INFORMATION ON CONDITIONED REINFORCEMENT

A review of *Conditioned Reinforcement*,
edited by Derek P. Hendry¹

LEWIS R. GOLLUB²

UNIVERSITY OF MARYLAND

Proponents of an experimental analysis of behavior usually avoid such questions as "Why does a reinforcer reinforce?" Instead, they discover and identify reinforcers by their effects, such as conditioning or maintaining operant behavior, and study interactions involving reinforced behavior. The compulsion to explain reinforcement in terms of some ultimate biological cause, whether unconditioned or conditioned, is not a cross for the experimental analyst to bear.

In contrast, theorists who explain reinforcement in terms of some internal mechanism, such as drive reduction, must invent subsidiary processes to account for reinforcing events that are not derived from some plausible reduction in drive. Thus, Hull invented an internal response and stimulus system in which a hypothetical reinforcement mechanism (r_G) produced stimulation (s_G) which had rewarding power. If, instead, a reinforcer is identified solely in terms of its effects on the operants it follows, no special consideration is needed for conditioned as opposed to other reinforcers. In addition, an endless series of reductions may be avoided (Kelleher and Gollub, 1962). A particular foodstuff, usually called an "unconditioned" reinforcer, depends for its effect on the organism's having had that food before, and hence depends on conditioning. The se-

quence of operant and respondent behaviors in the alimentary canal, beginning with ingestion of the foodstuff, is a continuous process leading out of the study of behavior into physiology.

Experimental analysts of behavior might study conditioned reinforcement to devise methods or procedures that would enhance their control over behavior. It would seldom be necessary to inquire of a specific response whether its reinforcement was primary or conditioned. Nevertheless, conditioned reinforcement has played an important role in the behavior analyst's research and theory. Accustomed to studying behavior controlled by reinforcers, he looks for a source of reinforcement in accounting for any observed operant. Thus, sequences of responding have been analyzed into chains of discriminated operants (Skinner, 1938). In each link of such chains, the discriminative stimulus (S^D) is said to serve not only as the occasion for a subsequent operant, but also as a conditioned reinforcer for the operant that precedes it. This analytical description was extended and generalized by Keller and Schoenfeld (1950), in their Discriminative Stimulus Hypothesis. According to their analysis, conditioned reinforcers are always discriminative stimuli, and discriminative stimuli are conditioned reinforcers. In other words, conditioned reinforcement always involves operant chains.

Alternatively, some investigators claim that responding can be reinforced by stimuli that are not discriminative stimuli in the usual sense. That is, if a primary reinforcer is presented in the presence of a stimulus without being dependent on a designated response, that stimulus can still be a conditioned reinforcer (*cf.* Kelleher and Gollub, 1962). According to these experiments, stimuli need only be paired with primary reinforcers to function as conditioned reinforcers.

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Attempts to prove the exclusive validity of one or the other of these two formulations have generally been unconvincing. Experiments have established an empirical edifice for each account which, although not fully explaining all the data presented by the other formulation, is too well constructed itself to permit empirical disproof. A fair assessment of the *status quo* acknowledges two different, although sometimes overlapping, procedures for establishing conditioned reinforcers.

Because of its importance in virtually all systems of behavior, conditioned reinforcement has been reviewed frequently during the past 20 years (Miller, 1951; Myers, 1958; Kelleher and Gollub, 1962; Wike, 1966). The book now under review is another attempt to clarify research and theory in this area. In October 1967, Derek Hendry chaired a meeting of "young experimental psychologists who were actively investigating conditioned reinforcement . . . to acquaint the participants with the current work and thinking of their colleagues" (p. xv). This volume is based on that conference, and contains the papers delivered there, revised after their presentation and discussion. It also contains abbreviated versions of two previously unpublished doctoral theses that are frequently cited in the literature on conditioned reinforcement.

The title of the book may be a bit misleading to some readers, since no attempt was made to include papers representing the entire field of conditioned reinforcement. The papers were prepared as conference reports on current research, not as thorough or critical reviews of the experimental literature. The book thus resembles a one-issue behavioral journal, with a few added features such as a general introduction and a glossary of technical terms. Granted this structure and *raison d'être*, a review of such a book should examine the thoroughness with which each author documents his particular discoveries, and whether, as Hendry suggested in the Preface, any new formulations evolve as valuable explanatory models.

This review will thus be concerned primarily with the substantive findings of the individual papers. The organization of the review is procedural. Three basic procedures were used in almost all of the experiments reported: (1) The concurrent chained schedule, which was analyzed in some detail (Chapters 6 and 7)

and was used as a major measure of conditioned reinforcement (Chapters 8 and 12); (2) Brief-stimulus presentation procedures, in which a response produces a brief (0.3- to 5-sec) presentation of a stimulus which at other times accompanies food delivery (Chapters 2, 3, 4, 5, 8) or a period of time during which some behavior may produce food (Chapter 13); (3) Stimulus-presentation procedures similar to the above, except that the duration of the response-produced stimulus may be longer, and the stimulus accompanies or precedes alternative schedule conditions (Chapters 9, 10, 11, 12, 14).

