REVISTA MEXICANA DE ANÁLISIS DE LA CONDUCTA 1999, **25**, 143-160 NÚMERO 2 (SEPTIEMBRE)
MEXICAN JOURNAL OF BEHAVIOR ANALYSIS NUMBER 2 (SEPTEMBER)

BEHAVIOR THEORY TODAY: A RETURN TO FUNDAMENTALS

TEORÍA DE LA CONDUCTA HOY EN DÍA: UN REGRESO A LOS FUNDAMENTOS

H. M. JENKINS[1]
McMASTER UNIVERSITY

ABSTRACT

While behavior modification as an applied art is expanding vigorously, the laboratory study of animal learning, which provided much of its rationale, is in the midst of a downward reappraisal. In the 1940's and 50's behavior theory based on animal learning was at the center of experimental psychology. It is no longer.

The decentralization in academic psychology was accompanied by a widespread realization that the boldly proclaimed laws of behavior might be more accurately described as interesting phenomena with unknown boundary conditions. Our new position is, I think, healthier than the old. Giving up pretentions makes it easier to reexamine fundamental questions.

I would like to discuss the bearing of certain recent developments on three questions fundamental to behavior theory:

What reinforces a response? Two recent development of great interest and potential are Richard Herrnstein's formulation of the relative law of effect and John Platt's analysis of shaping.

What produces stimulus control? Leo Kamin's admirable series of experiments on overshadowing and blocking, and Robert Rescorla's work on the stimulus-reinforcer relation have greatly changed our conceptions of the necessary conditions for stimulus control.

How do the stimulus-reinforcer and response-reinforcer relations combine in the control of behavior? Autoshaping, like the Breland's observations on misbehavior, force us to consider the joint action of the stimulus-reinforcer and response-reinforcer relation. It alerts us to the possibility that the stimulus-reinforcer relation can exert a dominant role in the development and maintenance of directed actions of the whole organism.

One can abstract a theme from these diverse developments. The effect of a

[1] Reprinted from *Revista Mexicana de Análisis de la Conducta*, 1975, *1*, 39-54.

reinforcer depends on a context. It is not enough to know that a certain movement or stimulus was followed by a reinforcer. It is necessary to learn how to incorporate the setting of that event within an extended interval. Moreover, a reinforcer occurs in an immediate context that includes multiple stimuli bearing different relations to the reinforcer. We have to do more than recognize multiple determination, we have to learn its rules.

Key words: behavior theory, reinforcement, stimulus control, stimulus-reinforcer and response-reinforcer relations

RESUMEN

Mientras la modificación de la conducta como arte aplicado se está expandiendo con vigor, el estudio de laboratorio del aprendizaje animal, el cual proporcionó gran parte de su fundamento, se encuentra en un proceso de reevaluación retrospectiva. En los años cuarenta y cincuenta, la teoría de la conducta basada en el aprendizaje animal era el centro de la psicología experimental; ya no lo es más.

La descentralización de la psicología académica se vió acompañada de una conciencia generalizada de que las audazmente proclamadas leyes de la conducta podrían describirse con más precisión como fenómenos interesantes con condiciones limítrofes desconocidas. Mi opinión es que nuestra nueva postura es más saludable que la anterior. Al abandonar pretensiones, se facilita la visión de cuestiones fundamentales.

Me agradaría examinar la relevancia de ciertos avances recientes sobre tres cuestiones fundamentales de la teoría de la conducta:

¿Qué refuerza a una respuesta? Dos avances recientes de gran interés y con posibilidades son la formulación de Richard Herrnstein sobre la ley relativa del efecto y el análisis de John Platt sobre el moldeamiento.

¿Qué produce el control del estímulo? La admirable serie de experimentos de Leo Kamin sobre ensombrecimiento y bloqueo, y el trabajo de Robert Rescorla sobre la relación estímulo-reforzador, han cambiado en gran medida nuestras concepciones sobre las condiciones necesarias para el control de estímulo.

¿Cómo se combinan las relaciones estímulo-reforzador y respuesta-reforzador en el control de la conducta? El automoldeamiento, como las observaciones de los Breland sobre conducta inapropiada, nos forzan a considerar la acción conjunta de la relación estímulo-reforzador y respuesta-reforzador. Nos pone en alerta sobre la posibilidad de que la relación estímulo-reforzador pueda ejercer un papel dominante en el desarrollo y mantenimiento de acciones dirigidas de todo el organismo.

Se puede abstraer un tema de estos avances diversos. El efecto de un reforzador depende de un contexto. No es suficiente saber que un determinado movimiento o estímulo fue seguido de un reforzador. Es necesario aprender a incorporar la situación de ese acontecimiento dentro de un intervalo ampliado. Más aún, un reforzador ocurre en un contexto inmediato que incluye estímulos múltiples que poseen relaciones diferentes al reforzador. Tenemos que hacer algo más que reconocer solamente la determinación múltiple, tenemos que aprender las reglas.

