TIMEOUT AS A REINFORCER FOR ERRORS IN A SERIAL POSITION TASK

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After learning to press keys in a predetermined serial position sequence, with timeouts scheduled as a consequence of errors, monkeys developed stereotyped errors. As soon as a new trial started, the animals would make an error. On trial after trial, they pressed the same incorrect key at the first member of the sequence, even though they had previously learned the sequence. First-member errors occurred even when sequences of fully bright keys marking correct choices were presented. When timeout was eliminated as a consequence of one first-member error, subjects switched to an error that did produce the timeout. When all first-member errors failed to produce timeout the monkeys ceased responding. Both prefeeding and reduction in reinforcement density resulted in stereotyped errors occurring earlier in the session.

Boren (1963), Boren and Devine (1968), and Sidman and Rosenberger (1967), developed methods for teaching monkeys to press different levers or keys in predetermined sequences. The length of the chain or sequence is gradually increased by adding new members to the beginning of the chain in a stepwise manner across successive trials. Incorrect presses, or errors, produce a period of timeout from positive reinforcement. The present research used a variant of the Sidman and Rosenberger procedure in which new members were added to the end rather than to the beginning of the chain. This research confirmed that monkeys could learn sequences up to nine members long. But we also noted that animals typically ended the experimental sessions by continually repeating the same error, trial after trial. The present report describes the "stereotyped error" behavior, examines the possible relevance of several variables—error timeout, task complexity, reinforcer satiation, and reinforcement density—to the occurrence of these errors, and questions experimentally the effectiveness of the error-timeout contingency in teaching serial position sequences to monkeys.

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METHOD

Subjects

Four male rhesus monkeys were maintained at 80% of their free-feeding weights; this criterion was adjusted each month by adding 1 g to the maintained weight. All animals had been subjects in previous research with variants of Sidman and Rosenberger's procedure; Monkey R-7 had also participated in Ray's (1967) study of the course of acquisition of a line-tilt discrimination; Monkeys R-19 and R-30 were subjects in Sidman and Fletcher's (1968) auto-shaping experiment. Consequently, all subjects had already undergone magazine training and shaping of key pressing, and all had considerable experience with the general procedure described below.

Apparatus

Sidman and Rosenberger (1967) described the sound-resistant experimental chamber and stimulus display. The subject area, approximately 61 by 61 by 61 cm, was separated from stimulus and reinforcement equipment by an aluminum wall. Three translucent circular stimulus-response keys (2 cm diameter) were mounted horizontally on this wall, 12.7 cm apart and 31 cm above the animal's floor. Behind each key was a 7.5-W Christmas tree bulb; potentiometers driven by stepping motors controlled the brightness of each bulb in-

dependently. Reinforcers (1-g banana pellets) were delivered into a tray located 19 cm below the center key. House light was provided by a 60-W bulb.

Sequences of correct keys, control of light intensity, and recording of the stimuli and responses were arranged automatically by solid-state circuitry. A 20-pen event recorder provided records of key presses, fading steps, and reinforcements.

General Procedure

Each session started with a two-member sequence. To begin a trial, one of the three keys was lighted. When this key was pressed it became dark and a second key was lighted. When the subject completed the two-member sequence by pressing the second key, the house- and keylights were extinguished for 0.25 sec, and a new trial began with the first member of the sequence. Reinforcement, in the form of 1-g banana pellets, was arranged on a variable-ratio four schedule (VR 4) for correct completion of the sequence. This schedule of reinforcement continued throughout the experiment except where noted. After the subject completed 10 correct two-member sequences in a row, with each correct response cued by a brightly lighted key, the first member was faded dark over 14 trials. With the first member dark, the second member was similarly faded. After the second member was faded, the third member was added to the end of the sequence. The third member was at first brightly illuminated, and was then faded dark over 14 trials. New members of the sequence continued to be added and faded, one member at a time. Each successive member was added only after the preceding members had been faded dark and the subject had completed two additional correct sequences in a row. At any point during the session only the two most recently added members of the sequence could be faded (an inherent apparatus limitation). The sequence was gradually lengthened and faded until the animal was pressing the keys in sequence, but with no lights as cues. After the lights had been faded dark, the serial position of the correct key was the only available cue.