Concurrent Chained Schedules

The two articles on concurrent chained schedules provide a valuable introduction to some of the more important data and theory on this topic. The first paper (Chapter 6), a shortened version of a 1960 doctoral thesis by S. M. Autor, makes this widely cited work generally available for the first time. This paper represents the first in a long series of studies on concurrent chained schedules from the Harvard University Laboratories.

In this procedure, two keys were available to the subject (generally a pigeon). At the beginning of each sequence, both keys were lit. As determined by equal but independent intermittent schedules, a peck on one key terminated the period of concurrent response alternatives (the initial links). In Autor's experiment, as in most of the other research on concurrent chained schedules, each of the initial links had a variable-interval (VI) schedule associated with it. A peck after a certain period of time, determined by the irregular series of the VI schedule, terminated the presentation of both concurrent initial links. A food-reinforcement schedule was then in effect for pecks on that key (the terminal link), and the other key was dark. After a period of time during which food reinforcements were delivered, the sequence began again with the concurrent initial links. The two food-reinforcement schedules in the terminal links were generally the major independent variable of the experiment.

The rationale for Autor's experiment, and one which has been adopted by most of the investigators in this area, is stated as follows. "The relative frequency of responding on the two keys during the first links was used as a

measure of the relative strength of the conditioned reinforcers which controlled this responding. In other words, the reinforcing strength of a stimulus, in this case a conditioned-reinforcing stimulus, was measured by the relative degree of responding which it maintained" (p. 152). The concurrent first links are thus treated in the customary manner for a pair of concurrent operants (Catania, 1966). Since the concurrent schedules are equal, the relative response rates are taken as measures of the relative reinforcing effectiveness of the stimuli associated with the terminal links.

Autor reports two experiments. In the first, food reinforcement in the terminal links occurred after varying periods of time under variable-interval schedules. The main effect of variations in the average frequency of food reinforcement in the terminal links was a nearly proportional relative frequency of pecking during the initial links. At the two highest frequencies of food presentation, however, the relative rates of responding tended to be somewhat less than proportional to the reinforcement frequencies. In a second part of this experiment, responding in the terminal links was reduced essentially to zero, but quite similar effects were found on responding in the initial links.

Similar functions were also obtained in a third experiment when food reinforcement in the terminal links depended on the number of pecks (under variable-ratio schedules of reinforcement), rather than on the passage of time. Because the relative frequencies of responding during the first links were proportional to the relative frequencies of food presentation in the terminal links under three widely different schedules of food reinforcement in the terminal links, Autor concluded that "this relation, then, can be attributed to the different frequencies of food reinforcement, and is not necessarily mediated by responding during the second links" (p. 161). The particular emphasis on frequency of food reinforcement also derives from the fact that "the patterns of responding during the first links were thus not determined in any obvious way by the patterns of responding during the second links" (p. 158).

The second article concerned primarily with concurrent chained schedules is by E. Fantino (Chapter 7). (The data in this paper have also

appeared in greater detail in papers published in this Journal after the Chicago Conference.) Briefly, these experiments revealed several limitations on the generality of what Hendry has called "Autor's law", that the relative response rate in the initial link matches the relative frequency of primary reinforcement in the terminal link. In one experiment, Fantino showed that when a high response rate was required in one terminal link the relative response rate in the corresponding initial link of that chain decreased. Although there was a trend toward a similar result when a low rate was required, there was a fair amount of overlap for two of three birds required to respond slowly, and the effect was not shown as conclusively. In a second experiment, the same frequency of food reinforcement was provided in each terminal link, but terminal links were scheduled for different durations of time. Therefore, different numbers of reinforcements occurred in each. Although the relative response rate in the initial link increased as number of reinforcements in the terminal link increased, ". . . a given change in the relative magnitude of the independent variable does not produce an equal change in the relative rate of responding during the first link" (p. 183).

These deviations from a strict proportionality of responding to reinforcement frequency led Fantino to consider alternative formulations of how concurrent chains are controlled. He proposed (a point now documented, *cf.* Fantino, 1969) that the total temporal values of the schedule, in both initial and terminal links, must enter into a prediction of responding during the initial links. A new formulation, with a set of predictive equations, is presented. Choice between the initial links is said to depend on the change in overall frequency of food reinforcement that results from entering a given terminal link of a chain. This variable includes the schedules in the initial links as important determiners of overall frequency of reinforcement, a point previously not recognized. Now that the importance of the schedules in both the initial and terminal links (and their relationships) has been demonstrated (Fantino, 1969), experiments using concurrent chained schedules, especially when reinforcement frequency in the terminal links is manipulated, must be reevaluated. Although this formulation is liable to change with

further test,³ it has initiated an important and fruitful reconsideration of this quite important technique.

