

EFFECTS OF TWO PROCEDURES FOR VARYING INFORMATION TRANSMISSION ON OBSERVING RESPONSES¹

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Two experiments were conducted with pigeons to examine the effects of procedures that varied information transmission on observing responses. The basic procedure for Experiment I was one in which a trial terminated in either non-contingent reinforcement or timeout. Pecking during a trial produced either green (positive) or red (negative) keylights. If no pecking occurred no differential stimuli appeared. The probability of positive trials was either 0.25, 0.50, or 0.75. Observing response rates and relative frequencies of occurrence were highest when the probability of positive trials was 0.25 and lowest at 0.75. In Experiment II, a modified chain procedure was used in which responding produced either red or green lights. Reinforcement or timeout followed light onset by 15 sec. The correlation between the stimuli and the event at the end of the trial (reinforcement or timeout) was varied. Reinforcement followed green 100%, 90%, 70%, or 50% of the time that green occurred. Since the overall probability of reinforcement remained at 0.50, reinforcement followed red in either 0%, 10%, 30%, or 50% of the time that it occurred. The rate of responses that produced these stimuli varied as a function of the correlation. The greater the probability of reinforcement after green, the higher the response rate.

In an observing response experiment, two schedules of reinforcement (or one schedule and extinction) are usually arranged to occur successively. The observing response produces discriminative stimuli associated with these schedules. For instance, if a fixed ratio is in effect, an observing response made during that time will produce a stimulus correlated with that schedule. A different stimulus would be produced if the observing response were made during the time when another schedule was in effect.

It is assumed by some writers that both of the stimuli in the observing response situation are conditioned reinforcers. Hendry (1969a) summarized this point of view and stated a general hypothesis of conditioned reinforcement, including observing responses. This hypothesis is called the "information hypothesis" by Hendry. It subsumes previous information hypotheses stated by Egger and Miller (1962, 1963) and Berlyne (1960). If the value of the

stimuli produced by the observing response is assumed to follow the quantitative rules specified by information theory (Attneave, 1959), then observing response strength should be maximal when the probability of either stimulus is 0.50.

A number of experiments have attempted to test this hypothesis. These include studies by Eckerman (1970), Hendry (1965, 1969b), McMichael, Lanzetta, and Driscoll (1967), McMillan (1970), and Wilton and Clements (1971). These studies are not all in agreement, but they suggest a trend. The studies by Hendry (1965), McMichael *et al.* (1967), McMillan (1970), and Wilton and Clements (1971b) all used a procedure in which one stimulus produced by the observing response was correlated with reinforcement and the other correlated with nonreinforcement. They all suggest that the strength of observing responses is greatest at some point where the probability of a stimulus correlated with reinforcement is less than 0.50. The data from the studies of Hendry (1969b) and Eckerman (1970) show very little effect of manipulating the probability of the schedules and their correlated stimuli.

In a recent study, Wilton and Clements (1971b) found that response rate was greater when the probability of the positive stimulus was 0.20 rather than 0.80. This study used a

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procedure different from some of the others in that the "observing response" not only served to produce the stimuli but was required to produce the reinforcer. There was not a non-observing response option. This procedure is similar to a chain schedule or delay of reinforcement procedure. In addition, the experiment did not include a probability of 0.50 for the positive stimulus so that it is not known whether response rate at this value would have exceeded the other values or been intermediate between them.

On other grounds, however, the procedure used by Wilton and Clements was superior to some of those previously reported. The experiments by McMillan (1970) and Hendry (1965) both used a procedure in which the observing response was being maintained concurrently with food behavior. It is possible that response competition from this behavior makes it impossible to assess accurately the strength of observing behavior (Kelleher, Riddle, and Cook, 1962; Kendall, 1965).

Experiment I employed a procedure somewhat similar to the one used by Wilton and Clements (1971*b*) except that there was a non-observing response option. In Experiment II, the correlation between the stimuli and reinforcement was altered but the probability of reinforcement remained the same throughout the experiment.

