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ENHANCEMENT OF CONDITIONED REINFORCEMENT BY UNCERTAINTY[1]

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Pigeons were trained in three conditions. In the baseline condition, the birds responded on a fixed-interval schedule with the response key white. When the interval was completed, the key turned either red or green for a delay interval that was terminated by a grain presentation dependent on no key pecks during the final 2 sec. In the uncertainty condition, no grain was presented at the end of the delay periods when the key was red. In the certainty condition, the white light appeared only on occasions when pecking would turn the key green and produce food. Otherwise, the key was illuminated red throughout the total time period. The highest response rate in white occurred in the uncertainty condition, the next highest in the certainty condition, and the lowest in baseline. The results suggest that uncertainty facilitated responding, although uncertainty is not a necessary condition for conditioned reinforcement.

Key words: uncertainty reduction, information, conditioned reinforcement, chain schedules, pigeons

Kendall (1973*b*) and Wilton and Clements (1971) showed that pigeons peck at a higher rate in the initial member of a chain schedule in which reinforcement is delivered in half, rather than all, of the terminal links. This finding is obtained when different stimuli are correlated with reinforcement and nonreinforcement in the terminal links. In another experiment (Kendall, 1974*a*), pecking one key produced one of two colors and a delay period. Reinforcement followed half of the delays. A peck on a second key turned that key white for a delay period, and food was delivered following the delay. The pigeons pecked more often at the key that produced intermittent reinforcement if the stimuli during the delay were correlated with reinforcement and nonreinforcement, *i.e.*, when they provided differential information. Without correlated stimuli, they pecked more often at the key that produced the white light and delayed reinforcement.

Kendall (1974*a*) interpreted these data in terms of an hypothesis about conditioned reinforcement. According to this hypothesis, the more time spent in stimuli correlated with nonreinforcement, the more conditioned reinforcer value is enhanced. This hypothesis, developed from Notterman (1950), predicts that the enhancement of conditioned reinforcement by intermittent reinforcement in the Kendall (1973*b*) and Wilton and Clements (1971) experiments may be duplicated in a situation where there is no uncertainty reduction by differential stimulus presentation.

METHOD

Subjects

Four female White Carneaux pigeons, which had experience in an experiment on concurrent chain schedules, served.

Apparatus

A Lehigh Valley Electronics two-key pigeon chamber was used with the right key covered. The chamber was 32 cm long, 36 cm high, and 35 cm wide. The 2.5-cm diameter left key was 26 cm from the floor and 8.5 cm from the center of the panel; it was operated by a force of approximately 0.15 N. The lower edge of the feeder aperature (6 by 5 cm) was 11 cm from the floor. The response key could be transilluminated by white, red, or green. White noise in the room masked extraneous noises. Scheduling was accomplished with electromechanical circuitry.

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Procedure

Baseline. A two-component chained schedule was the baseline condition. Two different stimuli, red and green, were associated with the terminal link. The first link was a fixed-interval schedule of 12 sec (FI 12-sec), during which the key was white. When the interval had timed out, the next response produced either red or green. Each color appeared 50% of the time in an unpredictable sequence. A 20-sec delay interval was in effect during either color. In either color, food delivery depended on the absence of a key peck during the final 2 sec of the delay interval. Each peck during the final 2 sec added another 2 sec to the delay period. Pecks during the delay before the final 2 sec had no scheduled consequences. During the 3.5-sec grain presentations, all lights were off except the hopper light.

Uncertainty. In this procedure, no food was presented when the terminal-link stimulus was red. Instead, there was a 3.5-sec blackout. Food was presented following green. The condition is designated uncertainty, because pecks during the initial link of the chain produced either a stimulus correlated with food (green) or a stimulus correlated with blackout (red).

Certainty. The chain was the same as in previous conditions when the delay stimulus was green. However, when pecks would have led to red and a subsequent blackout, the red light appeared throughout. Red was present for 32 sec and was followed by a 3.5-sec blackout. Responding during this 32-sec period had no scheduled consequences except to postpone the blackout for 2 sec if the peck fell in the last 2 sec of the interval. This condition is called certainty because pecking at white always produced green followed by food.