Procedures Involving Brief Stimulus Presentations: Stimuli Paired with Primary Reinforcement

A second important method for investigating conditioned reinforcement involves the response-dependent presentation of a stimulus for a brief period of time. The major independent variable is the organism's history with respect to that stimulus—especially the occurrence of that stimulus in relation to food delivery.

Research on reinforcement-paired brief stimuli has frequently involved second-order schedules of reinforcement. Under second-order schedules, the behavior on which reinforcement depends is itself subject to a reinforcement schedule. For example, food may be presented every third time the pigeon satisfies a fixed-interval 1-min schedule requirement. This would be designated FR 3 (FI 1-min), "a fixed ratio of fixed intervals." This schedule can form the baseline for examining the effects of a brief, reinforcement-paired stimulus. Such a stimulus can follow each of the three ratios, such that its third presentation precedes the delivery of food. Under other procedures, a different stimulus might be presented before food from that presented at the termination of the other two FI schedule components.

M. J. Marr (Chapter 2) reviews second-order schedules, and integrates these procedures with chained schedules. Several different variables are shown to be important. First, there are the specific temporal associations of the brief stimulus described above. Marr also emphasizes the overall schedule contingencies for the primary reinforcer (such as the minimal time between food reinforcements). Under the schedule mentioned above, at least 3 min must pass between food reinforcements. Thus, the primary reinforcer occurs with certain fixed temporal constraints that could affect behavior in ways complementary to or opposed to those of the component schedules.

Marr also reports some interesting results from his previously unpublished doctoral thesis. Although this study was actually concerned with the effects of brief presentations of stimuli paired with schedules, it will be reported here. This study ingeniously combined a second-order schedule with chained schedules of reinforcement, such that key pecks were reinforced under second-order schedules by brief presentations of stimuli paired with different members of a chained schedule. The results were that the stimulus paired with the terminal member of the chain maintained higher response rates in the second-order schedule than the stimulus paired with the initial member. The degree of difference between responding for each stimulus also was shown to depend on the parameter value of the chained schedule. These results are taken as a rather direct demonstration that the stimuli that are associated with the different components of the chain act with differential effectiveness as reinforcers.

The component schedule in a second-order schedule specifies a "behavioral unit" on which reinforcement is dependent. Does the behavior generated by such component schedules have a "unitary" character? Marr presents experimental illustrations on both sides of this question, and calls for further experiments ". . . to determine the limitations of treating second-order schedule components as actual unitary responses" (p. 50).

A series of experiments is reported by J. de Lorge (Chapter 3), in which brief stimuli terminate second-order schedules. The maintained performance when the brief stimulus accompanied food reinforcement was compared to the performance when the brief stimulus before food delivery was different from that which terminated the other components of the second-order schedule. Although the absolute response rates under both conditions were variable, the stimulus paired with food generally maintained a higher average response rate than the unpaired stimulus, for periods as long as 90 daily sessions.

In most of the studies presented or summarized by Marr and de Lorge, responding that produced the brief stimulus was more frequent when that stimulus also immediately preceded food at the termination of the final component. When a different stimulus accompanied all but the final schedule component

³And has somewhat, according to a paper soon to be published in this Journal, "A choice model for simple concurrent and for concurrent-chains schedules," by Nancy Squires and Edmund Fantino.

(giving the same "information" about the passage of components) responding was no more frequent, and often less frequent than when no stimulus at all was given. In these studies, then, brief stimulus presentations increased responding because the stimulus was paired with food.

In other techniques for studying brief-stimulus presentations, the responses that produce the brief stimulus are not effective in producing food reinforcement, and may even postpone it. J. R. Thomas (Chapter 4) showed that brief (0.3-sec) operations of the feeding device (so brief that no food could be obtained) sustained patterns of responding characteristic of the schedule according to which the brief stimulus was presented. The brief stimulus was available during periods of time that alternated with periods during which pecks were reinforced with food under fixed-ratio schedules. As characterized by Thomas, the brief stimulus is presented "in the signalled absence of primary reinforcement".

Two types of evidence suggested a conditioned reinforcing effect. First, under certain conditions, very high response rates were maintained. Second, the temporal pattern of responses that produced the brief stimulus resembled the usual patterns under the same schedule of food reinforcement. Low rates were produced by extinction (no brief stimulus) and by the presentation of the brief stimulus only after a period of non-responding of a certain length (DRO schedule). Typical pause-and-run patterns occurred when the brief stimulus occurred after a fixed number of pecks (FR). Unfortunately, precise quantitative information on these effects was limited. The data were presented solely in the form of sample cumulative response records, from "terminal" performances, and the number of sessions under each condition was generally not given.