EXPERIMENT I

METHOD

Subjects

Of 11 pigeons used, Birds 1, 2, 3, and 4 had previously served in another observing response experiment using a similar procedure. These birds were female White Carneaux. Birds 9, 10, 11, and 12 were naive at the outset of this experiment. They were male Silver Kings. Birds 14 and 15 had served in another observing experiment using an identical basic procedure before participating in Experiment I. Bird 13 was trained for the other experiment but did not participate. These three birds were also male Silver Kings.

Apparatus

Two commercial (Lehigh Valley Electronics) pigeon chambers were used. The front panels contained two response keys, one of which

(the right) was covered by a piece of metal. Electromechanical scheduling and recording equipment was situated in an adjacent room. The room that contained the pigeon chamber was provided with a white masking noise.

Procedure

Birds 1, 2, 3, and 4 were placed in a situation in which there were 60 trials per session. A trial lasted for 32 sec unless a peck occurred during the final 2 sec, in which case it was prolonged for an additional 2 sec. Initially, half of the trials terminated in a 3-sec presentation of grain or a 3-sec period during which the houselight was turned off and no grain was presented (timeout). Immediately following a positive trial (ending in food) or a negative trial (ending in timeout), a new trial was initiated. The response key always remained dark unless six pecks occurred during a trial (FR 6). If the ratio was completed, the response key was illuminated by one of two colored lights, either red or green. If the trial was positive, green was presented; if it was negative, the color was red. Once a light was produced, it remained lit until the food or timeout occurred. Failure to complete the ratio in no way affected the outcome of the trial or any subsequent trial, but the key remained dark until trial termination, at which time the ratio counter was reset to zero.

Since the birds had previously served in another experiment using this procedure, only a small amount of special training was undertaken. Before being placed on the FR 6 schedule, the birds were trained for a few sessions on FR 1 followed by a few more at FR 3. This was followed by training at FR 6 for 15 sessions. Following training at FR 6 with half positive and half negative trials, the probability of a positive trial was altered for all birds. For Birds 1 and 3 the probability of a positive trial became 0.25; for Birds 6 and 8 it became 0.75. There were 15 sessions under the new condition.

The procedure for Birds 9, 10, 11, and 12 was basically the same as for the first four birds except that instead of producing the stimuli during a trial on a fixed-ratio schedule, a fixed-interval schedule was used. The fixed-interval (FI) schedule was FI 10-sec. The 10-sec interval began at the onset of a trial and the first response following the lapse of 10 sec produced either the red or green light on the key,

depending on the type of trial. A new interval was initiated on each trial, so that if no response had been emitted on a previous trial, the first response on the next trial would not produce a stimulus until 10 sec had elapsed.

Since the pigeons were naive they were not placed directly on this schedule, but received preliminary training. Briefly, the training consisted of key-peck training by successive approximation using food reinforcement. Following two or three reinforced pecks, the observing response procedure was introduced with 2-sec trials and an FR 1 response requirement. The duration of the trials was gradually increased over a period of three daily sessions. When the trial duration reached 32 sec, a 5-sec fixed-interval was introduced for one session. Following this, the birds were placed on FI 10-sec for 15 sessions with the probability of positive and negative trials each being 0.50. Birds 9 and 10 were switched to the 0.25 condition and Birds 11 and 12 to the 0.75 condition after the training at 0.50. Each bird was given 15 sessions at the new condition.

Birds 13, 14, and 15 were run on a procedure identical to that of Birds 1 through 4 with these exceptions: the duration of positive trials was 30 sec and the duration of negative trials was 15 sec. Birds 13 and 14 had been used in a previous experiment so that no preliminary training was necessary. Bird 13 had been trained to participate in that experiment but due to difficulties of maintaining its observing behavior, it did not serve. It was placed on an FR 2 observing response requirement and trained with the stimulus durations given above for this experiment. All birds were given at least 15 sessions of training with the probability of a positive trial at 0.50 with the stimulus durations given above. Birds 14 and 15 were trained with FR 6 and Bird 13 with FR 2. Following these sessions, Birds 13 and 14 were switched to the 0.75 condition and Bird 15 to the 0.25 condition. All birds were given at least 15 sessions on these new values and then Birds 13 and 14 were switched to the 0.25 condition while Bird 15 was switched to the 0.75 condition.