If the subject pressed an incorrect key, the houselight was turned off and the next trial was postponed for at least 5 sec. Timeout con-

tinued until the animal had not pressed any key for 5 sec. After the timeout, the houselight came on and a new trial began at the beginning of the sequence. If the failed member had been in a fade mode, it was presented two steps brighter on the next trial. Errors on members not in the fade mode did not affect their subsequent illumination.

Each session continued until the subject had successfully learned a sequence of nine members or until one of two failure criteria had been reached. The criterion of mastery as each new sequence member was added was two consecutive correct trials with all keys in their fully faded (off) position. Thus, after the addition of a new member to the sequence, the minimum number of trials for mastery was 16, 14 required for fading, and two additional trials. Mastery of a complete nine-member sequence required at least 144 trials, plus the 10 at the start of the session before fading began. The failure criteria were: (1) 30 min without completion of a sequence (an error always reset the sequence back to the beginning), or (2) 60 min without the addition of a new member to the sequence. An animal could meet the 30-min failure criterion by continuing to respond but always making an error before it completed the sequence, or by ceasing to press the keys, or by a combination of errors and pauses. It could meet the 60-min criterion only if it completed two or more sequences but never succeeded in fading out the two most recently added members.

After a session ended, the animals always remained in the darkened chamber for at least 30 min before being returned to their home cages. Home-cage feeding was scheduled 60 min after each session. On days when the animals did not serve in the experiment they were fed 24 hr after the previous feeding. Sessions were separated by at least 48 hr, and different sequences were scheduled in successive sessions.

PRELIMINARY OBSERVATIONS OF STEREOTYPED ERRORS

Although the subjects often learned sequences up to nine members long, many sessions ended when the animals met the failure criterion of 30 min without completing a sequence. In meeting this criterion the animals continued to respond, but they characteristically pressed a wrong key at the first member

of the sequence, even though they had learned a longer sequence earlier in that session. As soon as the houselight came on, beginning a new trial, the animal would press one of the two incorrect keys and produce the 5-sec timeout; when the timeout ended, the animal would again press a wrong key, usually the same one as before. The session would continue this way for 30 min, the animal rarely progressing beyond the first member of the previously learned sequence.

Figure 1 contains four examples of this stereotyped error pattern. These examples, selected from many available, illustrate the generality of the phenomenon across subjects, key sequences, sequence lengths, and session durations. Each graph represents an animal's performance only after the last member of the sequence had been added; since this terminal point depended on the subject's performance, it varied from session to session. Session duration in these examples ranged from 40 to 120 min. Each point in Figure 1 shows that animal's last response on successive trials (all responses up to the final one had to be correct for the animal to proceed that far). Each sequence member is numbered consecutively on the ordinate, and is represented by three points, A, B, and C, which denote the three possible keys the animal might have pressed; the bold letter shows the correct key at each sequence member. Using Monkey R-30 as an example, one may read the graph as follows: the animal had learned a seven-member sequence, A, C, B, C, B, A, B, and on Trial 395 the eighth member (Key C correct) was added. On Trial 395, the animal completed the eight-member sequence correctly. On Trial 396, the animal progressed only as far as Member 2, where it pressed Key B instead of Key C. From Trials 402 to 457, the animal usually completed the sequence correctly, with occasional errors at Members 6, 7, 2, and 1. From Trial 458 to the end of the session, the animal never again progressed correctly through the whole eight-member sequence. In fact, after Trial 469 the animal never went beyond Member 2, and from Trial 495 to the end of the session it usually terminated each trial by pressing Keys C or B instead of the correct Key A at Member 1.

The graphs for Monkeys R-5, R-7, and R-19 represent essentially the same pattern of responding, although the stereotypy at the end

is perhaps even more striking. Monkey R-19 typically terminated the late trials of the session by pressing Key C at the first member, when Key B was correct; Monkey R-7 pressed Key C when Key A was correct; and Monkey R-5 usually pressed Key B when Key C was correct, although it switched to Key A at the very end of the session. (The omitted trials for Monkeys R-7 and R-19 were exactly the same as the trials immediately preceding and following the omissions.)

The occurrence of this stereotyped error pattern, in which the animal would press the same incorrect key on trial after trial, as soon as each new trial began, gave rise to the following experiments.