Thomas' experiments corroborate effects previously reported by Zimmerman (see below). Although they did not evaluate the important controlling parameters, they did illustrate the potent effects of a brief stimulus paired with food. Interactions between the type of food-reinforcement schedule producing the brief stimulus, as well as adventitious reinforcements, were not explored. Also, no control procedures were reported, such as on the effects of presenting unpaired stimuli.

Related experiments are reported by J. Zimmerman (Chapter 5). Zimmerman first reviews the previous research of his group, showing that if pecks on one key produced the initial stimulus conditions of the primary reinforcer (the feeder and its light operate, and all other lights go out) for 0.5 sec, responding was maintained for long periods of time. (In this situation, a mechanical shutter prevented the pigeon from getting grain during the brief operation of the feeder.) Concurrent with the brief-stimulus presentations, pecking on a second key was reinforced with longer operations of the feeder, with food available (*e.g.*, for 4 sec) according to various schedules of reinforcement. The experiments reported in this chapter remove one possible objection to the earlier work (as well as to Thomas' experiments). One might object that both accessible food and the brief stimulus are delivered dependent on a key peck. Because both responses have the same topography, the increased rates might result from other causes than conditioned reinforcement, *e.g.*, response induction, or "frustration" (see below). Also, because there was a required response for primary reinforcement, an adventitious chain of pecking first one and then the other key might have been established. In the experiments reported in this chapter, key pecking never produced food, only a brief (0.5 sec) operation of the feeder. Not only was the accessible food presentation not dependent on responding, it was postponed for 6 sec by each key peck.

Data from a number of studies are reported, showing the continued maintenance, at generally low rates (about four to nine responses per minute) of pecks that produced inaccessible food. Interestingly, the rate of such pecks tended to increase as the frequency of accessible food presentation decreased. This result resembles the effects of increased relative frequency of reinforcement under concurrent schedules of reinforcement (Catania, 1966). And, when the longer presentations of food were discontinued, pecking that produced the brief food presentation was sometimes sustained for very long periods of time. Two of five birds, with seven to 16 months of training, continued pecking at rates as high as 32 responses per minute, after nine sessions, and four to 10 responses per minute, after 32 sessions in which only the brief stimulus was produced. Brief stimuli paired with food de-

livery can maintain substantial amounts of behavior. Indeed, Hendry (Pp. 385-386) considers these effect "functional autonomy in the pigeon".

The experiments eliminate the suspicion that response similarity between the responses that produce the brief feeder operations and those that produce the long operations accounted for maintenance of the former. They do not, however, entirely eliminate the possibility of delayed adventitious reinforcement. Pecking was followed, after a delay, by accessible food. Previous control experiments showed that an arbitrary, unpaired stimulus did not maintain responding. However, some interaction, depending possibly on saliency of the stimulus (the operation of a key light *versus* that of the feeder), also needs to be eliminated. Substantial rates can be maintained under a 6-sec delay contingency (Dews, 1960; Chung, 1965).

Other forms of evidence that substantiate a reinforcing effect for the brief stimulus are the patterns and rates of responding maintained under different schedules of the brief stimulus. At different times, fixed- and variable-interval schedules, fixed-ratio, and DRL schedules were arranged. The fixed-ratio schedule commanded the highest rates (nine to 14 responses per minute) with a higher frequency of short interresponse times. However, it also had the highest frequency of brief-stimulus deliveries, greater than twice that of the next highest schedule. Moreover, no evidence was presented in the cumulative records to indicate any grouping of responses under fixed-ratio reinforcement (*cf.* Thomas, above). Additional experiments are therefore needed to identify the important parameters in this paradigm—a greater exploration of schedules with control of the duration and frequency of the brief stimulus, duration of the delay contingency, *etc.* Such an analysis might profitably be oriented around the fact that these situations are concurrent or conjoint schedules, and might therefore involve the kinds of manipulations and analyses that have been used with these schedules.

In the fifth paper concerned with investigations of stimuli paired with primary reinforcers, R. H. Schuster (Chapter 8) proposed a "functional analysis of conditioned reinforcement". "Functional analysis" is not explicitly defined, but such a viewpoint has led Schuster

to conclude that "a sustained reinforcement-like effect with an arbitrary stimulus is only possible when the stimulus is itself a cue for primary reinforcement . . ." (p. 222). "Cue" is elsewhere defined as a "stimulus which is presented to a subject and reports a set of conditions for the subsequent occurrence or non-occurrence of primary reinforcement." This definition should be compared with the treatment of "information" by Hendry, discussed below.