Palabras clave: teoría de la conducta, reforzador, control de estímulos, relaciones estímulo-reforzador y respuesta-reforzador

---

Behavior theory, grounded in the experimental analysis of learning in animals, was at the center of psychology in the late forties and fifties. Many believed that the analysis of learning in a few representative animals, and in a few specially favorable experimental arrangements, would yield laws of great generality. Behavior in nature and in human society was, of course, to be found in many forms. No one denied that naturally occurring behavior patterns in lower animals had species specific, non environmental determinants, and no one denied that people, unlike other animals, spoke a language with a complex structure. Despite great variations in the behavioral raw material, the laws governing the modification of behavior were believed to apply everywhere. When we understood the basic laws, we would be able to see their expression beneath the guise of "topographical" variations.

This very optimistic view has been called "general process learning theory." Out of it grew the behavior modification approach, which is having a profound impact on practical human affairs. Although its conceptual roots are in animal-based behavior theory, it is making progress on its own by the application of the experimental method of human behavior.

While behavior modification has been developing apace, general process learning theory has been seriously challenged. The child, has been taking some hard knocks.

Psychologists were not content to wait for the arrival of general laws to unravel the mysteries of naturally occurring behavior patterns and of complex human behavior. The study of natural patterns, such as courtship, mating, maternal behavior, aggression, and so on began to reveal behavioral organizations and behavioral determinants that were outside the scope of a learning-based behavior theory. Moreover, the study of uniquely human behavior, such as memory for words and sentences, began to develop new and interesting results without the help of behavior theory. It became obvious that the experimental study of behavior is a broader enterprise than the behavior theory of the forties and fifties envisioned.

Impact of Ethology on Behavior Theory

More important than the loss of control over outlying regions was the challenge to general process theory on its home ground. The assumption that the learning process itself was fundamentally the same beneath the guise of different animal forms, different response systems, different stimuli and different reinforcers was challenged. The challenge lay in the ethological concept of evolutionary specialization of learning processes.

The concept of specialization was most forcefully brought to bear on learning, not by ethologists, but by experimentalists who were influenced by ethology. Among them were Keller and Marion Breland, John Garcia, Paul Rozin, Sam Revusky, Robert Bolles, and Sara Shettleworth.

The finding with greatest impact was the now classic one reported by Garcia and Koelling in 1966 (Garcia and Koelling, 1966). They showed that aversion to a novel taste was readily formed when taste was paired with drug-induced nausea as the primary aversive stimulus, but not so readily formed when an externally delivered painful shock was the aversive stimulus. On the other hand, aversion to a light-sound stimulus was more readily formed with the externally induced pain of shock that with the internally induced nausea. The adaptiveness of a readiness to associate taste with nausea and external stimuli with external pain is clear. In nature, stomach trouble usually comes from something you have eaten, hence tasted, whereas externally induced pain usually comes from external objects. An animal specially prepared to make those kinds of associations would be right more often than not.

Why is the Garcia phenomenon a challenge to general process learning theory? It is a challenge because a basic, although implicit, assumption of general process learning theory might be called the assumption of interaction-free combinations of stimuli, responses and reinforcers. Differences in the salience or conditionability of stimuli, in the conditionability of responses, and in the power of reinforcers are allowed, but the assumption is that there are no especially effective combinations.

The assumption of interaction-free combinations is implicit in the abstract statements of behavioral laws. Stimuli, responses, and reinforcers are treated as classes of events, not as particulars. Garcia's finding show, however, that behavioral principles of great generality are not to be found by recasting descriptions into abstract language as though the particular stimuli, responses, and reinforcers were interchangeable. It does not follow that an ethological perspective is incompatible with the existence of very general principles of behavior change. A major task for behavior theory is to formulate principles that incorporáte the specializations that evolution has shaped.

Search for Fundamentals

In the remainder of the paper I make some suggestions about where the search for fundamental principles might lead. Unfortunately, much of what I can say is abstract in the same way that the behavior theory I have criticized is abstract. That reflects ignorance about the nature of the constraints imposed by specialization and how they might be incorporated into general principles. Where I can, I offer some suggestions about specialization and learning.

Behavior theory centers around three commonplace facts that are set out below:

Central Phenomena for Behavior Theory

Phenomena	Paradigm
Stimuli come to act as signals for other stimuli (stimulus-reinforcer relation)	Focus in respondent conditioning
Responses can be selectively strengthened by a reinforcer (response-reinforcer relation)	Focus in operant conditioning
Stimuli become signals for reinforced responses (stimulus-response-reinforcer relation)	Focus in discriminative operant conditioning

I have two suggestions about these central phenomena. First, in order to fill in the "somehows" in each of the above statements it is absolutely essential to look at the context in which the events -the stimuli, responses, and reinforcers- occur. Suppose, for example, a response is followed immediately by a stimulus known to be a reinforcer. I will argue that we cannot tell whether or not this isolated happening, taken by itself, will strengthen the response. It is necessary to pay attention to the events that surround this episode and that form the context in which it occurs.

My second suggestion is that the stimulus-reinforcer relation has more scope and power in the control of behavior than is generally recognized in the response centered formulations of Thorndike and Skinner.

