FAILURE TO PRODUCE RESPONSE VARIABILITY WITH REINFORCEMENT

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Two experiments attempted to train pigeons to produce variable response sequences. In the first, naive pigeons were exposed to a procedure requiring four pecks on each of two keys in any order, with a reinforcer delivered only if a given sequence was different from the preceding one. In the second experiment, the same pigeons were exposed to this procedure after having been trained successfully to alternate between two specific response sequences. In neither case did any pigeon produce more than a few different sequences or obtain more than 50% of the possible reinforcers. Stereotyped sequences developed even though stereotypy was not reinforced. It is suggested that reinforcers have both hedonic and informative properties and that the hedonic properties are responsible for stereotyped repetition of reinforced responses, even when stereotypy is negatively related to reinforcer delivery.

Key words: complex operants, differential reinforcement, stereotypy, variability, pigeons

In the course of being trained to emit operant responses for reinforcers, animals typically develop response topographies that are both stereotyped and efficient. Although the movements that compose the rat's lever press or the pigeon's key peck may be variable and uneconomical early in training, as training proceeds, extraneous movement tends to drop out, and variability tends to diminish. By the time training is complete, the operant is usually highly stereotyped with regard to properties such as force, duration, and location (e.g., Herrnstein, 1961; Notterman & Mintz, 1965; Schwartz, 1977).

Recently, the study of the development of stereotyped response topographies has been extended to situations in which the required response is more complex than a single key peck or lever press (Schwartz, 1980, 1981a, 1981b; Vogel & Annau, 1973). In these experiments, the required operant was a sequence of responses. Pigeons were exposed to trials that began with two response keys and the top left light of a 5 by 5 matrix of lights illuminated. When they pecked one of the keys, the illuminated matrix light moved down one row, and when they pecked the other key, it moved across one column. When they had pecked

each key four times, so that the bottom right matrix light was illuminated, a reinforcer was delivered. Thus, to obtain reinforcers pigeons had to peck each of the keys four times, in any order. If they pecked either key a fifth time, the trial ended without reinforcement. In all, there were 70 different sequences of responses that would result in reinforcement.

The consistent finding in these studies was that despite the wide range of sequence variability permitted by the reinforcement contingency, stereotyped sequences developed. For each pigeon, one sequence came to dominate all others, occurring on 50 to 90% of trials. Though the dominant sequence varied from pigeon to pigeon, for each pigeon it was highly stereotyped from trial to trial and session to session.

This reliable finding led Schwartz (1980, Experiment 4) to ask whether sequence stereotypy could be prevented if the reinforcement contingency required variability. Thus, pigeons were exposed to the sequence task just described, with the reinforcement contingency modified so that a given sequence was only reinforced if it differed from the sequence that had occurred in the preceding trial. Pigeons were exposed to this procedure after a lengthy period of training with the regular sequence task, which had resulted in the development of stereotyped sequences. Schwartz found that in 40 sessions of exposure to this contingency requiring sequence variability, only one of eight

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pigeons showed an appreciable increase in sequence variability. In the initial sessions of the procedure, the pigeons obtained reinforcers in about 32% of trials; at the end of the procedure, they obtained reinforcers in about 36% of trials. In contrast, when the sequence task contained no requirement of sequence variability, pigeons obtained reinforcers on 70 to 95% of trials.

This finding led Schwartz to speculate that perhaps reinforcement was not an effective procedure for producing variations in response topography. Perhaps reinforcement led inexorably to stereotyped responses. Schwartz showed in another experiment (Schwartz, 1980, Experiment 5) that response sequences were not completely unmodifiable. If sequences were required to begin with two left key pecks, or with a left-right alternation, pigeons modified their sequences accordingly. However, when they were simply required to vary sequences, behavior was not modified effectively.

However, it would be premature to suggest that reinforcement cannot produce sequence variability. There were two features of Schwartz's procedure that might have worked against the variability requirement. First, the pigeons were highly trained and were emitting stereotyped sequences when the procedure began. Perhaps with naive pigeons that had not yet developed stereotyped sequences, the variability contingency could effectively control behavior. Second, in the Schwartz experiment, the interval between trials was 10 sec. Thus, to master the contingency, pigeons had to bridge a 10-sec delay between what they had just done and what they would do next. Although one can imagine strategies that would effectively bridge the delay (e.g., the pigeon could spend the entire intertrial period next to the key on which the next sequence should begin), such a long intertrial period certainly does not optimize the chances for successful performance.

The present experiments were designed to explore further whether pigeons could learn to vary response sequences. Experiment 1 removed both of the obstacles that were present in the initial experiment: the pigeons were naive at the start of training, and the intertrial interval was reduced to .5 sec. Experiment 2 attempted to produce sequence variability by first explicitly establishing a repertoire that contained two distinct sequences that occurred with appreciable frequency.