Before considering these experiments in detail, I will review some of the arguments that Schuster says require a new theory. He proposes that the effects of stimuli which follow a response "can be predicted from the reinforcing consequences being cued by the stimulus" (p. 234, italics deleted). This statement implies that pairing with a primary reinforcer does not imbue a stimulus with any special properties (although certain "short-term" effects akin to reinforcement are recognized). But this explanation does not account for the experiments by Marr and de Lorge, which showed that arbitrary brief stimuli in second-order schedules might have different effects on response rate as a function of whether or not they are paired with food, even when they have the same functional relation to the overall schedule and to food reinforcement. Similarly, the long-term maintenance of responding that produces brief operations of the feeder (Thomas and Zimmerman), especially the schedule-induced temporal patterns, seems to require more in refutation than an appeal to frustration-induced rate increases.

The second part of Schuster's attack on the traditional accounts of conditioned reinforcement are a series of experiments with response-produced brief stimuli that are paired with food. Crucial to the interpretation of these experiments is a decision on which behavioral effects would prove the existence of conditioned reinforcement, and which would not. Schuster maintains that rate increases alone would not suffice, because they could be due to effects other than reinforcement, *e.g.*, frustration. Choice experiments, utilizing a modification of the concurrent chain procedure are seen as crucial. But there are data (Fantino, Chapter 7) that imply that relative response measures from concurrent chain schedules are rather complex indicators of the reinforcing strength of the terminal links. Schuster's choice

experiments, therefore, must be interpreted with caution.

One example will be cited. In Exp. 3, a modification of the concurrent chained schedule procedure was used. Both terminal links were VI 30-sec, but in one of them each eleventh peck produced a brief (0.7-sec) stimulus complex (conjoint FR 11), which also preceded food reinforcement. This conjoint reinforcement schedule had its expected effects, and the response rate in the terminal component with brief stimulus presentations was somewhat higher than that in the other terminal component.

Relative frequency of responding during the initial link preceding the conjoint brief-stimulus schedule was, however, somewhat lower than that on the other key. Schuster interprets this effect as invalidating the pairing hypothesis that a stimulus paired with food is a reinforcer. He points out that the higher response rate in the terminal links (one type of evidence for a reinforcement effect) enigmatically conflicts with the lower relative rate in the initial link. This experiment does not, however, invalidate any particular theory of conditioned reinforcement, but rather corroborates Fantino (Chapter 7; 1968) that higher response rates in a terminal link produce lower preferences in the initial links.

The same moral can be drawn from Schuster's attempt to invalidate the currently popular explanations of conditioned reinforcement as from the older debates between the Hullian and Tolmanian learning theory camps. Behavioral experiments are generally complex, and the many variables involved allow numerous explanations unless experimental analysis through interlocking studies and parametric manipulation is performed. Competing theories are best eliminated by powerful demonstrations of experimental control, and Schuster has not yet produced these for his functional analysis.

Procedures Involving Response-Produced Stimulus Presentations: Stimuli Paired with Schedules

There has been a recent increase in the amount of research on the "observing response" procedure. When first developed, the procedure was explained in terms of the discriminative stimulus hypothesis of conditioned reinforcement (Wyckoff, 1952, 1959). It is now

used by some investigators to invalidate that hypothesis.

Under this procedure, two different schedules of reinforcement (or, one schedule and a period of extinction) are arranged in alternate periods of time in the presence of a single stimulus. The observing response produces a distinctive stimulus, unambiguously correlated with the schedule then in effect, but does not change the schedule in any way. Its only effect is to convert the mixed schedule (several contingencies occurring in the presence of a single stimulus) to a multiple schedule (with a specific stimulus correlated with each separate contingency). The final group of six chapters considers several variations of this problem.

The first chapter in this group is a shortened version of the experimental portion of the now "classic" dissertation by L. B. Wyckoff, Jr. (Chapter 9). The results demonstrate that if a certain behavior (called an observing response) produces a stimulus correlated with whichever of two reinforcement conditions (FI or EXT) is currently in effect, it will be sustained.

The primary reinforcement conditions apply to another response, *e.g.*, key pecking, and the observing response does not affect the schedules, which alternate irregularly in time. In this experiment, the observing response was defined as standing on a large pedal along one side of the chamber. One interesting result of the experiment was the change in pedal pressing when the correlation of the stimuli with the two schedules was reversed. That is, the color that had been paired with the fixed-interval schedule was now paired with extinction, and *vice versa*. During the initial sessions following the reversal, pedal pressing decreased to very low levels. It increased only when the key-pecking behavior in the presence of each stimulus began to occur at different rates.

How are these data to be interpreted? Wyckoff (1952, 1959) followed the notion of Keller and Schoenfeld (1950) that discriminative stimuli were conditioned reinforcers, and that what proved stimuli to be discriminative stimuli was that they controlled different rates of responding. He also proposed a quantitative model (Wyckoff, 1959) that related the discriminative stimulus and conditioned reinforcing strengths of stimuli.

Besides the historical importance of the Wyckoff experiment, it is distinguished in one

other way from the other papers reported in this book. It is the only one in which differences between mean performance measures of groups of subjects (or individuals, as far as that goes) are evaluated by standard statistical techniques. Although there is an occasional reference to a difference between groups that is not statistically significant, the reader is at least provided with data to evaluate the reliability of the supposed group differences.