I will also find it necessary to return to the ethological concept of specialization when trying to understand how an animal behaves toward a stimulus that has become a signal of a reinforcer. For that purpose, it is important to pay attention to the animal's ecological niche -the special part of the environment to which it is adapted as the result of evolution.

What makes a Stimulus a Signal of a Reinforcer?

Two recent developments from the work of Robert Rescorla and Leo Kamin bear significantly on the signalling process. In each case, the basic experiments made use of the conditioned emotional response procedure or CER (Estes and Skinner, 1941), rather than the Pavlovian preparation. A brief comment on experimental paradigms for the study of signalling is in order.

When a stimulus becomes a signal of a reinforcer it acquires a *family* of new functions. Pavlov's experiments concentrated on just one of these, that of eliciting a conditioned reflex. Depending on the choice of the reinforcing stimulus -or UCS in Pavlovian terminology- the signalling stimulus may also acquire an emotion arousing effect.

The development by Estes and Skinner of the CER paradigm gave us a very sensitive method for assessing the signalling function of a stimulus through its emotion arousing effects. In one version of the CER procedure, the signalling stimulus or CS is first presented in relation to the reinforcer or UCS, which is a brief painful shock. The CS is later presented alone while an animal is making some operant response for a positive reinforcer delivered on an intermittent schedule (e.g., a rat bar pressing for food delivery on a variable interval schedule). One assesses the signalling function of the stimulus through its ability to suppress the operant behavior.

Pavlov's answer to the question of how a stimulus becomes a signal was attractively simple. According to Pavlov, it does so by being presented together with a biologically stronger stimulus, the reinforcer or UCS. But, this answer must be incomplete because it assumes something about what is going on between the local stimulus-reinforcer episodes, or trials; namely, that nothing is going on.

Rescorla (1967; 1968) has examined this assumption explicitly. The essentials of his experiment are shown in Figure 1. In Rescorla's procedure there is certain probability that a shock will be presented in each second while the CS is on. The higher the probability, the higher the average rate at which shocks occur during the CS. There is also a shock probability during each second of the intertrial period, and therefore some average shock rate outside of the CS.

Rescorla found that when the shock rate during the stimulus was the same as the shock rate outside of the stimulus, the stimulus did not acquire conditioned emotional properties as measured by suppression of the operant response. In order to condition suppression, the shock must occur at a higher rate during the stimulus than outside of it. Moreover, the larger the difference between the shock rates in and out of the stimulus, the greater was the suppressive effect conditioned to the stimulus.

Another way to express Rescorla's findings is to say that the acquisition of signalling function depends on the contingency between stimulus and shock. The isolated episode consisting of the joint occurrence of stimulus and shock is not sufficient to produce conditioning. Rescorla's experiment certainly demonstrates the importance of the context provided by the between-trial events in determining whether joint ocurrence of stimulus and reinforcer will or will not make the stimulus a signal of the reinforcer.

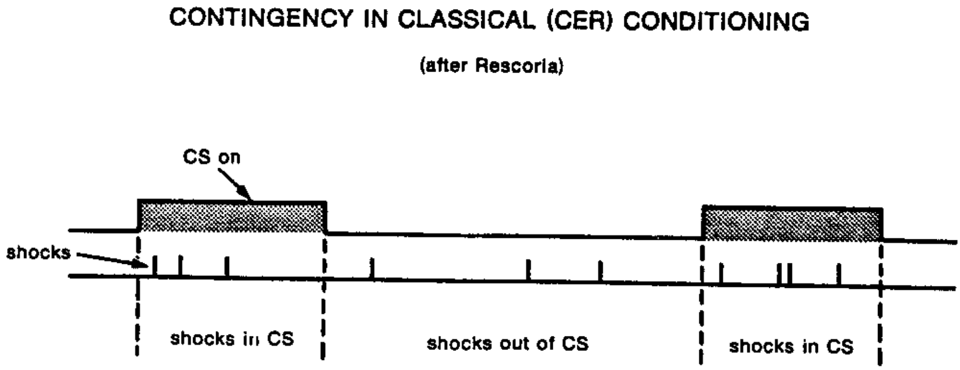

Figure 1. Plan of Rescorla's experiment on the role of contingency in classical (CER) conditioning.

The second development that bears significantly on the signalling process is from the work of Leo Kamin (Kamin, 1969). It demonstrates the importance of context of another kind by showing that whether a given stimulus becomes a signal of shock depends on what other stimuli are present, and on their status as signals. The plan of Kamin's basic experiment is shown in Table 1.

Table 1. The Blocking Experiment (after Kamin, 1969)

	Blocked Group	Control Group
Acquisition Phase 1	light → shock	------
Acquisition Phase 2	light plus → shock sound	light plus → shock sound
Suppression Test	sound?	sound?

Although the groups receive an equal number of sound-shock exposures, the sound acquires almost no signal value in the Blocked Group, while it acquires strong signal value in the Control Group.

