OBSERVING RESPONSES AND INFORMATIVE STIMULI¹

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Pigeons were trained on a trial procedure. A trial began with the illumination of a pecking key by a white light. After a fixed interval, a key peck could turn the key to one of two equi-probable colors and produce a delayed trial outcome—an equi-probable occurrence of either reinforcement or nonreinforcement. After a trial, the key turned dark and the trial ended. The response could be made into an observing response by correlating the key colors with the outcomes. Response rates in the fixed interval then increased to a level greater than when the colors and outcomes were uncorrelated. In another phase, the response produced only the colors. The trial outcomes occurred some seconds after the fixed interval without a response being required. Correlating the colors with the outcomes again increased response rates. In a second experiment, a further condition was added in which reinforcement was the outcome on every trial. Response rates were lower than when there were equi-probable reinforcement and nonreinforcement outcomes with correlated colors, and about the same as when there were equi-probable outcomes with uncorrelated colors. The results suggest that stimuli providing information about the probability of reinforcement are themselves reinforcing.

Wykoff (1952) developed a procedure for studying observing responses. Trials were arranged so that at any time within a trial a pedal-pressing response could produce one of two equi-probable stimuli. Towards the end of a trial, a different response could produce one of two equi-probable outcomes—reinforcement or nonreinforcement. The stimuli could be correlated with the outcomes so that pedal pressing produced one stimulus when an outcome was to be reinforcement, and the other stimulus when the outcome was to be nonreinforcement. When the stimuli and outcomes were so correlated, the pedal-pressing response was called an observing response, and the rate of pedal pressing was then higher than when the stimuli and outcomes were uncorrelated.

In the present study, two experiments were conducted. The first showed that a modified form of Wykoff's procedure gives the same results; the second used this modified procedure to test Wykoff's explanation of observing responses. Wykoff's explanation is de-

scribed in the introduction to the second experiment.

EXPERIMENT 1

The occurrence of observing responses was first demonstrated under conditions quite similar to Wykoff's. On a fixed-interval (FI) schedule, a pecking response produced one of two equi-probable stimuli that could be correlated or uncorrelated with the outcomes of reinforcement and nonreinforcement. The outcomes were delivered without a response being required (rather than being contingent upon another response as they were in Wykoff's procedure). Next, the procedure was modified so that the outcomes were contingent upon the pecking response. Thus, unlike Wykoff's procedure, the response that produced the stimuli now also produced the outcomes; these occurred some seconds after the stimuli. In both conditions, response rates were measured both when the stimuli and outcomes were correlated and when they were uncorrelated.

METHOD

Subjects

Three adult homing pigeons were maintained at about 80% of their free-feeding weights. Each pigeon had previously been trained to key peck on a variety of variable-

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interval reinforcement schedules with horizontal and vertical lines illuminating the pecking key.

Apparatus

One sound-insulated operant conditioning chamber contained a translucent response key of 0.75 in. (19 mm) diameter that could be illuminated from behind by either a white, red, or green light. A grain magazine was centered below the key. Reinforcement consisted of a 3-sec exposure to a grain mixture. Sessions were arranged through relays and timers contained in an adjoining room.

Procedure

A bird was placed in the chamber, and 5 min later the onset of the houselights initiated a session. Simultaneously, a trial began with the illumination of the pecking key by a white light. The first peck to occur after 15 sec (FI 15-sec) changed the light to either red or green. The key remained illuminated until the end of a trial. *Independently of these events* an outcome automatically occurred 50 sec after the beginning of a trial, provided that no response occurred within the 5 sec immediately preceding the scheduling of the outcome. If such a response occurred, the outcome was delayed and continued to be delayed until no response occurred for 5 sec. This prevented a pecking response being immediately followed by an outcome. When the outcome was reinforcement, the food magazine was raised and a light illuminated the food. When the outcome was nonreinforcement, only the light came on. A Lehigh Valley probability generator, set to a value of 0.5 determined whether the outcome was to be reinforcement or nonreinforcement. A trial terminated with an outcome and the key then darkened for 60 sec, until the next trial. Sessions of 30 trials each were conducted every day.

Initially, the red and green keylights were correlated with the trial outcomes. Thus, the response that produced them was an observing response. For Birds 191G and 188G, an effective key peck turned the key red on reinforcement trials and green on nonreinforcement trials. For Bird 183G, the reverse applied. The stimuli and outcomes remained correlated until the rate of responding on the FI schedule was stable for 25 sessions. The birds were then run for 25 sessions with the colors and out-

comes uncorrelated. The colors, still produced equi-probably by key pecking, were now determined by a randomized schedule independently of the trial outcomes. Finally, there were 15 more sessions with the colors and outcomes correlated. The left-hand portion of Fig. 1 diagrams the arrangement of events in this first (outcome noncontingent) condition.