As Wyckoff (1952) first noted, several factors could account for the maintenance of observing behavior in these experiments. There is delayed primary reinforcement of the observing response itself, as well as the fact that the stimuli that the observing response produces are discriminative stimuli, and therefore (Keller and Schoenfeld, 1950) conditioned reinforcers. There is yet another factor. When discriminative control is established, the presentation of the stimulus correlated with extinction causes the response rate to decrease. This increases the overall probability of a key peck being reinforced.

This multiplicity of explanatory factors would not obtain with other sets of schedules. In particular, schedules requiring a fixed number of responses per food delivery (fixed-ratio schedules) have been proposed as particularly important tests of the information hypothesis (Hendry, Chapter 12). Because primary reinforcement under fixed ratio bears exactly the same relationship to responding under both differential and nondifferential stimulus conditions, the maintenance of observing responses might be more readily explained by the "information" presented by the stimuli. Of course, adding stimuli to fixed-ratio schedules has profound effects on responding (Fester and Skinner, 1957). Experiments based on this procedure will therefore involve complex interactions.

S. B. Kendall (Chapter 10) reports some extensions of his previous work to an observing-response procedure with fixed-ratio schedules. In one interesting experiment, observing responses were maintained during a 30-sec period that preceded the opportunity for food reinforcement after either 10 or 100 key pecks. Twice as many observing responses were made when the color correlated with FR 10 was produced rather than that paired with FR 100.

When only a single food-reinforcement schedule was presented for a while, either FR

10 or FR 100, fewer observing responses occurred. This was interpreted in terms of the stimulus now not being "informative", since only a single schedule could follow. Unfortunately, only mean data points for "terminal" performances are reported. Transition data under the changes between the multiple and single-valued schedules (as in Wyckoff's paper) would have been most interesting. Also, the procedure allowed (and generated) a certain amount of adventitious reinforcement, in that observing responses were followed, after a delay, by the opportunity for food reinforcement, as in a chained schedule.

Kendall discussed why the "information" hypothesis was not a fully satisfactory explanation of his data. Instead, he concluded (with Wyckoff, 1952) that the conditioned reinforcement effects depended on the development of differential control by the discriminative stimuli. As in other studies on conditioned reinforcement, higher rates were maintained by the stimulus correlated with a higher frequency of primary reinforcement (FR 10). This latter result is not easily accounted for within an information framework.

E. K. Crossman (Chapter 11) also studied the role of discriminative stimuli accompanying fixed-ratio schedules. In his study, responding on a green key was reinforced with food under FR 75. Under four alternative procedures, each presented for exactly 19 sessions, when the key was white, some stimulus event occurred after the first five responses, and food reinforcement, after the following 70. These two conditions were alternated within each session. Mean time to the first response (mean pause) was compared under each condition to the pause time under the FR 75 with no added stimuli. Interpretation of the results is extremely complicated because plots of mean pause times were highly variable, and were not always stable after 19 sessions. Moreover, some differences that appeared with one subject did not appear with the second, and there were no statistical evaluations of the differences.

The general trend was for pause times on the continuous FR to be smaller than those on the FR with a stimulus change after five responses. Under one condition, the stimulus change included a brief presentation of the feeder light, which, of course, precedes and accompanies food delivery. This condition also

produced longer pause times than the simple FR. This result could have several interpretations. The schedule is a degenerate second-order schedule (FR 5 FR 70), with two different "units". Marr (Chapter 2) speculated that primary reinforcement must depend on the same unit that produces the brief stimulus for strong reinforcing properties to emerge. The result has an even simpler explanation, somewhat independent of conditioned reinforcement. It resembles the experiments of Ferster and Skinner (1957) on block and continuous "counters" in FR schedules. They showed that when the stimulus conditions at the beginning of a fixed-ratio schedule differed from those at food reinforcement, the rate at the beginning was lower. Exactly these conditions held here.

The most thorough treatment of the information hypothesis is presented by D. P. Hendry (Chapter 12). Leaving aside the rather speculative introduction, which seems to be somewhat peripheral to the experiments performed, let us examine the experiments themselves. Two series involving fixed-ratio schedules are reported. In the first, responses on an observing key were followed by a change in the color of a second key to one explicitly correlated with the value of the current fixed-ratio schedule, either FR 20 or FR 100. Since observing responses did not change the food reinforcement schedule, their maintenance was taken to indicate that the production of the distinctive stimuli was reinforcing.

Inconsistencies develop early. For example, Fig. 12.5 shows that observing responses frequently occurred before the pigeons started responding on the food key. In addition, pigeons also made observing responses after 20 to 35 pecks on the food key, a condition under which the food schedule must be FR 100 rather than FR 20. Why?