RESULTS

The results for Birds 1, 2, 3, and 4 may be seen in Figure 1. Both relative frequency and response rate measures were taken. Relative frequency is the proportion of trials on which

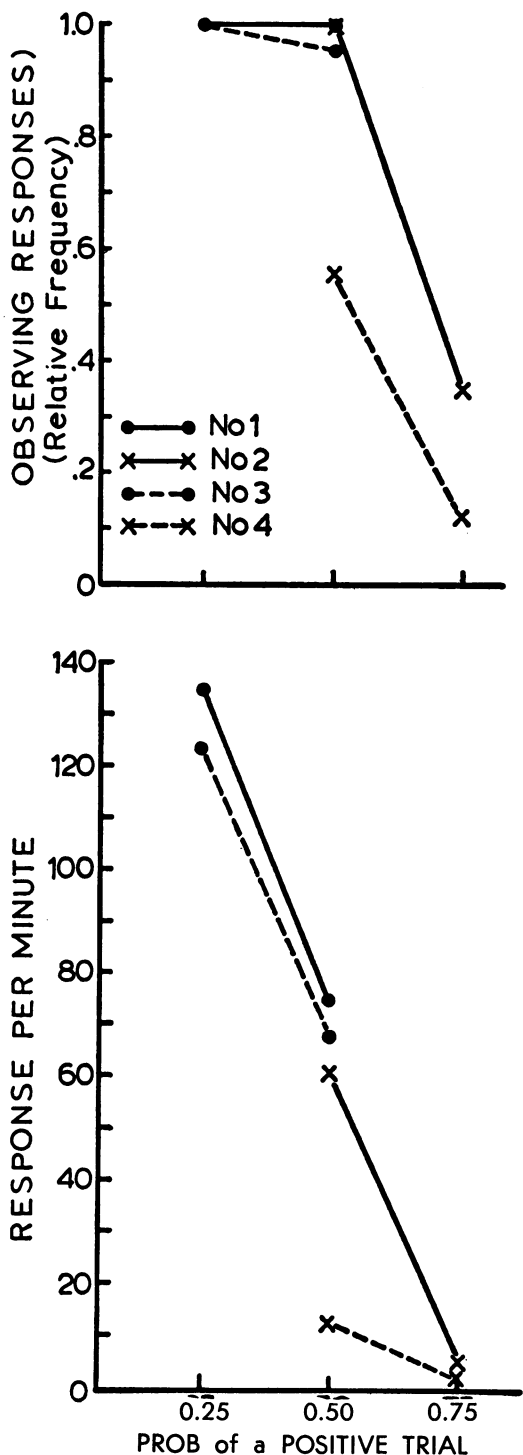


Fig. 1. Relative frequency (top panel) and rate (bottom panel) of observing responses as a function of the probability of a positive trial for Birds 1, 2, 3, and 4. Relative frequency is the number of observing responses divided by the number of trials.

the FR 6 was completed and a stimulus produced. The time spent in the presence of red or green was not included in response rate calculations. All data are averages over the last four sessions of a given condition. Relative frequency data are shown in the top panel and response rates are shown in the lower panel.

Birds, 1, 2, and 3 were completing the observing response requirement on about every trial when the probability of a positive trial was 0.50. Bird 4 was completing the requirement on only about half of the trials. The relative frequency of observing responses for Birds 1 and 3 remained about the same when they were changed to the 0.25 condition. The response rate increased, however, suggesting that observing responses were strengthened. The relative frequency for Birds 2 and 4 decreased when they were changed to the 0.75 condition. The response rates for both birds decreased.

The results for Birds 9, 10, 11, and 12 may be seen in Figure 2. These birds were on a fixed-interval schedule and the data presented are response rates. The rate is based on only the time from the onset of a trial until a stimulus was presented. The probability of completing the observing response requirement and producing a stimulus is not presented for these birds because there were few instances of failure to complete the interval requirement.