EXPERIMENTS 1A AND 1B

The consistency of the error behavior led to the suspicion that the error timeout was actually reinforcing errors—the behavior the timeout was designed to reduce in frequency. Stereotyped errors may actually have been reinforced by the removal of stimuli associated with the training procedure. Experiments 1A and 1B investigated this possibility with Monkeys R-7 and R-19 as subjects.

METHOD

Experiment 1A: Elimination of Timeout for all First-Member Errors

The first change in the basic procedure was to eliminate the timeout after stereotyped (first-member) errors began to appear regularly within a session. Fading and sequence-lengthening procedures were the same as before, except that the first member of the sequence remained fully bright at the start of each trial. This procedural change was necessary to signal the beginning of a new trial, since extinction of the houselight no longer preceded trial reset after first-member errors. Two sequences (Sequence 3: A, B, C, B, C, A, C, B, A and Sequence 4: A, C, B, C, B, A, B, C, A) were scheduled during alternate sessions. After the animals made 10 consecutive stereotyped errors, timeout no longer occurred after stereotyped errors, even though such errors continued to be followed by trial reset. Timeout, however, remained a consequence of errors that the animals made later in the sequence. This procedure continued for nine sessions.

Fig. 1. Limits to which the animals progressed in all trials after the addition of the last member of the sequence. The last response of each trial is plotted across trials. Bold letters on the ordinate show the correct key at each member of the sequence, and the sequence members are numbered consecutively.

Experiment 1B: Selective Elimination of Timeout

Since two wrong keys were available to the animal at each sequence member, it was possible to apply or eliminate the timeout selectively as a consequence of each of the possible wrong responses. In Experiment 1B, the timeout was applied selectively only to errors on the first member of the sequence. All errors at later members continued to produce the timeout, and trial reset continued to be a consequence of all errors, even at the first member.

The same two sequences used in Experiment 1A were again scheduled during alternate sessions; both had Key A correct on the first member. The experiment proceeded in five stages. First, baseline data were obtained with the correct key of the first-member fully bright, and with the timeout and reset contingencies present as usual for all errors. Then, timeout was eliminated as a consequence of incorrect presses of Key C on the first member, when Key A was actually correct. That is to say, at the first member the animal could produce the timeout only by pressing Key B in error. After several sessions, the timeout contingencies were reversed; first-member errors on Key B no longer produced timeout, but errors on Key C did. After several more sessions, timeout was removed as a consequence of all first-member errors, whether Key B or Key C. The final change was a return to the original baseline contingencies, in which all errors produced the 5-sec timeout.

RESULTS

Experiment 1A

Both monkeys developed stereotyped errors as usual, pressing an incorrect key and producing the timeout even though the correct first member of the sequence was always a bright key. When the timeout no longer occurred as a consequence of stereotyped errors, the animals at first continued to press a wrong key at the first member, usually in a rapid burst. Then, they began occasionally to press the correct key at the first member and to make errors on later members instead. The major behavioral change, however, was the eventual occurrence of long pauses. Instead of pressing a wrong key, the animals simply stopped responding.

In Figure 2, the occurrence of long pauses is reflected in marked decreases in the rate of trial completions. A comparison of curves A, B, and C, the last three sessions in which timeout was eliminated, with curves D, E, and F, the three sessions preceding elimination of the timeout, illustrates the behavioral change. Stereotyped errors ceased when they were no longer followed by timeout, and were replaced by pauses, which had rarely occurred before.

Experiment 1B

During baseline (Figure 3, phase 1), Monkey R-7 developed a marked preference for Key C errors on the first member, but Monkey R-19 distributed its errors nearly evenly between the two incorrect keys. The first-member error percentages sum nearly to 100, indicating that the animals rarely made errors at later sequence members. When Key C errors no longer produced the timeout (phase 2), both animals decreased the percentage of Key C errors on the first member and increased the percentage of Key B errors. This relation reversed when timeout was eliminated as a consequence of Key B errors and was reinstated for Key C errors (phase 3). During these alterations of the timeout contingency, the frequency of errors at later sequence members remained low and unchanged. When timeout no longer occurred after either type of first-member error (phase 4), the percentages of both Key B and Key C first-member errors declined. This was essentially a replication of Experiment 1A. The percentages as well as the absolute frequency of errors at other sequence members increased when timeout no longer followed first-member errors, and periods of no responding were interspersed among the errors. Finally (phase 5), reinstatement of the timeout for all errors roughly equalized the two types of first-member errors.