Hendry accounts for these late observing responses as serving to "confirm" that the long ratio is in effect. That such an *ad hoc* explanation can be derived from the information hypothesis seems to weaken its status as a consistent theory of conditioned reinforcement. Alternatively, one notes that pigeons tend to engage in other behavior, including pecking keys, during pauses at the beginning of long ratio schedules (Appel, 1963).

One strong experiment in this series involved changes in the food reinforcement

schedule in a single long session. At various times during the session, only a single food reinforcement schedule (FR 20 or FR 100) was arranged. Whenever the pigeon was exposed to either the long or the short ratio only, observing responses decreased. The quite rapid decrease after each change from two schedules to one was an impressive result, and challenges alternative views based on pairing or discriminative stimuli. From a discriminative stimulus viewpoint, it implies that differential discriminative control is lost very rapidly when only one schedule of reinforcement is arranged. Further experiments along these lines are clearly warranted.

In a second series of experiments, quantitative comparisons were made between a single FR schedule and combinations of FR schedules presented as multiple or single fixed ratios, or variable ratios with the same mean numbers of pecks per food delivery. The purpose of these comparisons was, in part, to see how preference in a type of concurrent chain schedule, and relative response rate for combinations of ratio schedules, depend on frequencies of reinforcement. The traditional explanations of conditioned reinforcement in terms of discriminative stimuli were represented by computations of arithmetic and harmonic mean reinforcement frequencies. These quantities were then used to account for preference data (in a modified concurrent chain situation) compared to a single fixed-ratio value. Unfortunately, the current level of understanding concurrent chained schedules indicates that we are still far from knowing the appropriate method for combining groups of different interreinforcement intervals. In any case, Hendry's analysis also results in a not unambiguous conclusion, with neither discriminative stimulus nor information effects adequately accounting for the data.

One possible reason for adopting an information viewpoint about conditioned reinforcement would be if the mathematical measure of information were applicable to behavioral problems. Hendry examined this possibility. The information hypothesis was tested explicitly in an experiment where FR 10 and FR 100 schedules were arranged with different relative frequencies. Under these conditions, the correlated stimuli would provide different amounts of information. The schedule generated a relatively constant rate of preference,

a prediction directly opposed to the information hypothesis. Much more work is necessary to decide whether an uncertainty viewpoint contributes any additional information.

R. E. Schaub (Chapter 13) investigated an observing response that consisted of pecking on the same key as that which produced food reinforcement. This complex if ingenious arrangement was programmed as follows. Periods of variable-interval reinforcement and extinction alternated irregularly in time, with a single key color. Pecks on the key produced, for 1.5 sec, a distinctive color, correlated with the current schedule. Enhancement of responding during the extinction period, compared to the performance of a yoked control bird with the same stimulus displays, was the measure of conditioned reinforcement. Mean curves for the pigeons whose pecks changed the stimulus display tended to be higher than those of the yoked subjects, although statistical evaluation of these rather close group data was lacking.

Other experiments attempted to evaluate whether the production of both the stimulus correlated with extinction as well as the one correlated with VI were reinforcing. According to an information hypothesis, both should be. Unfortunately, the experiment was run for only 24 sessions, and the mean curves did not appear to have stabilized at that point. Schaub described a two-factor model based on associative properties (pairing with reinforcement or non-reinforcement) and informational sources of strength. As he notes, however, "Clearly, with two factors representing opposite polarities, any result can be explained." (p. 355).

J. A. Dinsmoor, G. A. Flint, R. F. Smith, and N. F. Viemeister (Chapter 14) present the only paper dealing with aversive stimuli and observing behavior. In the basic procedure, key pecking was reinforced with food, and, during one condition, every twentieth peck produced an electric shock. This punishment condition alternated after random periods of time with a non-punishment condition. Responses on a second key changed the color of the food key to one paired with the shock condition, or to another correlated with the no-shock condition. In other words, the pigeon could replace a stimulus that accompanied a moderate frequency of shock with either of two stimuli, one of which accompanied a high

shock frequency, and the other, no shocks. After exploring a number of different parameters in this complex situation, a set of values was found under which observing responses were maintained. In other words, pecking that produced a stimulus correlated explicitly with availability *versus* nonavailability of shock was sustained. It is probably of some importance that shocks were scheduled according to the number of responses emitted on the food key. In the presence of the stimulus correlated with shock, a lower rate on the food key reduced shock frequency without substantially reducing the frequency of food presentation. These results are also consistent with the findings of Lockard (1963) and others that a situation in which shocks are correlated with some environmental or temporal stimulus is generally preferred to one in which shocks occur without such consistency.