EXPERIMENT 1

METHOD

Subjects

Six experimentally naive White Carneaux pigeons were maintained at 80% of their free-feeding weights.

Apparatus

Four Gerbrands pigeon chambers (G7313) contained three-key pigeon intelligence panels. The keys were Gerbrands normally closed keys, requiring a force of .1 N to operate. They were spaced 7.5 cm apart, center-to-center, and were located 21 cm above the grid floor. A grain hopper was directly below the center key, 5.5 cm above the grid floor, and a pair of houselights was located in the ceiling of the chamber. The houselights were illuminated throughout experimental sessions, except during 4-sec feeder operations, when a light in the feeder was illuminated.

On the left wide wall of each chamber was mounted a 5 by 5 matrix of red lights, spaced 2 cm apart. The lights were .84 cm in diameter and .04 amp (Dialco No. 507-3917-1471-60D). The top row of lights was 20 cm from the grid floor, and the right column (closest to the intelligence panel) was 4 cm from the panel.

Scheduling of experimental events, data collection, and data analysis were accomplished with a Digital Equipment Corporation PDP 8/E digital computer using interfacing and software provided by State Systems Incorporated, Kalamazoo, Michigan.

Procedure

Pretraining. The pigeons were trained to eat from the food magazine, after which they were exposed to a modified autoshaping procedure (Brown & Jenkins, 1968). Each session consisted of 50, 6-sec trials, separated by a variable intertrial interval ($X = 40$ sec). Each of three trial types was equiprobable: either the left key was illuminated with white light, or the right key was illuminated with white light, or both keys were. These three types of trials occurred in random order. After 6 sec, the key-light(s) was extinguished and the feeder operated. Key pecks were recorded but had no programmed consequence. Each pigeon was exposed to the autoshaping procedure for five full sessions after the one in which pecking be-

gan. At the end of pretraining, all pigeons were reliably pecking both keys (when illuminated).

Sequence Training Procedure. Daily sessions consisted of 50 trials, separated by an intertrial interval (ITI) of .5 sec. At the beginning of each trial, the two side keys were illuminated with white light and the top left matrix light was lit. Each peck on the left key extinguished the currently illuminated matrix light and lit the one to its right; each peck on the right key also extinguished the currently illuminated matrix light and lit the one beneath it. Four left key pecks were required to move the matrix light from extreme left to extreme right, and four right key pecks were required to move the matrix light from extreme top to extreme bottom. To obtain a reinforcer it was necessary to move the matrix light from the top left to the bottom right, that is, to peck each key four times. A fifth peck on either key terminated a trial immediately, without reinforcement. In all, there were 70 different sequences of left and right key pecks that could satisfy the reinforcement contingency.

All pigeons were placed on the sequence procedure immediately after the autoshaping pretraining described above. Generally, this pretraining was sufficient to ensure that pigeons would peck both keys on most sequence trials. If they were pecking both keys, they tended to obtain enough reinforcers in early sessions to keep them pecking until they mastered the contingency. However, one pigeon (A10) tended to peck exclusively on one key and thus obtained no reinforcers at all. For this pigeon, a special procedure was instituted. To decrease the tendency to persevere on one key, it was exposed to a single session in which either keylight was extinguished when it had been pecked four times. After one such session, it was returned to the regular sequence procedure.

Variability Requirement

Aside from having to peck each key four times, the pigeons were required to vary their response sequences. To produce reinforcement, a correct sequence had to be different from the sequence that had occurred on the immediately preceding trial. Thus, repetition of a single sequence was never reinforced. After 100 sessions of this procedure, the variability requirement was removed for 30 ses-

sions. It was then reintroduced for 50 sessions and removed again for 30 sessions. Thus, the present experiment differed from the one reported in Schwartz (1980) in two respects: the ITI was .5 rather than 10 sec, and the variability requirement was imposed before stereotyped sequences could develop.

RESULTS AND DISCUSSION

In previous experiments of this type, there have been three dependent variables of primary interest: the number of reinforcers obtained, the number of different sequences emitted, and the frequency of the sequence that became dominant. Figure 1 shows the number of reinforcers obtained per session by each pigeon, averaged across the first and last five sessions of each procedure. The procedure requiring sequence variability is labeled "DIF" (for different sequences) in the figure, and the standard sequence procedure is labeled "SEQ." One hundred sessions of exposure to the variability contingency did not result in mastery of the contingency. Only Pigeon A9 was obtaining more than 20 reinforcers per session by the end of training. That this represents ineffective performance in contrast to what one observes on the standard sequence task is clear from the second pair of bars for each pigeon. Within five sessions of exposure to the standard procedure, five of the pigeons were obtaining 40 or more reinforcers a session. By the end of 30 sessions, all pigeons were performing effectively. When the variability contingency