In a second condition, the trial outcomes were contingent upon FI responding. Thirty-five seconds after an effective key peck had produced either the red or green stimulus, an outcome occurred, provided that no response occurred within the last 5-sec before the outcome was to occur. If such a response occurred, the outcome was delayed, and continued to be delayed until no response occurred for 5 sec. As before, this prevented a pecking response being immediately followed by an outcome. The period of 35 sec between the FI response and the occurrence of the outcome was chosen so that a trial outcome would occur at approximately the same time as when the outcomes were not response contingent, given that an effective response occurred shortly after the completion of the FI 15-sec interval. Apart from the contingency of outcome, the procedure was as in the first condition. Twenty-five sessions with the colors and outcomes correlated were followed by 45 sessions with the colors and outcomes uncorrelated. The right-hand portion of Fig. 1 shows the arrangement of events in this second (outcome contingent) condition.

To finish the experiment, the outcomes were again made noncontingent. Thirty sessions with the colors and outcomes correlated were followed by an additional 25 sessions in which the colors and outcomes were uncorrelated.

RESULTS AND DISCUSSION

The three birds are not discussed individually because they produced similar data (Fig. 2). For each bird, there was no discriminable difference in the response rates between the condition in which the outcome was contingent and that in which it was noncontingent. In both conditions, response rates rose when the stimuli and outcomes were correlated and declined when they were uncorrelated. Thus, as in Wykoff's experiments, the conversion of a response into an observing response led to an increase in its emission, and this was demon-

Fig. 1. The arrangement of events in each condition. The letter R refers to a key-peck response.

Fig. 2. Rate of responding on the FI schedule as a function of food contingency and correlation of colored stimuli.

strated regardless of whether the response was required for the occurrence of the trial outcome.

When the stimuli and outcomes were uncorrelated in the noncontingent condition, response rates did not decline to a near-zero level, and probably not to an operant level. This suggests that responding was reinforced adventitiously, thereby accounting for pecking rates being no different in the contingent and noncontingent conditions. Adventitious conditioning by the primary reinforcer may occur in all observing-response experiments, for although an immediate reinforcement of pecking can be prevented, as in the present experiment, delayed reinforcement may always occur.

Visual observation of the birds showed a high frequency of pecking at the chamber wall after an FI response had produced a key color that signified the certainty or possibility of reinforcement. Such pecking continued until the occurrence of a trial outcome. The observations were not thorough enough to determine whether wall pecking differed between the various conditions and schedules.

EXPERIMENT 2

Wykoff (1959) accounts for the emission of observing responses by assuming that the strength of a conditioned reinforcer is a positively accelerated function of the frequency with which it is followed by reinforcement. Reinforcement always follows one of the stimuli produced by an observing response and never follows the other. Hence, the net reinforcing effect of the two stimuli is greater than if both are followed equally often by reinforcement and nonreinforcement. Thus, the critical operation in the observing-response experiment is the consistent pairing of a stimulus with reinforcement. If this is true, some further predictions can be made about a response that produces the two stimuli. When the stimuli are correlated with equiprobable outcomes, such that reinforcement always follows one stimulus and never the other, the response should not be stronger than when reinforcement always follows both stimuli (CRF schedule). And the response in this latter condition should be stronger than when the stimuli are uncorrelated with equiprobable outcomes, such that reinforcement follows both

stimuli intermittently. If these relations do not obtain, Wykoff's hypothesis would seem deficient, and a different account of observing responses might be suggested. In the present experiment, rates of responding on the correlated and uncorrelated schedules of Exp. 1 were compared to those obtained when reinforcement was the outcome on every trial (CRF).

In order to test Wykoff's hypothesis, in the manner described, it is necessary for the outcomes to be response contingent. When the outcomes are noncontingent the consequences of not responding differ between the three schedules. For instance, reinforcement occurs on half the trials for the schedules having equiprobable outcomes, and on all the trials for the CRF schedule. Under these circumstances, the occurrence of any difference in response rates is of little value in the evaluation of Wykoff's hypothesis. The result could be attributed to differences in the reinforcement of not responding, and an adequate test of the hypothesis must exclude this possibility. Wykoff's hypothesis concerns the reinforcement of responding and any result must unequivocally pertain to this. On the other hand, when the outcomes are response contingent, the events that follow not responding are the same for the three schedules. For instance, reinforcement follows equally often (never) on all of them. Hence, differences between response rates must result from differences in the consequences of responding, *i.e.*, to the reinforcing effects of the produced stimuli. Thus, Wykoff's hypothesis can be tested.

METHOD

Subjects

Four adult homing pigeons, 131Y, 103Y, 186G, and 199G, locally obtained and experimentally naive, were maintained at about 80% of their free-feeding weights.

Apparatus

The apparatus was the same as that used in Exp. I.