All pigeons initially had the baseline condition. Birds 1 and 2 had the sequence baseline, certainty, uncertainty, certainty, and baseline; Birds 3 and 4 had the sequence baseline, uncertainty, certainty, uncertainty, and baseline. Each condition lasted for at least 20 sessions, except the final baseline condition, which lasted 15 sessions. When the birds had been exposed to a condition for 20 sessions, the daily response rates were inspected for any consistent increasing or decreasing trend in response rates across the last several sessions. If there was, the birds were continued on that condition until it appeared to the experimenter that the rates showed no trend.

RESULTS

Means and ranges of the last four sessions under a given condition are presented in Figure 1. The bars are arranged according to the sequence of conditions. In the baseline and uncertainty conditions, the birds responded in white when either green or red was the consequence, and the rate presented is the total number of responses to white divided by total time in white. In the certainty condition, the birds responded in white only preceding green; this is the rate presented. In the certainty condition, the key was illuminated red for the time that it would have been white in either of the other two conditions. Since the birds rarely responded in this period, these data do not appear in the figure.

The lowest response rates in white appeared in the baseline conditions. Higher rates in the uncertainty condition were consistent with the data of Kendall (1973*b*) and Wilton and Clements (1971). Response rates in the uncertainty condition typically were higher than in the certainty condition. For Bird 4, a change from uncertainty to certainty produced no decline, but a return to the uncertainty condition produced an increase in rate. For Birds 1 and 2, rates in the certainty condition following uncertainty were not as low as when certainty preceded uncertainty. For Bird 3, the uncertainty response rate following certainty was not as high as the uncertainty response rate preceding certainty. Thus, there was some failure to recapture the response rate that occurred before a change from certainty to uncertainty and *vice versa.* This is also reflected in the overlapping ranges. A within-subjects two-tailed *t*-test comparing the uncertainty and certainty rates reached significance ($t = 4.17$, $df = 3$, $p < 0.05$). It was not deemed necessary to compare baseline rates with either certainty or uncertainty by a statistical test because the difference between the means was quite substantial, with no overlap in the ranges.

DISCUSSION

One explanation of the difference between the baseline and certainty conditions is that the higher rates in the certainty condition were due to the omission of reinforcement at the end of half of the terminal members of the