Fig. 1. Reinforcements per session for each pigeon averaged across the first and last five sessions of each procedure in Experiment 1. The first bar in each pair is from the first five sessions and the second is from the last five. The procedures are labeled on the X-axis. The procedure requiring variability is labeled DIF and the standard procedure is labeled SEQ.

was reintroduced, reinforcers obtained immediately declined and increased only modestly over the course of 50 sessions. Only Pigeon B6 improved beyond the level it had reached in its first exposure to the variability contingency. When the variability requirement was again removed (last pair of bars), the pigeons again rapidly began obtaining more than 40 reinforcers per session. Thus, whether pigeons were naive (first pair of bars) or experienced (third pair of bars), the variability contingency had only modest success in increasing variability. This finding replicates and extends Schwartz (1980).

Figure 2 presents for each pigeon the number of different sequences per session. The data are taken from the same sessions as in Figure 1, and include both correct (four pecks on each key) and incorrect sequences. For all but Pigeon A10, sequence variability decreased substantially over the course of exposure to the variability requirement. By the end of that procedure, the other five pigeons were emitting 4 to 8 different sequences per session. Once this level of variability was reached, it remained, virtually unchanged, for the remainder of the experiment. For Pigeon A10, there was only a modest decline in sequence variability during prolonged exposure to the variability contingency. This decline continued over the course of the next two procedures, reaching a level comparable to that of the other pigeons. Thus, in every case, sequence variability decreased, although the reinforcement contingency required sequence variability.

Figure 3 presents the frequency of the sequence that became dominant for the same sessions as depicted in Figures 1 and 2. Each panel also indicates what each pigeon's dominant sequence was. In initial exposure to the variability contingency, each pigeon's dominant sequence occurred fewer than ten times per session. Pigeon B8 was an exception; but its dominant sequence at the start of training was RRRRR (see asterisk in the figure), indicating a strong tendency to perseverate on one key early in training. For the other pigeons, despite the fact that repetition of their correct, dominant sequence was never reinforced, its frequency increased over training. By the end of the variability procedure, dominant sequences were occurring nearly 30 times per session, averaged across all birds. That the variability contingency had some effect is clear

Fig. 2. Number of different sequences per session for each pigeon averaged across the first and last five sessions of each procedure in Experiment 1. The first bar in each pair is from the first five sessions and the second is from the last five. The procedures are labeled on the X-axis. The procedure requiring variability is labeled DIF and the standard procedure is labeled SEQ.

from the next pair of bars in Figure 3. When exposed to the standard sequence procedure, the frequency of the dominant sequence increased for all pigeons but B8. By the end of this phase of the experiment, the group mean

Fig. 3. Frequency of the dominant sequence per session for each pigeon averaged across the first and last five sessions of each procedure in Experiment 1. The first bar in each pair is from the first five sessions and the second is from the last five. The procedures are labeled on the X-axis. The procedure requiring variability is labeled DIF and the standard procedure is labeled SEQ. Each pigeon's dominant sequence is indicated in the appropriate panel of the figure. In addition, for Pigeons A9, B6, and B7, a second sequence is identified with an asterisk. This sequence occurred with substantial frequency in the procedure marked by the asterisk in the appropriate panel. Pigeon B8 also has a second sequence identified with an asterisk. This was its dominant sequence in the first five sessions of training, after which the other indicated sequence replaced it.

frequency was 40. When returned to the variability contingency, the frequency of the dominant sequence decreased substantially for three of the pigeons. These three pigeons (A9, B6, and B7) satisfied the variability contingency by roughly alternating between the dominant sequence and another one. The asterisks in the sixth bars of the panels for these three pigeons indicate that the sequence identified by the asterisk increased during this procedure. Thus, Pigeon A9 intermixed LLLRR-RRL sequences with the dominant LLLL-RRRR sequence. Perhaps more interesting, Pigeons B6 and B7 mixed incorrect sequences (either RRRRR or LLLLL) with their dominant one. Note that this is a relatively effective strategy. If a pigeon strictly alternated LLLL-RRRR with LLLLL, it would obtain 25 reinforcers per session. In contrast, if it emitted LLLLRRRR on all 50 trials, it would obtain only a single reinforcer per session.

To summarize, these data suggest that reinforcement produces sequence stereotypy in the face of a contingency that should discourage it. This effect occurs in animals that have never experienced consistent reinforcement for stereotyped sequences, and it occurs when the time between trials is short enough to minimize memory problems, to the extent that they can be minimized.