DISCUSSION

When one first-member error no longer produced timeout, the animals switched to the first-member error that did; when neither first-member error produced timeout, the animals made errors later in the sequence, and then ceased responding. The error-timeout contingency seemed actually to maintain the stereotyped error pattern.

Fig. 2. Cumulative trials for the last 40 min of six sessions for each subject. Solid vertical lines represent the beginning of stereotyped error responding, and broken vertical lines show where the error timeout was removed from the procedure.

Could the reinforcer for first-member errors have been session termination rather than the timeout? Two considerations argue against this possibility: first, the animals could have terminated the sessions just as quickly and with less effort by ceasing to respond; second, they could also have terminated the sessions by meeting the success criterion.

The first alternative, ceasing to respond, was rarely observed and was never sustained except when timeout as a consequence of first-member errors was eliminated. But perhaps the timeout acquired some reinforcing potency because a 30-min timeout always preceded the animals' return to their home cages, thereby giving errors greater immediate reinforcement than pausing could achieve. If this were so, however, one would have expected

elimination of the timeout for first-member errors to produce sustained second-member errors, rather than pauses. The emergence of stereotyped errors rather than pauses is a matter of some interest, and will receive attention in the general discussion.

The second alternative, meeting the success criterion, could have terminated the sessions even more quickly, and usually with fewer responses, than either pausing or making errors for 30 min. Although the animals occasionally did learn two nine-member sequences, this was not the usual finding. Perhaps the increasing complexity of the task as the sequence was lengthened made the success criterion unreasonably difficult for the animals, and they "chose" to make errors instead. Experiment 2 examined this possibility.

Fig. 3. Percentage of total errors plotted across sessions. Phases are both numbered and described along the abscissa.

EXPERIMENT 2

If the success criterion were indeed too stringent, causing the animals to make first-member errors in order to terminate the session, such errors might be eliminated by making the success criterion easier for the animals to attain. In Experiment 2, therefore, the task was simplified by eliminating the fading, so that the correct key at each sequence member was always cued by a bright light.

METHOD

Subjects were Monkeys R-7 and R-19. Sequence-lengthening procedures were the same as before, except that the correct key at successive members remained fully illuminated throughout each session. Sequence length was gradually increased in the same stepwise manner as before, with each step continuing for 16 trials in order to control approximately for the fading trials of the original procedure. Reinforcement was arranged on a VR 4 schedule for completion of the sequence, with a 5-sec timeout and trial reset contingent upon errors. Sequences 3 and 4 were presented alternately for three sessions each, with at least 48 hr between sessions. The subjects were not required to learn the serial position of the members, but merely to press the lighted keys one after the other. Sessions ended when the animals met the success criterion or one of the two failure criteria.

RESULTS

With all the correct keys fully bright, errors were less frequent than when keys had been faded dark, but they increased in frequency before becoming stereotyped. First-member errors occurred as usual and terminated each session. The records looked like those in Figure 1, and need not be repeated. The presence of the presumably less difficult, fully cued sequences did not prevent the occurrence of first-member errors.

DISCUSSION

The animals' repeated errors at the first member of the sequence, the member they had learned first and practised most during each sequence, were apparently reinforced by the timeout, independently of their role in bringing the sessions to an end. First-member errors predominated over both pausing and

successful performance even though the latter two forms of behavior would have terminated the sessions as quickly or more so, and even when successful performance could be achieved simply by pressing lighted keys.

When the correct keys were cued by lights, and the animals did not have to learn the serial sequences, the procedure reduced to a complex ratio schedule of reinforcement. Behavior that produced timeout from the opportunity to earn positive reinforcement has also been reported in connection with fixed-ratio schedules (Appel, 1963; Azrin, 1961; Thompson, 1964; Zimmerman and Ferster, 1964). The occurrence of such behavior in Experiment 2 suggests that the emergence of the timeout as a reinforcer was not dependent on the complexities imposed by the more "cognitive" aspects of the sequence-learning task—time-ordered sequences, multiple temporal and spatial cues, memory, *etc.* Apparently, variables that are neither more nor less complex than those inherent in ratio schedules of reinforcement need be invoked to clarify the emergence of stereotyped errors and their reinforcement by timeout even in the context of complex sequence learning.