Kamin's interpretation of blocking, based on an extensive and beautifully designed series of experiments, was as follows. In order for a UCS to produce an increment in conditioning to a CS which precedes it, the UCS must have surprise value. It must not already be fully signalled. In the first phase of the experiment, light becomes a reliable signal of shock in the Blocked Group. By the time sound is added in the second phase, the shock no longer has surprise value since it is fully predicted by the light. Therefore, no learning about the added sound stimulus occurs. In the Control Group, on the other hand, shock does have surprise value in the second phase since there has been no prior training to establish the light as a signal of shock. Both the light and the sound become signals of shock as the result of phase 2 training in the Control Group.

Kamin's concept of surprise value provided the starting point for a simple and powerful theory of stimulus-reinforcer relations that was formulated by Wagner and Rescorla (Rescorla and Wagner, 1972; Wagner and Rescorla, 1972). In bare outline, the principal assumptions of the theory are as follows. The increase in signal value (or conditioned strength) acquired by a stimulus on a conditioning trial depends on the difference between the current signal value and the asymptotic or maximum posible value. The greater the difference the greater the increase. Current signal value is the sum of the values of all the stimuli that are present on the trial. The *maximum* value, which this sum approaches asymptotically, depends only on the power of the reinforcer, and not on the number of signals.

Consider how these assumptions apply to the blocking experiment. In the Blocked Group, the light in the first phase of training acquires signal value up to the maximum supportable by the characteristics of the shock as a reinforcer. No further conditioning takes place in the second phase, where the sound is now also present, because the current signal value, based on the light alone, is already at asymptotic value. It will be seen that, assuming equal conditionability of light and sound, each stimulus will have acquired at asymptote just half of the signal value it would have acquired had it been only stimulus. To use a Pavlovian term, each stimulus exerts some *overshadowing* effect on the other. Incidentally, the more conditionable is one member of the pair, the less signal value will be acquired by the other since conditioning ceases as soon as the sum of the values for the more and less conditionable stimuli reaches the asymptotic value.

The application of this formulation to the Rescorla experiment on the role of contingency in conditioning rests on a further assumption. The setting in which the experiment is carried out affords a constant background stimulus that persists unaltered throughout the presentation of the experimental stimulus. When the shock rate is the same in and out of the experimental stimulus, the background stimulus eventually acquires all of the available signal strength, leaving the experimental stimulus as a neutral or indifferent stimulus.

The correspondence between the Wagner-Rescorla formulation and Kamin's is clear if one supposes that when conditioning has been carried to the asymptote, the reinforcer is fully predicted and has no surprise value. Any stimulus with signal value reduces the amount of surprise value in the reinforcer and hence limits conditioning to all stimuli, itself as well as other accompanying stimuli.

The basic ideas about what makes a stimulus a signal that are common to Kamin's concept of surprise value and to the Wagner-Rescorla extension of the concept might be phrased as follows. For a stimulus to acquire signal value, there must be some uncertainty about the occurrence of the reinforcer. The less probable the reinforcer is at any given moment, considering all of the predictive stimuli available at that moment, the more uncertain is the reinforcer. Uncertainty is directly related to improbability. A stimulus gains signal value just to the extent that it provides a basis for a reduction in uncertainty about the arrival of the reinforcer. In these terms, blocking occurs because no further reduction in uncertainty about the arrival of the reinforcer is possible when the second stimulus is added. Contingency is critical in the acquisition of signal value because without it, the stimulus cannot reduce uncertainty about the arrival of the reinforcer. When there is no contingency, uncertainty is the same before the stimulus as it is during or after the stimulus.

Although I will not attempt here an explicit operationalizing of the concept of uncertainty, it is clear that the concept is by its nature dependent on context. To assess a reduction in uncertainty one must know the level of uncertainty before as well as after the presentation of the stimulus.

Let me now turn the discussion of the stimulus-reinforcer relation in a different direction, and in so doing get a start on my second suggestion about the research for fundamentals -the suggestion that the effect on the stimulus-reinforcer relation on the behavior of the whole animal is more direct than is generally recognized with résponse-centered reinforcement theories.

Stimulus-Reinforcer Relation in the Control of Behavior

Several years ago Paul Brown and I (Brown and Jenkins, 1968) stumbled on a surprising effect. If you signal the arrival of food to a hungry pigeon by lighting the pigeon key briefly just before food arrives, the pigeon will almost certainly end up approaching and pecking the key after about 20 to 40 stimulus-food presentations. The localized stimulus that signals the arrival of food becomes a thing to be approached and contacted even though this behavior has no effect on the delivery of food. Here, then, is another effect of a stimulus-reinforcer relation on behavior -it can induce skeletal action directed towards a signalling object.

We called the phenomenon auto-shaping. It was not a good term and Eliot Hearst and I (Hearst and Jenkins, in press) are trying to replace it with "sign tracking". The most striking result of the auto-shaping procedures is that the signalling object becomes sought after with great vigor. The term sign tracking is intended to suggest this aspect of the phenomena. Let me describe some unpublished observation to illustrate.