There is evidence that a contingency requiring variability has some effect on stereotypy, since there was less stereotypy when that contingency was in force than when it was not. However, it should be noted that there is greater reinforcement intermittency in the variability procedures than in the standard sequence procedures. This intermittency of reinforcement might contribute to sequence variability as much as the variability contingency does. The question raised by these data is whether any procedure can be found that will effectively prevent or eliminate sequence stereotypy.

EXPERIMENT 2

Experiment 1 demonstrated that a contingency that required variable response sequences failed to prevent stereotyped sequences from developing, even in naive pigeons. This experiment employed a different strategy, suggested by the behavior of Pigeons A9, B6, and B7 in Experiment 1. If one could

establish a repertoire that included more than one dominant response sequence, perhaps pigeons would learn to alternate among the sequences in their repertoire when the variability contingency was imposed. Thus, a repertoire of two dominant sequences was shaped in the pigeons that served in Experiment 1, after which they were again exposed to the variability contingency.

METHOD

Subjects and Apparatus

The subjects and apparatus were the same as in Experiment 1. However, Pigeon B8 became ill shortly after the experiment began and was dropped from the experiment. Experiment 2 began immediately after Experiment 1 terminated.

Procedure

Most aspects of the procedure were the same as in Experiment 1. There were 50 trials per session, separated by a .5-sec ITI, reinforcement was 4-sec access to grain, trials began with the illumination of the top left matrix light, and so on. The sequence task differed from that in Experiment 1 in that an explicit attempt was made to train two distinct sequences. Each pigeon was trained to emit the sequences LLLLRRRR and RRRRLLLL. Training involved five stages. In the first stage, a trial began with only the left or right key light illuminated, left if an LLLLRRRR sequence was required and right if an RRRRLLLL sequence was required. After the pigeon pecked the lit key four times (moving the matrix light to the appropriate place), the key-light was extinguished and the other key was illuminated. Four pecks on this other key (again moving the matrix lights appropriately) produced a reinforcer. Pecks on either key when it was not illuminated had no consequence. Thus, as long as the pigeons pecked at all, they could not help but obtain a reinforcer on every trial.

The RRRRLLLL and LLLLRRRR (hereafter RL and LR respectively) requirements alternated irregularly from trial to trial. Which sequence was required was signaled both by the illumination of the appropriate side key and by the illumination of the center key. The center key was red on LR trials and green on RL trials. Pecks at it had no conse-

quence. The pigeons were exposed to this procedure for 20 sessions.

In the next stage of training, trials of the type just described alternated with trials in which both side keys were lit from the beginning, and the required sequence was cued by the color of the center key. If the center key was red, an LR sequence was required, and if it was green, an RL sequence was required. No other sequence was reinforced. On these types of trials, all the sequences that could occur on the standard sequence procedure were possible but not reinforced. This stage of training lasted for 20 sessions.

The third stage of training consisted of the same two types of trials as the second stage, but only one of every four trials guided the pigeons through the required sequence by having only the appropriate side key lit at any given time. In all other trials, both keys were available and the center key signaled the required sequence.

After 20 sessions, the fourth stage of training was instituted. Here, all trials were of the type in which both side keys were lit. Thus the side-key lights were no longer used to guide pigeons through the required sequence, but the color of the center key was still used as a signal. This stage was in force for 20 sessions.

In the final stage of training, signaling of required sequences by the center-key color was discontinued. All trials were of standard sequence type, with both side keys lit from the beginning. What was required was alternation between LR and RL sequences. If an LR sequence was reinforced on a given trial, the next reinforcement depended upon the occurrence of an RL sequence. All other sequences terminated trials without reinforcement. This requirement remained in effect until an RL sequence occurred, after which the next reinforcement depended upon an LR sequence. By strictly alternating between the two sequences, a pigeon could obtain a reinforcer on every trial. This procedure was in effect for 50 sessions.

After this sequence of procedures requiring two specific sequences, the pigeons were exposed again to the variability contingency of Experiment 1 for 50 sessions. It should be noted that neither procedure allowed reinforcement for repetition. They differed in that the variability contingency simply required different sequences to occur from trial to trial,

whereas the alternation contingency required specific sequences on each trial.