EXPERIMENT 3

Stereotyped errors did not occur during the early part of each session but emerged as the sessions progressed. It seems reasonable to suppose that some variable or variables correlated with session duration increased the potency of reinforcement by timeout as compared to reinforcement by food. One clearly suspect factor is food satiation. The purpose of Experiment 3 was to examine this possibility.

METHOD

The subject was Monkey R-19. Sessions were scheduled as usual but with a 2-hr access to free-food pellets immediately preceding some sessions. During the free-food period, the animals' home cage food tray was kept filled with banana pellets. At no time during the 2-hr period was the tray empty of pellets. This free-feeding procedure was interspersed among regular sessions so that each of the two sequences could be arranged with and without prefeeding. The two sequences were the same ones that had been used in the

previous experiments, and the standard sequence lengthening and fading procedures prevailed throughout.

RESULTS

All sessions ended with either mastery or first-member errors. Sessions in which the animal had been prefed were always terminated by first-member errors. In one case, stereotyped errors appeared before the animal had received a food pellet. However, the animal did consume all the banana pellets that were delivered in the experimental chamber. The earlier appearance of stereotyped errors kept the animal from learning as many sequence members as it did without prefeeding. This may be observed in Figure 4. Satiation hastened the emergence of stereotyped errors. The continued delivery of food pellets during standard sessions may be presumed to have been at least partially responsible for the emerging dominance of timeout over food as a reinforcer.

EXPERIMENT 4

A second variable correlated with session duration was food-reinforcement density (re-

inforcements per response or reinforcements per minute). Although the average ratio of sequence completions per reinforcement remained constant throughout the session (4:1), the ratio of individual key presses per reinforcement increased as new members were added. Thus, for a two-member sequence, reinforcement was delivered on an average of once every eight correct responses; for a nine-member sequence, the average ratio was one reinforcer for every 36 correct responses. Furthermore, the ratio also increased when errors occurred; because of the error-reset contingency, all correct responses in the sequence containing the error had their contribution to completion of the ratio requirement cancelled. Since errors tended to increase as the sequence became longer, this factor also tended to reduce reinforcement density with the addition of new members to the sequence. As food pellets became more sparsely distributed, the reinforcing potency of food, relative to that of timeout, might be expected to decrease. The purpose of Experiment 4, therefore, was to examine the effect of reinforcement density on the occurrence of stereotyped errors.

Fig. 4. Total members learned for sequences 3 and 4 and without 2-hr prefeeding. Sessions in which prefeeding was scheduled are represented by the solid bars and those in which it was not scheduled are shown by the broken bars. The bars represent consecutive sessions.

METHOD

The subjects were Monkeys R-7 and R-19. Sessions were scheduled as usual but with reinforcement sometimes arranged on a VR 10 rather than a VR 4 schedule for correct completions. Reinforcement density was reduced by a factor of 2.5 with this change in the ratio requirement. Sequences 3 and 4 were presented during alternate sessions.

RESULTS

With reinforcement arranged on a VR-10 schedule, animals developed stereotyped error responding sooner and terminated the sessions without learning the nine-member sequence. In two instances Monkey R-19 developed stereotyped errors when the sequence consisted of two members, both cued by lights. Figure 5 shows the number of correct trials, or sequences completed, during consecutive training sessions. The reduction in reinforcement density caused stereotyped errors to appear

earlier in the session. It may be inferred that the reduction in reinforcement density that occurred in standard sessions as the sequence length increased also contributed to the emergence of first-member errors.

EXPERIMENT 5

Task difficulty has not yet been directly implicated as a determiner of stereotyped errors. Making the task easy by maintaining the key-lights as cues for correct responses did not prevent stereotyped errors (Experiment 2). In some experiments not described here, stereotyped errors were also found to predominate late in the session, even when the animals had to learn sequences only three members long. But the results of Experiment 4 provide a mechanism whereby task difficulty could play at least an indirect role. If the animals make many errors at a stage of the sequence-learning task that they find difficult, the errors will automatically reduce reinforcement

Fig. 5. Number of correct trials for sequences with reinforcement arranged on either a VR 10 (vertical stripes) or a VR 4 (diagonal stripes).

density, measured either as reinforcements per response or as reinforcements per minute. Experiment 5 examined this possibility by deliberately scheduling the extreme case of reinforcement density reduction—extinction.