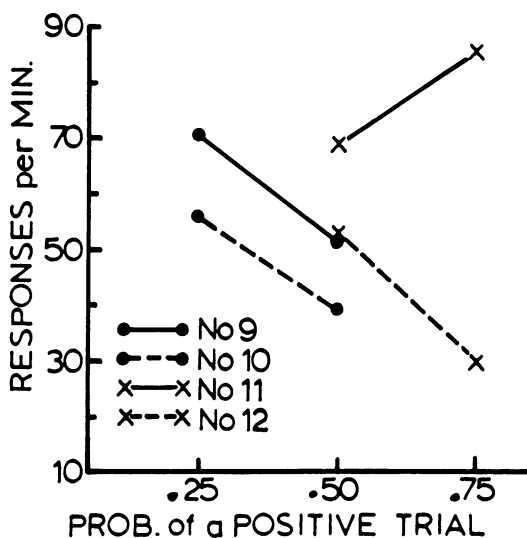


Fig. 2. Rate of responding in responses per minute for Birds 9, 10, 11, and 12 as a function of the probability of a positive trial.

The response rates of Birds 9 and 10 increased when they were switched from the 0.50 to the 0.25 condition. The results were not consistent for the other two birds, which were switched to 0.75. The response rate for Bird 11 increased and the rate for Bird 12 decreased.

The data for Birds 13, 14, and 15 are presented in Figure 3. Again, both relative frequency and response rate measures were taken. The reason for using unequal trial durations is that the relative frequency of observing responses was decreased somewhat by having shorter negative trials in the 0.50 condition. This permits the relative frequency of observing responses to increase when conditions are altered. For Birds 14 and 15, the two on FR 6, the relative frequency did increase somewhat in the 0.25 condition and decreased in the 0.75 condition. These manipulations did not affect the relative frequency of observing responses for Bird 13, however, which was on FR 2. Although an FR 6 is not large when maintained by food, previous experience with this procedure has shown that observing responses are hard to maintain with ratios much larger than FR 6. Ratios of this size may therefore be much more sensitive to manipulations than the FR 2 used with Bird 13.

The response rates for these are consistent with the trend of the previous data. The rates are highest at the 0.25 condition and lowest in the 0.75 condition.

In general, these data show that observing responses are strongest when the probability of positive trials is 0.25, intermediate at 0.50, and lowest at 0.75. One outstanding inconsistency is the data from a bird in the fixed-interval condition whose rate increased when switched from the 0.50 to the 0.75 condition.

EXPERIMENT II

Experiment I showed that altering the probability of positive trials affected the strength of observing responses. The data are consistent with findings by Hendry (1965), McMichael *et al.* (1967), McMillan (1970), and Wilton and Clements (1971*b*). In changing the amount of information transmitted by the procedures employed in Experiment I, however, other variables are also altered. The probability of reinforcement for a given trial is changed and the probability of either stimulus is also altered. These changes are in-