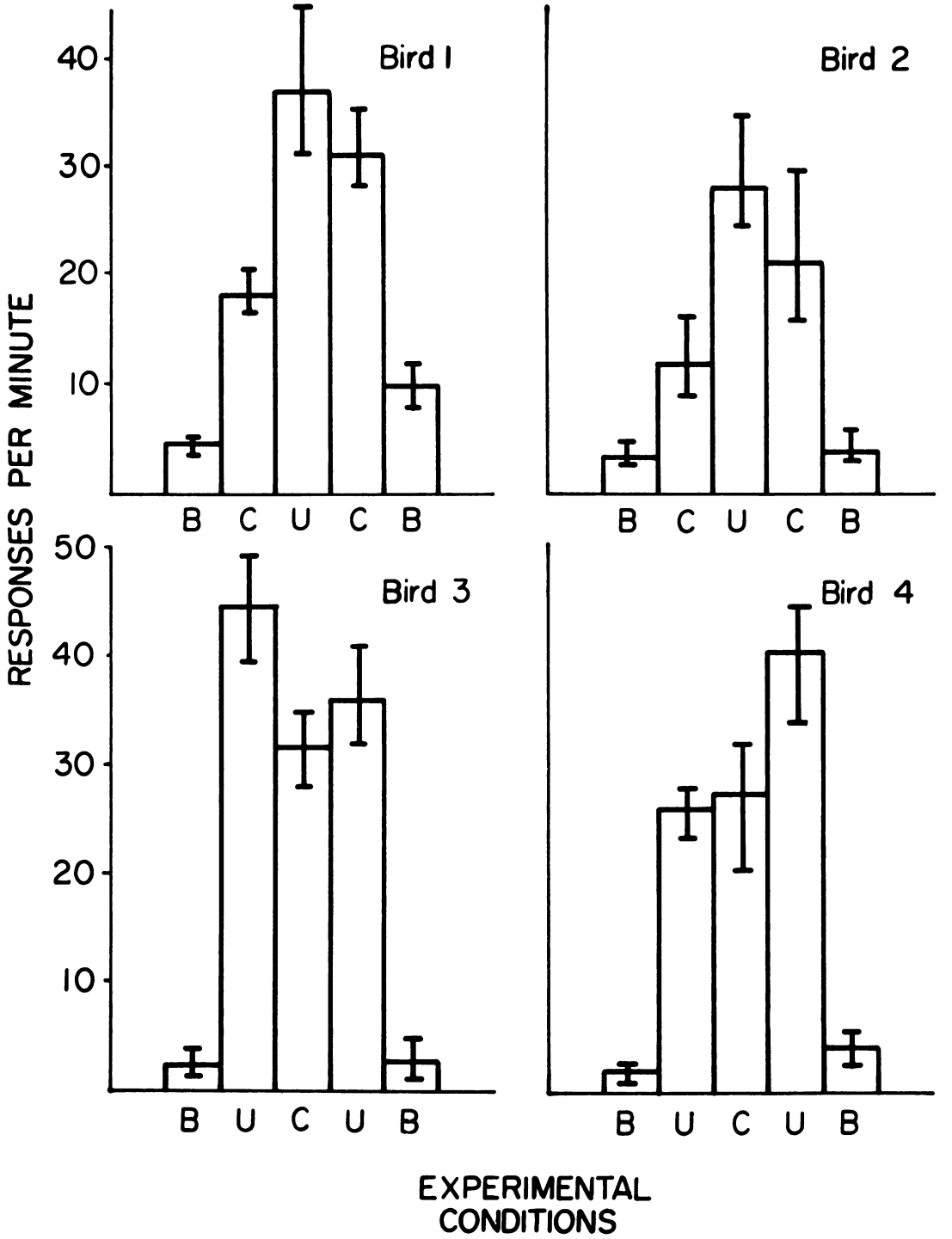

Fig. 1. Response rates in the initial member of the chain (white) for each subject under each condition. "B" stands for baseline; "C" for certainty and "U" for uncertainty. The bars are displayed in the order in which the bird underwent the sequence of experimental conditions.

chains. This explanation would also account for part of the difference between the baseline condition and the uncertainty condition, but would not apply to the difference between the certainty and uncertainty conditions. Staddon and Innis (1969) found that substituting a timeout for reinforcement at the end of some fixed-interval elevated the response rates in the subsequent interval. No data from the present experiment would refute this interpretation, but other experiments have shown that the response rates in the initial members of chains are a function of the degree of correlation between the terminal member stimuli and reinforcement or timeout (Kendall, 1973*b*; Wilton and Clements, 1971). Wilton and Clements showed that when the stimuli were entirely uncorrelated with reinforcement and timeout there was little difference in response rates between chains that always terminated in food and chains that terminated in food half of the time. In addition, Kendall (1973*b*) found that response rates were higher when each chain terminated in reinforcement when the terminal-link stimuli were not correlated with reinforcement and timeout.

Higher response rates in the certainty than in the baseline condition might be an instance of behavioral contrast (Reynolds, 1961). In a multiple schedule, withdrawing reinforcement in one component increases response rate in another component. In the certainty condition, one component was altered from a chain to extinction and the rate in the white component preceding green increased. Although contrast has been found in chained schedules, the present finding is somewhat novel. Responding in the initial member of a chain schedule was increased. Previous data show that response rates in the terminal member of a chain were increased (Findley, 1962; Wilton and Gay, 1969).

Informational analyses of observing responses imply an initial state of uncertainty, which is reduced by the production of stimuli (Berlyne, 1960). The term "uncertainty" may simply refer to the fact that a given outcome has a probability less than 1.0 or, in addition, it may refer to an aversive motivational state that the animal seeks to reduce (Berlyne, 1960).

In whichever sense it is used, there are findings at variance with the hypothesis that uncertainty reduction is a necessary condition for maintaining observing responses. For instance, a pigeon may peck several times when each peck produces a brief stimulus correlated with the more favorable of two reinforcement schedules. Each peck after the first produces redundant information, because the schedule cannot change until the next food presentation (Kendall, 1969, 1971). In addition, pigeons may emit an observing response in the presence of a prior stimulus that is correlated with the reinforcement, *i.e.*, the information is present before the observing response is emitted (Kendall, 1973*a*). Thus, it appears that uncertainty may enhance behavior reinforced by conditioned reinforcers, but plays a relatively weak role.

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