Figure 2 shows a somewhat elongated Skinner box. The food tray is located at the center of the back wall. There are lights at either end to serve as stimuli. The bird first learns to eat from the tray. Then it is exposed to the following procedure. Every so often the left light comes on for 5 seconds at the end of which the food tray makes grain available for 4 seconds. The left light signals food. The light at the right also comes on and off, but it is unrelated to the arrival of food. The bird soon begins to approach the signalling stimulus getting progressively closer to it in successive trials. Eventually the bird goes the full distance and pecks the light until the light goes out at the end of 5 seconds. It then runs to the food tray. The unrelated stimulus on the right is almost entirely ignored.

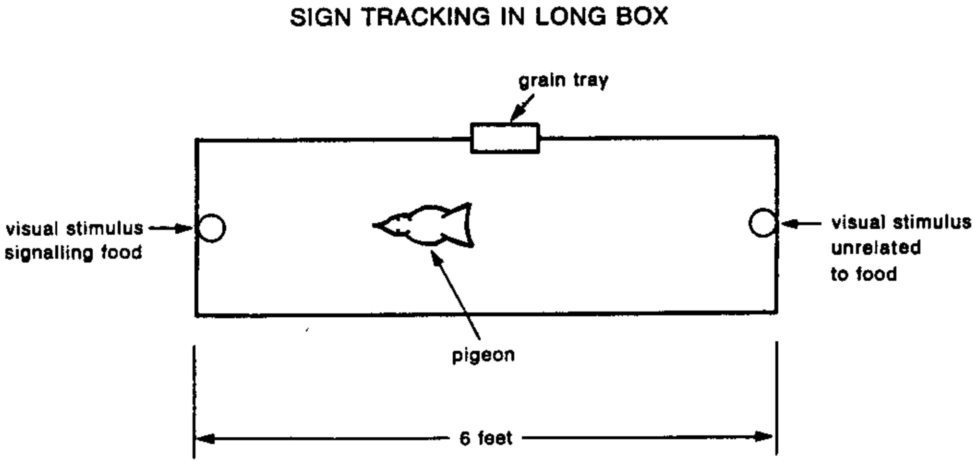

Figure 2. An apparatus for a sign-tracking experiment with a remote stimulus.

The fact that the signalling stimulus is about 3 feet from the food tray has an interesting consequence. The tray is raised immediately at the offset of the stimulus and it is only available for 4 seconds. By the time the bird reaches the tray, the food is about ready to disappear. Often it has already disappeared. Nevertheless, the birds persist in approaching and pecking the signal. You will recognize the long box arrangement as a spatial version of what Williams and Williams (1969) have called negative auto-maintenance, or more simply, omission training. In their procedure, a peck at the lighted key precludes the delivery of food. Only if a bird withheld its peck would food appear at the end of the trial. Despite this contingency, the birds persisted in making one or more pecks on a high percent or trials over a very long period of training.

What is important about sign tracking? Sign tracking shows us that the stimulus-reinforcer relation can induce complex skeletal action directed toward the stimulus. Neither the development nor persistence of these behaviors can be understood within the framework of operant learning.

Response-Reinforcer Relation in Control of Behavior

The stimulus-reinforcer relation is important, but it represents only one aspect of behavior change. There is, of course, the response-reinforcer relation. What are the critical conditions for the reinforcement of a response? Skinner's answer was admirably simple. When an emitted response is followed by a reinforcer, the strength of the response is increased. The phrase "followed by a reinforcer" is significant. In this formulation, the strengthening effect depends only on the temporal relation between response and reinforcer, not on a dependency between the response and the reinforcer. This statement of the basic law of operant conditioning makes no mention of the possible importance of the context surrounding a given response-reinforcer episode. Skinner's formulation of the response-reinforcer relation is similar to Pavlov's formulation of the stimulus-reinforcer relation in this respect. Both attempt to capture the essence of the relation within a narrow window in time.

Let me appeal to your intuition. Suppose you were trying to shape a pigeon to circle to the left. You have control of the usual handheld button that operates the feeder. But, there is an adversary -he can operate the feeder also, and he believes in the power of unconditional love; a belief which he expresses by feeding the pigeon frequently no matter what the pigeon is doing. I think you will agree that your adversary is in a strong position to prevent you from shaping the bird successfully. That would be rather uninteresting if the effect of his free reinforcements were simply to strengthen incompatible responses. It would be more interesting, and more in line with the role of contingency in the stimulus-reinforcer relation, if the free reinforcers were to reduce the effectiveness of the reinforcers which you deliver. Perhaps the *same* response-reinforcer episode, a left turn followed by food, is less effective because of the free reinforcers that occur at other times.

There is, in fact, evidence to suggest that is so. It comes from the many experiments that have been concerned with Herrnstein's formulation of the relative law of effect (Herrnstein, 1970). The law states that the strength of a response depends not only on the reinforcements for that response but on all other sources of reinforcement in the situation as well. When reinforcers produced by a particular response are held constant, the strength of the response decreases as a function of reinforcement from other sources. It is particularly interesting that it does not appear to matter how the other reinforcers are delivered -whether their delivery is, for example, dependent on some other response or is simply free. Catania (1973) has suggested that even when all the reinforcers are delivered for the same response each reinforcer reduces the effectiveness of all others. He speaks of reinforcers as self-inhibiting. In any case, it is clear from these experiments that the strengthening effect of reinforcers depends critically on the context provided by preceding reinforcers.