Procedure

The (contingent) procedure of Exp. 1 was used except in respects stated below. Each bird was trained to peck at the white key by an auto-key-peck training procedure (Brown and Jenkins, 1968). Daily sessions of 25 trials were

then conducted. The sequence of events within a session was generally the same as in Exp. 1, but at first, shorter time intervals were used within a trial so that each bird could adjust to the procedure. The birds' responses were initially reinforced on an FI 5-sec schedule, with a 6-sec interval between the effective response and the outcome (provided no further responses delayed the outcome by occurring within the preceding 5 sec). Over several sessions the FI was increased to 15 sec, and the interval between the response and the outcome to 35 sec. During these early sessions, key pecking was reinforced on every trial (CRF schedule). Four phases then followed, differentiated according to schedule. For Birds 103Y and 199G, the sequence of schedules was: equi-probable outcomes with correlated stimuli, CRF, equi-probable outcomes with uncorrelated stimuli, and equi-probable outcomes with correlated stimuli. When the outcomes were equi-probable and the stimuli were correlated, the red stimulus was correlated with reinforcement for Bird 103Y, while the green stimulus was so

correlated for Bird 199G. For the other two birds, 186G and 131Y, the sequence was CRF, equi-probable outcomes with correlated stimuli, equi-probable outcomes with uncorrelated stimuli, and CRF. When the reinforcement and nonreinforcement outcomes were equi-probable and the stimuli were correlated, the red stimulus was correlated with reinforcement for Bird 186G, while the green stimulus was so correlated for Bird 131Y. When the CRF schedule was in effect, each color was produced on half the trials, as when reinforcement and nonreinforcement was equi-probable. When response rates were stable for 25 sessions in the first phase, the subsequent phases were initiated. These consisted of 30 sessions each.

RESULTS

Because the birds behaved similarly (Fig. 3), they are not discussed individually. For each bird, the schedule consisting of equi-probable outcomes with correlated stimuli generated higher response rates than either the same schedule with uncorrelated stimuli or the

Fig. 3. Rate of responding on the FI schedule as a function of reinforcement frequency and correlation of colored stimuli. The headings "correlated" and "uncorrelated" apply to the conditions in which the outcome of reinforcement and nonreinforcement were equi-probable, and refer to the relation between those outcomes and the stimuli. The heading "CRF" refers to the condition in which reinforcement was always the outcome. (Note that Bird 131Y has a different ordinate scale on the graph representing its performance).

CRF schedule. The response rates on the latter two schedules were not noticeably different.

In some respects, the data are comparable with those obtained from Exp. 1. First, a main finding of Exp. 1 was replicated. When the outcomes were equi-probable, response rates were higher when the colors were correlated than when they were uncorrelated. Second, pecking at the chamber wall occurred when a color indicated the possibility of reinforcement, suggesting that the same behavior in Exp. 1 was not dependent on the birds in that experiment being non-naive. Third, under similar conditions, response rates in Exp. 2 were generally lower than in Exp. 1. Perhaps the extended key-pecking experience of the birds in Exp. 1 partially accounts for this. Good response topographies may have been acquired, and response rates might thereby have been increased.

DISCUSSION

Because the schedule with the equi-probable outcomes and the correlated stimuli produced higher response rates than the CRF schedule, and because the CRF schedule failed to produce higher rates than the schedule with equi-probable outcomes and uncorrelated stimuli, Wykoff's account of observing responses seems untenable. The preparatory response hypothesis of observing responses (Perkins, 1955; Prokasy, 1956) is also refuted by the present experiment. According to this hypothesis, food is most reinforcing when the stimulus preceding it elicits a classically conditioned salivary response. This enhances the reinforcing value of the food during consummation. Classical conditioning to a correlated stimulus occurs readily because food consistently follows. An uncorrelated stimulus also elicits salivation, but less readily because food follows it only intermittently. Thus, the reinforcing value of the food is not at a maximum, and it can be deduced that a response that produces correlated stimuli will be stronger than one producing uncorrelated stimuli. So, whenever possible, observing responses will occur. The present data pose essentially the same problem for this hypothesis as for Wykoff's. On the CRF schedule, both stimuli are always followed by food, and the salivary response should therefore be

as efficiently conditioned to them as to a correlated stimulus on a schedule with equi-probable outcomes. Hence, the latter schedule should not generate higher response rates than the CRF schedule, and the CRF schedule should generate higher response rates than a schedule having equi-probable outcomes with uncorrelated stimuli.

The present data, and those from other observing-response experiments are explained by the hypothesis that informative stimuli are reinforcing (Hendry, 1969). In the present experiment, the information content of the colored stimuli was not the same in the three conditions. When signalling an outcome with only the same probability as any stimulus present before it, a color was not informative (Garner, 1962). This happened both on the CRF schedule ($p = 1.0$), and on the schedule having equi-probable outcomes with uncorrelated stimuli ($p = 0.5$). On the other hand, a color was informative when the schedule was one of equi-probable outcomes with correlated stimuli. It signalled an outcome with a probability of 1.0, whereas any stimulus present before responding signalled it with a probability of 0.5. The highest response rates occurred on such a schedule, exactly what would be expected if information is reinforcing.

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