RESULTS AND DISCUSSION

Since the focus of this experiment was whether, if pigeons had a two-sequence repertoire, it would allow them to master the variability contingency, no data will be presented on the acquisition of LR and RL sequences through the various stages of the training process. Instead Figure 4 presents data from the final alternation procedure in which no exteroceptive cues to the required sequence were available. Figure 4 presents, for each subject, the mean reinforcements per session, LR sequences per session, and RL sequences per session, in the first and last five sessions of the procedure. By the end of training, the pigeons were obtaining 26 to 36 reinforcers per session (the group mean was 31). At the start of this stage, LR sequences were more frequent than RL sequences for Pigeons A9 and A10, and the reverse was true for Pigeons B6 and B7. By the end of 50 sessions, both sequences were occurring with substantial frequency for each pigeon. About 80% of all sequences were either LR or RL. For no pigeon did either sequence occur less than 15 times per session. Thus, it seems reasonable to conclude that the pigeons met the requirements of this task with substantial success. That they did so indicates that failure on the task requiring variability could not be attributed to difficulties pigeons might have remembering what they did on the previous trials. For on this alternation task, there were no exteroceptive cues available at the time of a trial to indicate what sequence was required,

Fig. 4. Reinforcements per session, LLLRRRR (LR) sequences per session and RRRRLLL (RL) sequences per session for each pigeon and for the group in the first and last five sessions of the alternation procedure.

Fig. 5. Reinforcements per session, LLLRRRR (LR) sequences per session and RRRLLLL (RL) sequences per session for each pigeon and for the group in the first and last five sessions of the variability procedure.

and the pigeons performed accurately. Clearly some aspect of what had occurred on the preceding trial must have been available to the pigeon as it began its next sequence.

Having established a two-sequence repertoire with the alternation task, the question of interest was whether this repertoire would facilitate performance under the variability contingency. The relevant data are presented in Figure 5. Figure 5 presents, for each pigeon, the mean reinforcements, and LR and RL sequences per session over the first and last five sessions of exposure to the variability contingency. Over the course of training, reinforcements per session decreased for every pigeon, quite substantially for Pigeons A10 and B5. Though performance was better at the end of this procedure than in past attempts to train variability (see Figure 1), at the end of training the pigeons were obtaining less than 50% of the possible reinforcers. What makes this decrease in accuracy surprising is that the variability contingency would seem to represent no significant change in procedure from the alternation contingency. Repetitions of a sequence would not be reinforced in either case, and alternations between the two sequences would be reinforced in both cases. Nevertheless, over the course of training, one of the sequences increased in frequency and the other decreased for every pigeon but B5 and B6. For every pigeon, performance at the end of the variability procedure was nearly identical to performance at the beginning of the alternation procedure (compare the fourth and sixth bar of each panel in Figure 5 to the third and fifth bar of each panel in Figure 4). Thus, in

the absence of an explicit contingency on alternation, sequences tended to drift back to the patterns observed before the alternation contingency was introduced. Establishing a repertoire that included two dominant sequences did not substantially facilitate performance under the variability contingency.

GENERAL DISCUSSION

The results of these experiments confirm Schwartz's (1980) earlier conclusion that reinforcement of variable response sequences in pigeons does not succeed. Sequence variability is only slightly greater under the variability contingency than in its absence, and variability decreases over exposure to the variability contingency. In the 1980 experiment, a number of possible explanations for the failure were proposed. One explanation was that once a stereotyped sequence has developed, it is resistant to modification, so that a variability contingency must overcome previous training. The present experiments ruled out this possibility by showing that stereotypy developed in the face of required variability even in naive pigeons. A second possible explanation appealed to the pigeon's memory limitations. To meet the variability contingency, the pigeon must remember at least a fragment of what occurred in the preceding trial. The present experiments ruled out this possibility in two ways. First, pigeons failed to master the contingency even when a very short (.5-sec) ITI was in effect. Second, with the very same ITI, pigeons mastered the alternation task, which would seem to make the same demands on memory as the variability task.

A third possible explanation, not ruled out by the present data, is that the variability task is simply too difficult for pigeons. But this cannot constitute an explanation without some indication of what makes it difficult. Perhaps the task is difficult because it requires that pigeons have a concept of "different." This may be too abstract a concept for pigeons. This is implausible for a few reasons. First, pigeons are able to perform effectively on tasks, like oddity discrimination, that require discriminative responding based upon the concept "different stimulus." Second, even if "different" is too difficult for pigeons, they could perform effectively by just alternating between two specific sequences. Experiment 2 built these se-

quences into their repertoires. Nevertheless, over the course of exposure to the variability contingency alternation deteriorated, with one of the two sequences becoming more frequent than the other.