I believe that when we understand this basic relation in some depth, we will see a close parallel with the role that context plays in determining whether a stimulus becomes a signal of the reinforcer. Let me insinuate the parallel by putting the matter this way; we strengthened a response to the extent that the response becomes a signal for the reinforcer. To make the response a signal of the reinforcer we want the response to reduce uncertainty about the arrival of the reinforcer. If reinforcers are appearing with considerable frequency there is less uncertainty about their arrival. In that context the response cannot reduce uncertainty as much, and the response is, therefore, less of a signal for the reinforcer.

I believe that Skinner was right to formulate the response-reinforcer relation in terms of temporal order rather than in terms of a contingency between response and reinforcer. On the other hand, I believe that it was a mistake not to make the formulation context dependent. The organism is not in direct contact with contingency, but contingency is extremely important because it controls the context within which response-reinforcer episodes occur.

Discriminated Operant

I turn now to the third and last of the commonplace facts at the center of behavior theory; somehow stimuli become signals for reinforced responses. That is another way of referring to the discriminated operant.

Let me begin with Skinner's formulation of the three-termed relation. Again, it is admirably simple. The increased strength due to reinforcement is greater in the presence of the stimulus conditions accompanying the reinforcement than in other stimulus conditions. Alter the original stimulus conditions and the response is weaker. Restore the stimulus conditions that were present during the reinforcement of the response, and the response is stronger. That is what generalization gradients show us and it is of course, what is meant by stimulus control. In Skinner's phrase, the stimulus has become an occasion for the reinforced response. Again, the formulation refers only to the immediate events within the stimulus-response-reinforcer episode.

We now know, however, from many experiments (Sutherland and Mackintosh, 1971), that whether a particular stimulus gains control of an operant response depends on what other stimuli are present and their functional status. The presence of a highly discriminable stimulus will prevent another stimulus from gaining as much control as it would have gained had it been the only stimulus correlated with the reinforcer. Further, the prior development of control by one stimulus prevents a stimulus introduced at a later time from acquiring the control it would have acquired had the first stimulus not already acquired control. In short, overshadowing and blocking are not restricted to the classical conditioning experiment where the focus is on the stimulus-reinforcer relation. Overshadowing and blocking also occur in the three-termed discriminated operant, where relations among stimulus, response, and reinforcer are directly involved. Context provided by concurrent stimuli is again critical.

The stimulus control of operant behavior is, of course, modifiable by discriminative training. Reinforcing the operant in the presence of one stimulating field and nonreinforcing it in another field, in which some parts or attributes have been changed, can convert an indifferent stimulus into a strongly controlling stimulus. How does selective reinforcement bring about this change?

When the reinforcement of a response is made dependent on the so-called discriminative stimulus, that stimulus becomes a signal for the reinforcer. The nonreinforced stimulating field, which is introduced when selective reinforcement begins, provides the context that establishes a signalling function for the discriminative stimulus. I would like to describe an example of the operation of selective reinforcement that suggests the importance of the stimulus-reinforcer relation in the discriminated operant.

The example grows out of experiments by Robert Sainsbury and myself (Jenkins and Sainsbury, 1970). I will describe a hypothetical experiment which conforms in essentials, although not in detail, to actual experiments. Pigeons are trained to discriminate between visual displays made up of separate elements similar to those shown in Figure 3. Training involves successive presentations of brief, discrete trials. In the first phase, all trials are positive. A single response to the lighted display produces the food reinforcer. The display always contains a single dot, the position of which is varied from trial to trial. Although a peck anywhere on the display is reinforced, the pigeon, as it turns out, pecks directly at the dot. In the second phase of the experiment, a go/no-go discrimination between two types of successively presented displays is trained. On half of the trials the display shown at the top of Figure 3, containing a dot and also a star, appears. This is now the positive display, and a single peck anywhere (at the star, at the dot, or on a blank area) is immediately reinforced. On the remaining half of the trials, only a dot appears and a peck now ends these trials without reinforcement. In this arrangement, then, the dot is a feature common to both positive and negative displays while the star is a distinguishing feature which identifies the positive display. If no response occurs within 5 seconds, all trials end without reinforcement.

As a result of training in the first phase, the pigeon begins differential discrimination training pecking at the common feature -the dot. But as the differential training proceeds, the peck location within the positive display shifts to the distinguishing feature -the star. The nonreinforced presentations of dot alone provide a context in which the star signals the availability of the reinforcer for responding.

A trial by trial inspection of the development of the discrimination shows that the shift to the distinguishing feature precedes the elimination of responding on the negative trials where only the dot appears. The shift within the positive display is an important stage in the eventual elimination of responses to the negative or no-go display.