The experiment made use of the phenomenon of “discriminated extinction”. If an animal is subjected repeatedly to alternating periods of reinforcement and extinction, it learns to discriminate the discontinuance of the reinforcement contingency, and extinction takes place more rapidly with successive exposures (Bullock and Smith, 1953; Perkins and Cacioppo, 1950; Wickens and Miles, 1954). In Experiment 5, the question being asked was: with repeated alternation of reinforcement and extinction for correct sequence completions, will the animals show discriminated extinction by ceasing to respond earlier, or by making stereotyped errors earlier?

METHOD

Subjects were Monkeys R-7 and R-19. Sequence lengthening and fading procedures were in effect in the standard manner throughout. Food pellets were delivered as usual for correct sequence completions (VR 4) until the animal had completed a predetermined number of sequences. Each session was thus divided into two phases: reinforcement in the first part of the session, followed by extinction for the remainder of the session. Sessions were ended by the animal's meeting the success or failure criteria.

RESULTS

After extinction began, the animals did not cease responding but instead, made stereotyped first-member errors. The number of unreinforced trials, correct and incorrect combined, between the time extinction started and the first occurrence of 10 consecutive first-member errors gradually decreased with repeated alternation of reinforcement and extinction periods. These results are shown in Figure 6.

When the animals reached a relatively stable level of discriminated extinction, the beginning of extinction was moved up to an earlier point in the session, after the animals had completed a smaller number of correct sequences. For Monkey R-7, extinction began after 400 instead of 500 correct sequence completions; for Monkey R-19, the change was

from 300 to 150 correct sequences. Figure 6 shows that the change temporarily disrupted the discrimination; the animals at first required more unreinforced trials to initiate stereotyped errors. This suggests that the discrimination was based not simply on the occurrence of unreinforced trials, but on some cue arising from the reinforcement phase as well, such as its duration or the number of pellets actually received.

The discrimination did reestablish itself, however, and the second part of the experiment actually constituted a replication of the first for both animals.

EXPERIMENT 6

The evidence presented so far suggests that the timeout became a more reinforcing consequence, relative to food, as the experimental sessions progressed. One might wonder what the function of the timeout was before stereotyped errors became predominant in each session. Did it function as an aversive consequence for errors and facilitate the learning of new sequences—the implicit assumption behind its inclusion in the procedure? Was it neutral? Or did it perhaps disrupt the animal's performance in some way even before it became a reinforcer for first-member errors? Experiment 6 sought to answer the following question: will the animals learn longer sequences when the timeout contingency is scheduled than when it is not?

METHOD

Four sequences were used that Monkeys R-7 and R-19 had never seen. The orders of correct keys in these sequences were: Sequence 1: (B, C, A, C, A, B, A, C, B); Sequence 2: (B, A, C, A, C, B, C, A, B); Sequence 5: (C, B, A, B, C, A, C, A, B); and Sequence 6: (C, A, B, A, C, B, C, B, A). The order of presentation of the sequences was as follows with + indicating timeout and – indicating absence of timeout: 1–, 2+, 1+, 2–, 5–, 6+, 5+, 6–. The standard training procedure prevailed throughout.

RESULTS

The results are summarized in Figure 7. Subjects either completed the nine-member sequence successfully or met one of the two fail-

Fig. 6. Increasingly rapid onset of stereotyped errors with repeated extinction periods. The number of correct sequences (C.S.) before extinction began in each session is indicated beneath each graph.

ure criteria. The timeout contingency did not facilitate the acquisition of new sequences; in fact, for R-7 the contingency appeared to be detrimental. For three of the four sequences,

R-7 learned nine members when the timeout contingency was not scheduled. The results for R-19 do not demonstrate the superiority of either procedure.

Fig. 7. Number of members learned for sequences 1, 2, 5, and 6. Sessions in which the error timeout was scheduled are shown by bars with wide stripes and those in which the timeout contingency was not scheduled are represented by open bars.