Although in the present experiment a variability requirement failed to promote variable response sequences, there is evidence in the literature that trained variability is at least sometimes possible. First, for at least some species (rats), in at least some situations (spatial learning), behavioral variability is the norm, and stereotypy is difficult even to train (e.g., Olton, 1979; Olton & Samuelson, 1976). Second, even for pigeons pecking keys, there may be some properties of responding for which variability can be trained. Blough (1966), for example, was able to produce variability in interresponse times. Although we have evidence that, on the sequence task, interresponse times are highly stereotyped (Schwartz, 1981, *Note 1*), it is possible that if reinforcement were made to depend upon variable interresponse times, such variability would occur. Third, Pryor, Haag, and O'Reilly (1969) successfully trained variable response patterns in porpoises. However, even if reinforcement induces stereotypy only in some circumstances, it is appropriate to ask why stereotypy should occur at all. What does stereotypy gain the animal? One possibility is that stereotypy gains efficiency. The animal comes to produce responses that maximize reinforcement and minimize effort. Thus, the rat may begin training with highly variable and inefficient lever presses and end with highly stereotyped, smooth, and efficient ones. Similarly, pigeons on the sequence task may come to develop sequences that minimize effort. Support for this possibility is that for most pigeons, the sequence that becomes dominant is one that involves only one switch between keys, presumably the least effortful sequence. However, an argument against efficiency is that the stereotyped sequences develop even in the face of the variability contingency, where they are decidedly inefficient.

One could make a somewhat different kind of efficiency argument, based upon cognitive rather than behavioral economy. It is possible that stereotyped sequences are automatized so that they do not require active attention for execution. Tests of this idea with human subjects have often assessed automaticity by having people engage in two tasks (one of them

putatively automatized) simultaneously (e.g., LaBerge & Samuels, 1974). If performance of the nonautomatized task is not affected by concurrent performance of the automatized one, one concludes that automatization spares limited processing resources. Schwartz (*Note 2*) has done an analogous experiment with pigeons in the sequence situation. He found that pigeons could perform the sequence task simultaneously with either a matching-to-sample or a conditional-discrimination task. For example, in the matching task, on each sequence trial both response keys were either red or green. After the pigeon performed a correct sequence, the keys were darkened for a moment, after which one was red and the other green. To obtain the reinforcer, the pigeon had to peck the key whose color matched the color of both keys during the sequence portion of the trial. Thus, the pigeons had to process key color while performing the sequence task. They were able to perform both sequence and matching tasks extremely accurately. However, when delays were introduced in the concurrent task (for example, three seconds with the keys dark intervened between the end of the sequence and the illumination of the keys with red and green for the matching choice), sequence performance deteriorated. This deterioration did not occur when correct sequences produced delayed reinforcement with no concurrent required task. Thus, even though response sequences were stereotyped, they still required cognitive "effort" for successful execution. Thus, it is not obvious that efficiency, whether behavioral or cognitive, fully explains stereotypy.

Some insight into the source of stereotypy may be gained by carefully examining what effects reinforcement is supposed to have. According to the law of effect, reinforcement increases the future probability of responses that have been followed by reinforcers. As Skinner (1935) pointed out, reinforcement strengthens (increases in probability) an operant, a class of responses. What defines that class must be some property on which reinforcement depends (see Schick, 1971). Suppose we wanted to use reinforcement to increase behavioral variability. What would define the operant class on which reinforcement depends? What objective property of responses would unite them into a class? It is clear that there is no such property. We could create such a property by,

for example, requiring variation among a fixed set of responses (as in the alternation task in Experiment 2), but then what we would obtain is strengthening of just those responses that had the specified property. Thus, while it is clear that reinforcement might create a varied, but definite and circumscribed response repertoire, it is not clear that it could increase variability *per se*. Indeed, if reinforcement were to be demonstrably successful in increasing variability, it would be hard to reconcile this with the technical meaning of the law of effect. This is not pedantry. The significance of understanding reinforcement as affecting response classes is that it solves the teleological problem of seeming to have cause (reinforcement) follow effect (behavior). If reinforcement did not strengthen a class of responses, it is unclear how it could intelligibly be said to have any effect at all.

If it does not make logical sense to suggest that reinforcement can increase variability, what is to be said about occasional demonstrations that reinforcement can increase novel behavior (e.g., Goetz & Baer, 1973; Pryor, Haag, & O'Reilly, 1969)? For example, when social reinforcement was made contingent on novel block designs in young children, the frequency of novel designs increased (Goetz & Baer, 1973). These effects may be understood by distinguishing two properties that the consequences of responding called "reinforcers" may have. The first property is hedonic. Organisms seem to want reinforcers. The second property is informational. Reinforcer delivery tells an organism that it has just done something properly.

From the definition of a reinforcer as a consequence of responding that strengthens a class of behavior it may follow that reinforcers must inevitably be both informative and hedonic. Since reinforcers are by definition response-dependent, they must provide feedback that responding was correct. And since, by definition, they increase the probability of responses that produce them, they must be hedonic. A consequence of responding that did not produce this increase would be judged not to be a reinforcer at all.