It is of interest to ask why the location of the peck shifts to the distinguishing feature. One might suppose that a trial and error process is involved. Because of the experimental conditions, a peck at the dot will be followed by the reinforcer on an average of half the trials. However, whenever the star is pecked the reinforcer always follows since unlike the common dot the star appears only on the positive display. Therefore, if the peck location just happens to shift to the star, the more favorable conditions of reinforcement for star-pecks than for dot-pecks could produce a preference for pecking the star within the display containing both features.

Another account is possible. Perhaps the bird perceives the predictive relation between star and the arrival of food even while responses are still being made to the common dot. In this account, the stimulus-reinforcer relation results in the perception of signal value and that leads to the shift. Here it is supposed that noticing pulls the response toward the distinguishing feature.

One way to examine this perceptual account is to prevent the bird from ever receiving the reinforcer for a peck at the star, and to see whether even under this condition there is a tendency to shift to the star. It is a simple matter to arrange things so that a peck at the star precludes the reinforcer that would otherwise be received for pecking anywhere else on the display.

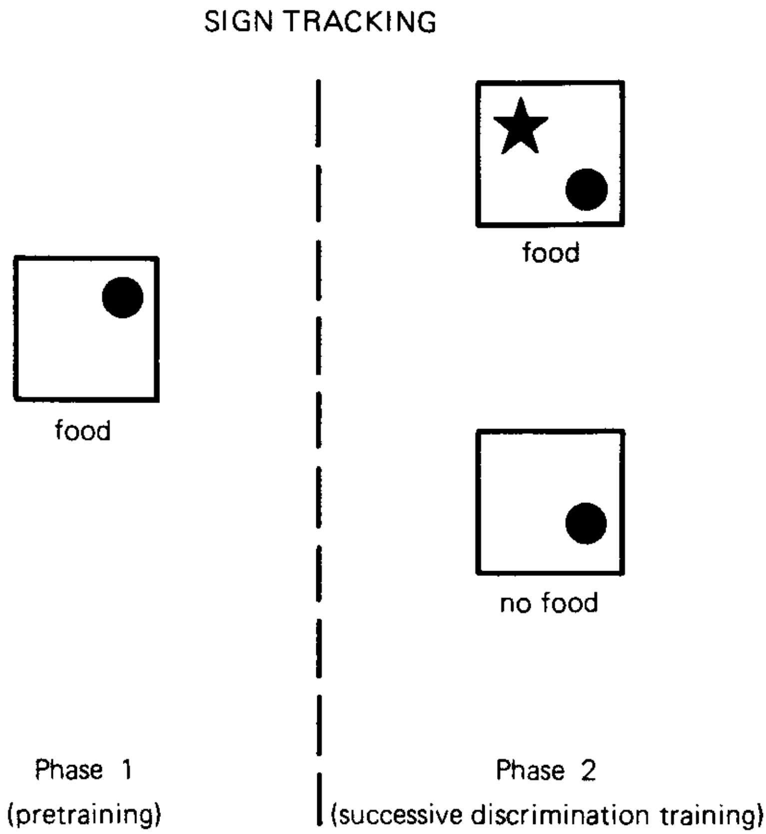

Figure 3. Plan of an experiment on the learning of a discrimination between displays consisting of a common element (dot), and a distinguishing element (start).

The results of an experiment run on this plan (Jenkins, 1973) were clear. There was a strong tendency to peck the distinguishing feature despite the loss of the reinforcer when they did so. From other conditions in the experiment, it is known that the introduction of the nonreinforced display containing only the common dot is necessary to the shift. In summary, the differential training with positive and negative trials makes the star a signal of the reinforcer and that pulls the response toward the star, as in other examples of sign tracking. The redirection of the response on the positive display allows the eventual elimination of the response to the common feature on the negative as well as on the positive display.

The discriminative behavior in the present example develops under the contingencies that define a discriminate operant. The reinforcer is contingent on both the response and the discriminative stimuli. But the example entails a special form of behavior. The response of pecking a signal of the reinforcer is auto-shapable. It could be generated simply by arranging the stimulus-reinforcer sequence. The question naturally arises, is the role of the stimulus-reinforcer relation in the control of the discriminate operant peculiar to an auto-shapable, sign tracking response?

It is too early to give a firm answer to this question, but there are indications that the stimulus-reinforcer relation also plays a critical role in the control of discriminative behavior when the response is more arbitrary, cannot be auto-shaped, and does not involve movements directed to a localized discriminative stimulus.

For example, I have made some observations on an arbitrary head-positioning response that was brought under the control of a diffuse auditory stimulus by discrimination training (Jenkins, 1973). When the stimulus-reinforcer relation was weakened by the introduction of intertrial reinforcers, the strength of the response in the presence of the discriminative stimulus declined (cf. Gamzu and Williams, 1973). A recovery of strength occurred when the intertrial reinforcers were removed, thereby improving the stimulus-reinforcer relation. This finding shows that the stimulus-reinforcer relation plays a role in the control of arbitrary responses, but a great deal is yet to be learned about the sensitivity of different behaviors to the stimulus-reinforcer relation.