DISCUSSION

The timeout apparently never did play its intended role, even before stereotyped errors appeared. Perhaps, by reducing reinforcement density, it even hastened the appearance of stereotyped errors and prevented the animals from learning new sequence members.

The possibility exists that a timeout longer than 5 sec might have facilitated sequence learning. Some preliminary experiments on this question, however, were not promising, and the inquiry was not rigorously pursued.

GENERAL DISCUSSION

Skinner (1953) defined self-control in terms of environmental manipulation. One arranges stimuli in one's own environment so as to set the occasion for the occurrence of desired behavior and for the nonoccurrence of undesired behavior. The reinforcements for such environmental manipulation are the changes in one's own tendencies to respond in certain ways. The phenomenon studied here derives

considerable interest from its resemblance to Skinner's formulation of self control.

By making stereotyped errors—repeated incorrect responses at the first member of a previously learned sequence—the animals removed the stimuli associated with the serial position task. A reasonable interpretation is that escape from the task itself and its associated stimuli was reinforcing. The finding becomes relevant to self-control as soon as one realizes that instead of producing periods of timeout, the animals could simply have stopped responding, as they did when stereotyped errors no longer initiated the timeout. One may draw the inference that production of the timeout served to remove stimuli that evoked undesired behavior; by making an error the animals removed the stimuli associated with the serial position task, and thereby eliminated their tendency to press the keys.

Why, when first-member errors no longer produced the timeout, did the animals cease responding instead of proceeding to the second member and making an error there that would have produced the timeout? One may

speculate that two consequences of such behavior would be in delicate opposition. In order to remove the exteroceptive stimuli, and thereby reduce its own tendency to proceed through the sequence, the animal would have to reinstitute a larger portion of that very chain of behavior.

Production of the timeout as a means of reducing the animals' own tendency to proceed through the serial position sequence seems directly analogous to the pausing that animals often initiate at the beginning of a fixed-ratio count. The beginning of the serial position sequence, like the beginning of a fixed-ratio count, exercises an unusually powerful suppressive function under certain conditions. Increasing satiation and decreasing reinforcement density hasten the appearance both of fixed-ratio pauses (Ferster and Skinner, 1957; Sidman and Stebbins, 1954) and of first-member errors in the serial position task. The analogy is enhanced by the experiments demonstrating that animals would respond to produce timeouts from fixed-ratio schedules of food reinforcement (Appel, 1963; Azrin, 1961; Thompson, 1964; Zimmerman and Ferster, 1964). With increasing reinforcement ratios, the animals produced increasing numbers of timeouts. As in the present experiment, they could simply have stopped responding. In a related experiment (Hearst and Sidman, 1961), rats could press one lever for food on a variable-interval schedule, and, concurrently, for shock on a fixed-ratio schedule. By pressing a second lever, the animals could produce a period of timeout during which the first lever was ineffective, *i.e.*, produced neither food nor shock. Even though the animals could simply have stopped pressing the first lever, some of them chose instead to remove the stimuli associated with the task.

Could first-member errors have been reinforced simply by stimulus change or novelty? These explanations seem more parsimonious than the appeal to self-control and escape mechanisms, but it is not clear that such parsimony is sufficient here. Stimulus change or novelty do not seem capable of explaining why the animals stopped responding instead of erring at the second member when first-member errors no longer produced the change of stimuli. Although the escape hypothesis also runs into trouble on this score, the behavior seems to require complex sources of

control that would diminish the utility of a stimulus change or novelty explanation.

The stereotyped error patterns observed in these experiments raise an interesting methodological consideration. The animals erred, with apparent deliberation, on the first sequence member, where they had previously performed correctly far beyond any ordinary learning criterion. Their errors did not represent learning failures. They were enhanced by reinforcer satiation and by decreasing reinforcement density. Clearly, subjects may err either because they do not know what to do or because they are averse, under the prevailing conditions of reinforcement and satiation, to doing what they perfectly well know how to do. It is probably worth considering the latter possibility in any instance in which a subject's performance deteriorates after a period of time, as in "forgetting", or after brain lesions or drug administrations that may diminish reinforcer effectiveness, or even after lengthy exposure to a rote task—sometimes referred to as boredom.

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