However, from the fact that reinforcers are by definition both hedonic and informative, it does not follow that all consequences of responding that control behavior are both hedonic and informative. When one is taking a

golf or piano lesson and hears "good" from the instructor, the "good" may control behavior through the information it provides and not because it is hedonic. The instructor's "good," as a purely informative consequence of a golf swing, may influence the form that a swing takes if it occurs, but it may not have any influence on its probability of occurrence. If the probability of playing golf increases, it may result from the fact that playing golf is more fun if one is playing well. On this analysis, the instructor's "good" controls responding by influencing response form. But it is not a reinforcer, because it does not, by itself, increase response probability. One might want to suggest that "good" is a reinforcer, increasing the probability of effective golf swings. On this view, the reinforcer would be functioning both to redefine and to strengthen the response class. However, this analysis is implausible, for if "good" were a reinforcer we would expect people to favor instructors who said "good" at a high indiscriminate rate, no matter what the swing looked like. But presumably if one encountered such an instructor, one would change instructors rather than increase the probability of playing golf. The suggestion here is not that playing golf is not reinforced, or that successful golf shots are not reinforcing, for they may be. It is only that "good" from an instructor may control behavior without reinforcing it.

If purely informative consequences of responding need not increase response probability, it is not hard to see how they could increase response variability. They would serve, as instructions do, to define the appropriate range of activities—to establish a goal. Then whether or not that goal was actually achieved (appropriate responses increased in frequency) would presumably depend upon other factors. Since informative response consequences do not strengthen, they do not depend for logical coherence on the existence of an objectively defined response class.

It might seem that if one is trying to increase behavioral variability, there must be some objectively defined physical properties of behavior on which one must depend before delivering the informative consequences. At the very least, some range of variability must be specifiable. However, this is not the case. One could set out to produce "creative" block design without having any idea in advance what a cre-

ative design will look like. All one must be able to do is recognize, after the fact, that a given design differs from previous ones. The range of variability will likely differ in extent and detail from subject to subject. Obviously, if one is attempting to increase variability in an automated experiment, say with animal subjects, criteria for reinforcement must be established in advance, as in the present experiments. But it should be recognized that the need for a priori criteria is a feature of automated methods and not of the shaping process itself. For example, in the Pryor, Haag, and O'Reilly (1969) experiment that increased novel responses in porpoises, the experimenters had virtually no a priori criteria. The animal's behavior established the experimenters' criteria.

This distinction between hedonic and informative properties of response consequences is not one that has been made systematically in the literature, though it has appeared occasionally. For example, Goetz and Baer (1973) pointed out that their social "reinforcement" of novel block designs might have depended on either or both of these properties. In a different context, the literature on second-order schedules of brief-stimulus presentation is concerned in part with distinguishing the discriminative and conditioned-reinforcing effects of these stimuli (see Gollub, 1977, pp. 299-308 for a review). It is a distinction that deserves attention, for it may be of practical as well as theoretical importance. Suppose an educator is interested in using reinforcement to promote novel or creative behavior. It might be that some response consequences will be effective at promoting novelty and others will not, depending upon whether they do or do not have hedonic (reinforcing) properties. A good deal of the controversy that surrounds the use of reinforcers in education could be resolved by means of this distinction. Consider, for example, the so-called "overjustification effect," the demonstration that reinforcement may decrease the baseline rate of occurrence of activities that are "intrinsically motivated," i.e., have high baseline rates (e.g., Deci, 1975; Feingold & Mahoney, 1975; Lepper & Greene, 1978; Lepper, Greene, & Nisbett, 1973). It is possible that reinforcers, since they produce stereotypy, undermine one of the characteristics of an activity (that it permits novelty) that makes it reinforcing. On the other hand, in-

formative but nonreinforcing response consequences might be used effectively to refine or shape the activity without encouraging stereotyped repetition. And if they did not encourage repetition, they would presumably not result in lowered baseline rates of occurrence.

The general significance of this distinction between hedonic and informative aspects of operant consequences comes clear in Horton's (1967) discussion of the similarities and differences between traditional African and scientific Western patterns of thinking. Horton suggests that the hallmark of Western scientific thought is that the practical and theoretical are kept distinct, whereas in traditional African thought, they are inextricably connected. As a result, in science one can construct or attack hypotheses, attempt to confirm or falsify them, without regard for any consequence but truth. In contrast, tests of hypotheses in African thought always have practical consequences. If, for example, an agronomist stumbled onto a new method of cultivation and improved crop yield as a result, the agronomist would attempt to establish a causal relation by withholding the new method and looking for decreased yield. For the African farmer, withholding the new method might mean starvation. Thus, the farmer might continue to repeat the new method that has worked (been reinforced) in the past, and perhaps never discover whether the relation between the new method and crop yield was spurious or not (see Schwartz, in press).