Ethology and the Laws of Learning

I have tried to guess where the search for general laws of behavior might lead in the near future. I have argued that the effect of a given episode, whether it be a stimulus-reinforcer or a response-reinforcer episode, is critically dependent on what is going on around it. Context is critical because it determines the signal value of one event with respect to another.

For a stimulus to be a signal of another event, it must provide a basis for a change in the likelihood of that event. I have borrowed from the language of information theory and said that the stimulus must reduce uncertainty about the occurrence of that other event. Context provides a reference point without which one could not talk about a reduction of uncertainty. I have also suggested that when we come to understand what makes a stimulus a signal, we will also understand the conditions for the reinforcement of responses. A response is strengthened when it occurs under conditions that allow it to serve as a signal of the reinforcement.

My remarks about the search for fundamentals contain a mixture of concerns. I have been concerned with abstract processes of behavior change. But I have also been concerned with species-specific patterns of behavior that are induced when a stimulus becomes a signal. Let me try to rationalize the mixture.

How can one explain the fact that a pigeon will peck at a lighted key that signals the arrival of food? An ethologist might observe that in the pigeon's normal habitat the signal that food is available is the visual stimulus afforded by the food itself. In nature, the signal of food is integral with the food. If the pigeon were designed by evolution to learn rapidly to approach and peck this visual signal of food as though it were the food itself, it would rarely go wrong. Sign tracking is adaptive in the pigeon's normal habitat. We play a trick to the animal by separating the visual signs of food from the food itself. By pursuing the signal instead of the place where food will arrive the bird shows that it is specialized to do well in a normal environment, but is not prepared for the abnormal circumstances of the experiment.

But these observations cannot explain how the visual stimulus, whether it is remote from the food or integral with it, becomes a signal for food. Perhaps there can be some very general answers to that question across different animal forms. The evidence at hand points that way. Moreover, the concepts of evolution and adaptation argue for the existence of a very general principle by which a stimulus becomes a signal. Organisms have evolved in an environment with a causal texture governed by physical principles. One would suppose that they have evolved nervous systems that are well tuned to that causal texture. To the extent that there is generality in the physical laws of causality, one would expect to find generality in the principle by which the environment modifies behavior.

REFERENCES

Brown, P. L., and Jenkins, H. M. Auto-shaping of the pigeon's key-peck. *Journal of the Experimental Analysis of Behavior*, 1968, *11*, 1-8.

Catania, A. C. Self-inhibiting effects of reinforcement. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 517-526.

Estes, W. K., and Skinner, B. F. Some quantitative properties of anxiety. *Journal of the Experimental Analysis of Behavior*, 1941, *29*, 390-400.

Gamzu, E., and Williams, D. R. Associative factors underlying the pigeon's keypecking in auto-shaping procedures. *Journal of the Experimental Analysis of Behavior*, 1973, *19*, 225-232.

Garcia, J., and Koelling, R. A. Relation of cue to consequence in avoidance learning. *Psychonomic Science*, 1966, *4*, 123-124.

Hearst, E., and Jenkins, H. M. *Sign-tracking: The stimulus-reinforcer relation and directed action*. Austin, Texas: The Psychonomic Society (in press).

Herrnstein, R. J. On the law of effect. *Journal of the Experimental Analysis of Behavior*, 1970, *13*, 242-266.

Jenkins, H. M. Effects of the stimulus-reinforcer relation on selected and unselected responses. In R. A. Hinde and J. S. Hinde (Eds.), *Constraints on learning*. New York: Academic Press, 1973.

Jenkins, H. M. Noticing and responding in a discrimination based on a distinguishing element. *Learning and Motivation*, 1973, *4*, 115-137.

Jenkins, H. M., and Sainsbury, R. S. Discrimination learning with the distinctive feature on positive or negative trials. In D. Mostofsky (Ed.), *Attention: Contemporary theory and analysis*. New York: Appleton-Century-Crofts, 1970.

Kamin, L. J. Predictability, surprise, attention and conditioning. In B. Campbell and R. Church (Eds.), *Punishing and aversive behavior*. New York: Appleton-Century-Crofts, 1969.

Rescorla, R. A. Pavlovian conditioning and its proper control procedures. *Psychological Review*, 1967, *74*, 71-80.

Rescorla, R. A. Probability of shock in the presence and absence of the CS in fear conditioning. *Journal of Comparative and Physiological Psychology*, 1968, *66*, 1-5.

Rescorla, R. A., and Wagner, A. R. A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. Black and W. F. Prokasy (Eds.), *Classical conditioning II*. New York: Appleton-Century-Crofts, 1972.

Sutherland, N. S., and Mackintosh, N. J. *Mechanisms of animal discrimination learning*. New York: Academic Press, 1971.

Wagner, A. R., and Rescorla, R. A. Inhibition in Pavlovian conditioning: Applications of a theory. In R. A. Boakes and M. S. Halliday (Eds.), *Inhibition and learning*. New York: Academic Press, 1972.

Williams, D. R., and Williams, H. Auto-maintenance in the pigeon: Sustained pecking despite contingent nonreinforcement. *Journal of the Experimental Analysis of Behavior*, 1969, *12*, 511-520.