Disinhibition of delay in fixed-interval instrumental conditioning¹

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A novel stimulus (change of key color) was presented intermittently to three pigeons during discrete-trial FI performance. When the new stimulus was presented, the usual FI scallop disappeared and responding by the Ss was at a moderate, steady rate throughout the entire interval. The novel stimulus effect in FI performance is similar to "disinhibition of delay" in Pavlovian salivary conditioning. With extended training on the new key color, the FI scallop quickly reappeared. Testing with the former training stimulus then evoked the novel stimulus effect.

Inhibition of delay in classical conditioning is very similar to the response pattern observed during fixed-interval (FI) performance schedules in instrumental conditioning (Kimble, 1961). The concept of inhibition of delay (ID) was introduced by Pavlov (1927) to account for the observed tendency of the conditioned response (CR) to occur late in the interval between the presentation of the conditioned stimulus (CS) and the unconditioned stimulus (US). In the Pavlovian salivary conditioning situation it was noted that when the CS-US interval was short (on the order of a few seconds) the CR usually occurred immediately. But when presentation of the US was delayed, occurrence of the CR was also delayed. Pavlov (1927) reported several experiments employing a variety of stimuli as the CS in which presentation of the US was delayed for 3 min. After conditioning was well-established, the number of drops of saliva during successive 30-sec periods gradually increased. In a FI schedule of instrumental conditioning the S is rewarded for the first response after the termination of a designated period of time. The characteristic behavior found after training on a FI reinforcement schedule is the FI "scallop" (Ferster & Skinner, 1957). At the beginning of the time interval there is little or no responding, but as the end of the interval approaches, the probability of a response increases. Generally, the pattern of instrumental responses (key-pecks, lever-presses, etc.) during a FI schedule closely resembles the pattern of production of drops of saliva in Pavlov's long-delay conditioning paradigm.

According to Kimble (1961), one important test of whether the relationship between ID in classical conditioning and the FI scallop in instrumental conditioning is more than similarity in form depends upon whether the FI response pattern can be "disinhibited" as the ID effect in classical conditioning can be. Pavlov demonstrated that when a novel stimulus is introduced into a delayed conditioning situation the typical pattern of ID is disrupted. In the presence of a novel stimulus the number of drops of saliva was found to be approximately evenly distributed within the delay interval instead of increasing gradually; i.e., the distribution of CRs "flattens out" in the presence of the novel stimulus. Pavlov viewed the action of the novel stimulus as being twofold: disinhibitory in the initial, usually inactive, part of the interval, and inhibitory in the later, high response, part of the interval. The phenomenon was labeled disinhibition of delay (DID).

The question which Kimble (1961) poses and which is the subject of this investigation is whether DID, as an empirical phenomenon, can be demonstrated in FI instrumental conditioning. There are at least two reports which suggest that the DID effect may be found in FI behavior. In one case, when the size and shape of the response key were changed, the S's FI pattern of responding shifted abruptly (Ferster & Skinner, 1957, p. 319). However, the stimulus change was confounded with a change in the reinforcement schedule. Furthermore, the use of cumulative response recording does not permit detailed comparison with the Pavlovian situation. Flanagan & Webb (1964) attempted to find DID in a 1-min FI schedule by presenting probe stimuli (noise and vibratory) at various points in the interval. Disruption of the FI scallop was produced, but the results were not strictly comparable with the Pavlovian results. The use of a probe stimulus during only part of the interval differs from Pavlov's technique of concurrent presentation during the entire interval. The introduction of the probe early in the FI period did produce results which are similar

to Pavlov's (1927) response protocols, however. The present investigation seeks to demonstrate the existence of a DID effect in FI response patterns by presenting a novel stimulus during the entire FI period.

METHOD

The three Ss were experimentally naive, male, adult White Carneaux pigeons maintained at 80% of their ad lib body weights. The experimental chamber was a standard automatic operant conditioning pigeon box. The chamber contained a translucent circular response key 2.5-cm in diameter which could be illuminated by one of three colored light bulbs (white, red, or green) mounted behind the key. The box was dimly lighted by a small house light in addition to the key light. Food reward could be provided by raising a grain hopper into position for 3 sec. Continuous Gaussian noise was presented through a 3-in. speaker in the chamber to mask any potentially disturbing external sounds. The number of responses made during each successive 5-sec period was recorded on a print-out counter.

After adaptation to the experimental chamber and to eating from the food hopper, the Ss were shaped to key-pecking. Approximately 30-40 key-peck responses were rewarded by presentation of the food hopper before any delay was introduced. Then the Ss were rapidly transferred to a 1-min fixed-interval (FI-1) schedule. The transfer to FI-1 was accomplished within a single session by increasing the delay between rewards by 5 sec after every second reward. Every reward was followed by a 5-sec time-out (TO) during which period the box was completely blacked out and the response key was inactive. The 5-sec TO began the next FI-1 period and was followed by the onset of the house light and the key light for 55-sec. After being transferred to the FI-1 schedule, the birds were given extended FI-1 training. Each daily session consisted of 60 FI-1 trials. Each pigeon was initially trained on a different key color. For S-1, the key color was white, for S-2, red; and for S-3, green.

