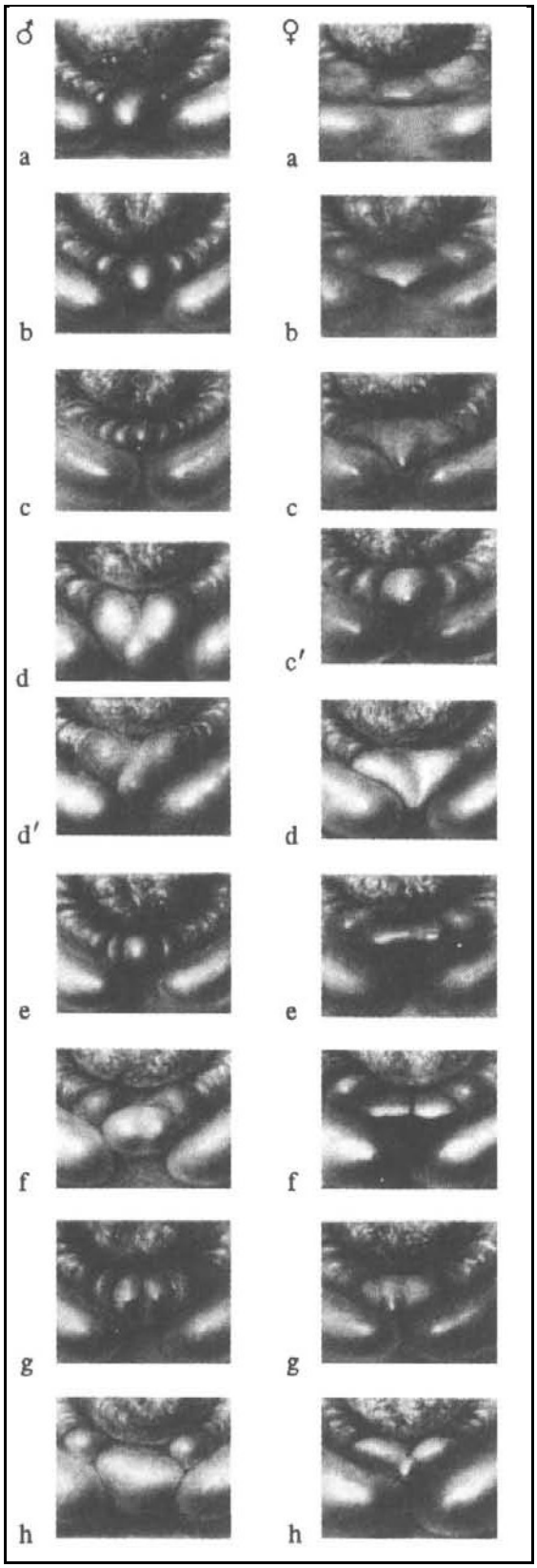


**Figure 1.** External genitalia of male (left) and female (right) day-old chicks (*Canfield, 1941*).

of day old chicks males on the left, females on the right which a chicken sexer must learn (needless to say by trial and error) to distinguish by a brief glance.

## PROBLEMS AND THE GENERATION OF PROBLEM-SOLUTIONS

For our present purposes the importance of recognizing that organisms need a conceptual scheme in order to relate their behavior effectively to environmental contingencies is that we need the notion in order to explain what a problem situation for the organism consists in. A problem situation may be defined as a stimulus event which, to use Jack Michael's (1982) powerful concept, constitutes "*an establishing condition*" for some behavior on the part of the organism, but which is not, at first sight at least, a member of any stimulus class for which it has an existing set of contingency-shaped behavioral repertoires, or "response classes".

In order to resolve a problem so defined, the organism needs somehow to use the unfamiliar problem stimulus to generate another stimulus or some modification of the problem stimulus itself which *is* a member of a stimulus class for which the organism *has* an existing set of contingency-shaped behavioral repertoires. Given a number of such stimuli or stimulus modifications, the organism will be in a position to emit a number of behavioral variations which can then be selected by their success or failure in resolving the problem.

One way of generating such mediating stimuli which is available only to linguistically competent humans is by talking to oneself. Another which is more widely available is by selectively attending to aspects of the problem stimulus in which it resembles members of a stimulus class for which a set of contingency-shaped repertoires exists. It is this use of selective attending behavior, I suggest, which provides animals with a method of generating 'intelligent' problem-solutions and accounts for phenomena such as Köhler's so-called "insight learning." However, it would be a mistake to suppose that, because human problem-solvers can use language to construct hypothetical contingency-specifications, they can dispense with selective attending as a method of assimilating the problem situation to stimulus classes for which an established contingency-shaped repertoire already exists. The only difference is that, in the case of linguistically

competent humans, selective attending is used to suggest different verbally formulated hypotheses as to the nature of the contingencies involved, rather than selecting the behavior directly as in animal problem-solving.

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