Consequences that have hedonic properties conflate the practical and the theoretical. If one wants the reinforcer, one repeats what has worked in the past. Stereotypy is the result. A consequence that is just informative need not conflate the theoretical and the practical. What it does is provide information about what is correct (true). Whether or not one continues to engage in the behavior that produced the informative consequence will presumably depend on other (hedonic, practical?) factors that are separable from the informative consequence *per se*.

If this distinction between informative and hedonic properties of consequences makes it possible to speak with logical coherence of consequences producing novel behavior, and if it helps establish procedures for the judicious use of consequences (of both types) in education, it does so at a price. For it is not clear

that the idea of informative but nonreinforcing consequences has much to do with the central ideas of behavior analysis over its history. To the extent that this distinction is important, it may indicate significant incompleteness in the traditional concepts of behavior analysis.

REFERENCE NOTES

1. Schwartz, B. Interval and ratio reinforcement of a complex, sequential operant in pigeons. Manuscript submitted for publication.
2. Schwartz, B. Stereotypy without automaticity in pigeons. Manuscript in preparation.

REFERENCES

- Blough, D. S. The reinforcement of least-frequent interresponse times. *Journal of the Experimental Analysis of Behavior*, 1966, 9, 581-591.
- Brown, P. L., & Jenkins, H. M. Auto-shaping of the pigeon's key-peck. *Journal of the Experimental Analysis of Behavior*, 1968, 11, 1-8.
- Deci, E. L. *Intrinsic motivation*. New York: Plenum, 1975.
- Feingold, B. D., & Mahoney, M. J. Reinforcement effects on intrinsic interest: Undermining the overjustification hypothesis. *Behavior Therapy*, 1975, 6, 367-377.
- Goetz, E. M., & Baer, D. M. Social control of form diversity and the emergence of new forms in children's blockbuilding. *Journal of Applied Behavior Analysis*, 1973, 6, 209-217.
- Gollub, L. Conditioned reinforcement: Schedule effects. In W. K. Honig & J. E. R. Staddon (Eds.), *Handbook of operant behavior*. Englewood Cliffs, N.J.: Prentice-Hall, 1977.
- Herrnstein, R. J. Stereotypy and intermittent reinforcement. *Science*, 1961, 133, 2067-2069.
- Horton, R. African traditional thought and Western science. *Africa*, 1967, 37, 50-71 & 155-187.
- LaBerge, D., & Samuels, S. J. Toward a theory of automatic information processing in reading. *Cognitive Psychology*, 1974, 6, 293-323.
- Lepper, M. R., & Greene, D. (Eds.). *The hidden costs of reward*. Hillsdale, N.J.: Erlbaum, 1978.
- Lepper, M. R., Greene, D., & Nisbett, R. E. Undermining children's intrinsic interest with extrinsic reward: A test of the "overjustification" hypothesis. *Journal of Personality and Social Psychology*, 1973, 28, 129-137.
- Notterman, J. M., & Mintz, D. E. *Dynamics of response*. New York: Wiley, 1965.
- Olton, D. S. Mazes, maps and memory. *American Psychologist*, 1979, 34, 583-596.
- Olton, D., & Samuelson, R. J. Remembrance of places passed: Spatial memory in rats. *Journal of Experimental Psychology: Animal Behavior Processes*, 1976, 2, 97-116.
- Pryor, K. W., Haag, R., & O'Reilly, J. The creative porpoise: Training for novel behavior. *Journal of the Experimental Analysis of Behavior*, 1969, 12, 653-661.
- Schick, K. Operants. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 413-423.
- Schwartz, B. Studies of operant and reflexive key pecks in the pigeon. *Journal of the Experimental Analysis of Behavior*, 1977, 27, 301-313.
- Schwartz, B. Development of complex, stereotyped behavior in pigeons. *Journal of the Experimental Analysis of Behavior*, 1980, 33, 153-166.
- Schwartz, B. Reinforcement creates behavioral units. *Behaviour Analysis Letters*, 1981, 1, 33-41. (a)
- Schwartz, B. Control of complex, sequential operants by systematic visual information in pigeons. *Journal of Experimental Psychology: Animal Behavior Processes*, 1981, 7, 31-44. (b)
- Schwartz, B. Reinforcement induced behavioral stereotypy: How not to teach people to discover rules. *Journal of Experimental Psychology: General*, 1982, 111, in press.
- Skinner, B. F. The generic nature of the concepts of stimulus and response. *Journal of General Psychology*, 1935, 12, 40-65.
- Vogel, R., & Annau, Z. An operant discrimination task allowing variability of reinforced response patterning. *Journal of the Experimental Analysis of Behavior*, 1973, 20, 1-6.

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