The experiment was carried out in three stages. Each stage was separated by several sessions of uninterrupted FI-1 training. Stage 1 was initiated after the FI scallop was well-developed and relatively stable. During each of four consecutive sessions, six test trials were presented randomly during the last 50 trials of each session with the limitation that at least five nontest trials had to intervene between successive tests. Only one change was introduced on a test trial: the key color was changed. The FI schedule was maintained; food was made available on the first response after 1 min. The stimulus change was made during the 5-sec TO so that when the TO ended the new key color came on and stayed on for the entire 55 sec remaining in the FI-1 period. Then the key light was changed back to the original color during the succeeding TO. For S-1, the test color was red; for S-2, green; and for S-3, white.

Following the four days of testing in Stage 1, three sessions of FI-1 training on the original color were conducted before beginning Stage 2. On the fourth day after Stage 1, a permanent key-color was introduced. The first 20 FI-1 trials were conducted with the original color. On Trial 21, the light was changed to the test color and was left there.

After changing to the new key color in Stage 2, the birds were given 10 sessions of FI-1 training on the new color. Then (Stage 3) tests with the original training color were conducted, following the same test procedure as in Stage 1.

RESULTS AND DISCUSSION

The responses of the Ss to presentations of the novel stimulus during the 24 spaced test trials are shown in Fig. 1. As a control for the usual FI-1 behavior in terms of both mean performance and variability, the test condition in Fig. 1 is compared with performance on the FI-1 trials immediately preceding each of the 24 test trials. On the trial before the test, typical FI behavior was evident: a post-reinforcement pause, followed by a gradual increase in the mean number of responses during the 11 successive post-TO 5-sec intervals. Presentations of a novel stimulus on the test trials produced a marked, abrupt, consistent change in performance for all Ss. When the key color was changed, the immediate reaction of the Ss was a moderate, steady rate of responding maintained throughout the 55-sec test period. This pattern of responding was usually observed for individual response protocols as well as for the averaged data. Even with only three Ss the interaction between conditions (test or training) and interval (the 11 successive 5-sec periods) yielded a highly significant effect, $F(10,20) = 15.33$, $p < .001$. After the test trial, when the response key was changed back to its original color, the birds immediately reverted to their usual FI behavior.

Fig. 1. Fixed-interval response patterns with and without novel stimuli (change in key color). Each test and FI comparison point consists of 24 spaced trials.

The results of Stage 1 demonstrate that the response to the novel stimulus can be maintained for several trials when the test trials are spaced. The purpose of Stage 2 was to explore the reaction to a novel stimulus within the FI-1 period when the shift to the new key color was permanent. The immediate reaction to the re-introduction of the new key color was as it was in Stage 1: uniform responding at an intermediate rate. Now, however, with repeated presentations of the new key color, the response pattern quickly shifted toward the FI scallop found before the change in key color. The first part of the FI response pattern to recover after disruption by a novel stimulus was the pause in responding early in the FI scallop. Succeeding trials showed further recovery of the FI scallop including enhancement of the response rate late in the interval. Performance on the new key color was virtually identical to the original FI performance after approximately 15-20 trials.

In Stage 3 tests were conducted with the original training stimulus. Once again, the FI scallop was disrupted by the introduction of a different key color, even though the color had been experienced on many trials before (Fig. 2). With this new stage of testing, however, several differences are apparent. The "flattening" effect was more temporary: the Ss adjusted to the new situation more rapidly and the FI scallop reappeared within 15-20 trials. The interaction between Stage (1 vs 3) and Test Trial (Tests 1-6) supports this contention, $F(5,10) = 3.75$, $p < .05$. Consequently, the response pattern shown in Fig. 2 is averaged over only 12 test trials. Even within 12 trials, however, the results for S-3 showed the beginnings of a shift toward the FI scallop. Also, the total number of responses emitted during tests were higher in Stage 3 than in Stage 1 during the first six tests, $F(1,2) = 28.56$, $p < .05$. In fact, S-2 at all points except the first produced more responses than the maximum mean rate during the control FI-1 period. However, the higher rate of responding during Stage 3 tests quickly disappeared so that after 12 tests the difference is not significant, $F(1,2) = 8.64$. The interaction

Fig. 2. Fixed-interval response patterns after training on the new key color. The test color is the original training stimulus. Each test and FI comparison point is based on 12 spaced trials.

between trial and stage of testing remains significant, $F(11,22) = 3.94$, $p < .01$. These results suggest that the prior experience in Stages 1 and 2 with the "novel" stimulus in Stage 3 temporarily raises the level of responding as compared with Stage 1. The flat distribution of responses within the FI-1 period is maintained in both stages and the increased mean rate of responding quickly disappears.

The "flattening" of the response distribution function in a FI schedule as a result of a simple change in the key color is a surprising effect. The usual result of a novel stimulus is a temporary suppression of the response rate (Ferster & Skinner, 1957). In the FI schedule, however, the presentation of a novel stimulus interrupts the well-learned pattern of responding and produces a strikingly different response pattern including an increase in response rate early in the interval. The results are in accord with expectations derived from the analogous Pavlovian conditioning, but the functional relationships between the Pavlovian delayed conditioning paradigm and the FI operant schedule remain unclear.

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