The Information Hypothesis

In the Preface, Hendry suggests that "The Information Hypothesis can accommodate many of the old ideas, and with progressive refinement and quantitative expression it may become the unifying conception of conditioned reinforcement" (p. xv). At the conclusion of this review it is therefore appropriate to consider the extent to which the papers under review strengthen one's acceptance of the information hypothesis. While many articles contained discussions that centered on the information hypothesis, that concept was most frequently used as a metaphor. Only rarely was a prediction derived from the information hypothesis that could not also be easily derived from the more traditional accounts of conditioned reinforcement (pairing and discriminative stimulus). And some predictions of the information hypothesis were clearly wrong.

Still, the information hypothesis might have two possible advantages over the other accounts. First, it might lead to quantitative predictions based on the mathematical theory of information. The one quantitative prediction based on information measurement was, however, clearly not confirmed.

Second, it might have the advantage of parsimony, replacing two mechanisms with one. In Chapter I, an informative stimulus is defined as being of one of two kinds: "cues", which control differentiated performances, and

"clues", which reliably predict reinforcers. Cues are based on differential S-R contingencies, and clues, on stimulus pairings. As with all discussions of the stimulus control of behavior, it is also recognized in the information hypothesis that not all physical energy events will become stimuli in the behavioral sense. Factors in the stimulus (modality, intensity, temporal relationship to other possible stimuli) as well as individual behavioral factors (history of stimulus control) will determine which events will or will not become effective stimuli.

In current parlance, a stimulus must be attended to in order to control behavior, whether as a conditioned stimulus through pairing, or as a discriminative stimulus for an operant. The information approach must await a yet unformulated set of rules regarding stimulus control. On the other hand, such principles are already under development in studies on discriminative stimulus control. The occurrence of differentiated performances in the presence of each stimulus condition identifies each as a discriminative stimulus. And it is in situations in which differential control develops that observing behavior is maintained. This includes different performances under different values of a schedule, *e.g.*, FR, as well as differences between reinforcement and extinction. It seems that what we may gain in the sense of parsimony we lose in precision.

CONCLUDING COMMENTS

An interesting contrast to Hendry's book is *Secondary Reinforcement: Selected Experiments*, edited by Edward L. Wike, published in 1966. This book reprints 48 articles dealing with various experimental and theoretical topics in conditioned reinforcement. Representative articles are included on the relation of the "strength" of conditioned reinforcement to the number, amount, and delay of primary reinforcement, schedules of primary and conditioned reinforcement, deprivation variables and stimulus variables. Three studies in the operant framework are also included, under "Miscellaneous Studies of Secondary Reinforcement". In addition, the more classic "hypotheses" about conditioned reinforcement are discussed. It is interesting to note that the experiment giving rise to the "information hypothesis", Egger and Miller (1962), is in-

cluded in the section on "The Discriminative Stimulus Hypothesis". This reasonable arrangement serves to emphasize that the information hypothesis may be a restatement of the discriminative stimulus hypothesis, concerned with what is a stimulus, not an alternative to it.

These reprinted articles are sandwiched between introductory and summary comments on conditioned reinforcement by Wike. The introductory sections are theoretically oriented, emphasizing the role of motivation and conditioned reinforcement in the systems of Hull and Skinner. Clear statements summarizing these viewpoints, as well as reviews of more limited treatments of secondary reinforcement, are given. The *Résumé* that follows the reprinted articles attempts to clarify what the experimental literature has shown. These summaries are based largely on non-operant experiments, and therefore are concerned with relatively limited ranges of independent variables, and group, rather than single-organism experimental designs.

Because these two books were published for different reasons, one primarily as a text, the other as a conference report, it would not be fair to rank them, since they would seldom compete with each other for any single use. In reading both of them, however, I was struck with certain differences and similarities. About 94% of the articles in Wike (the non-operant articles) were designed and performed according to the traditional hypothesis-testing tactic of experimental research. Large numbers of subjects were used, and were generally given a rather small amount of experimental training. The effects were often small in magnitude but the reliability of differences was firmly established by statistical tests. Many of the papers in Hendry were also concerned with testing for a difference between experimental treatments, a difference that might be important in deciding between competing theories. In most of the papers, small numbers of subjects were trained for comparatively large amounts of time, but effects were also often relatively small. Worse, however, only mean data were usually reported, so that neither the stability nor the reliability of the data could be determined, and the full power of an experimental analysis was not applied.

In summary, the Hendry book can be judged in two ways. First, it can be viewed as a con-

ference volume, the collection of the verbal reports presented at the 1967 conference. As such, it shares many of the faults and virtues of similar volumes, with papers of varying quality representing the presentations of the participants to each other and to a selected audience. When such reports are published as books, however, they become part of the archival literature, and are therefore subject to the same critical standards as any other published scientific contribution. What was permissible in the context of verbal communication, such as the presentation of exciting trends in current data and not fully elaborated designs, is now judged by a different set of standards. If the preceding criticism seemed unduly harsh at times, it was because of the latter element. Many interesting experimental paradigms and theoretical notions were presented, and many of these papers will, it is hoped, be the initial reports of important contributions that illuminate the problem of conditioned reinforcement.

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