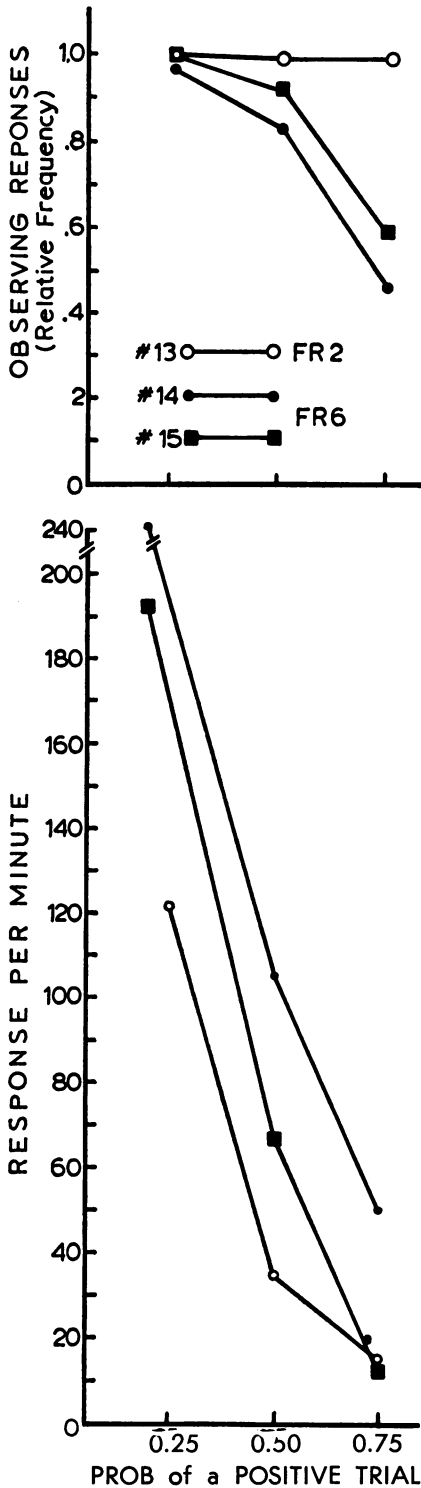


Fig. 3. Relative frequency (top panel) and rate (bottom panel) of observing responses as a function of the probability of a positive trial for Birds 13, 14, and 15.

evitable in using this procedure, but the overall amount of information transmitted by the stimuli can be altered without changing anything but the extent to which the stimuli are correlated with reinforcement or timeout. A zero correlation between the stimuli produced by the observing response and reinforcement is sometimes used as a control procedure in the observing response experiment (Wyckoff, 1969). A zero correlation is only one point on a continuum of correlation between the stimuli and reinforcement, however. A zero correlation is produced by arranging for reinforcement to occur with the same probability in the presence of either stimulus. In this condition, zero bits of information about reinforcement is transmitted by the stimulus since reinforcement is not predictable from knowledge of the stimulus. In the 0.50 condition of Experiment I, one bit of information is transmitted by the stimulus. In Experiment II, two other points on this continuum were studied.

METHOD

Subjects

Three female White Carneaux pigeons, which had served in a previous observing response experiment, were designated II-1, II-2, and II-3.

Apparatus

The outer shell of the pigeon chamber was constructed from half-inch particle board. The chamber containing the bird was a cube 31 cm (12-in.) on a side. The front wall contained an intelligence panel with two keys, a house-light and an aperture for the bird to obtain grain when the hopper was raised. Only one of the two keys was used. This key was located 4 cm (1.75 in.) to the right of the midline and 21 cm (8 in.) from the floor. This key had been made some years previously and broke during the final part of the experiment. This precluded obtaining recovery in one of the conditions for Bird II-3. The key required a light force of about 7 to 10 g (0.07 to 0.10 N) for its operation. The experimental chamber was located in a room that was provided with white masking noise. Electromechanical scheduling and recording equipment was located in an adjacent room.

Procedure

The pigeons were trained to peck the dark response key in the box and then were given training with increasing fixed-ratio schedules until FR 10 was reached. Food was the reinforcer. When this was done, delays were added. The delay to the end of the trial was increased gradually to 15 sec. Reinforcement did not occur at the end of every trial, only half of them. The other half of the trials terminated in a 3.5-sec blackout. This was the same as the grain hopper duration. During this training, the stimulus during the delay interval was green if the trial terminated in reinforcement and red if the trial terminated in a blackout. Immediately following reinforcement or blackout, the houselight came on and the response key was dark. This signalled the onset of a new trial. The time from reinforcement or blackout until the next reinforcement or blackout constituted a trial. This procedure was different from that of Experiment I in that completion of the FR 10 was required for food delivery, which followed the delay.

The birds' behavior was allowed to stabilize in the condition described above, with all reinforcers delivered following the green delay signal and all blackouts following the red one. Then, the procedure was altered so that the bird received less than 100% of its total reinforcers following green. The rest were delivered following red. In turn, some of the green lights preceded blackouts. The conditions studied in this experiment included 90%, 70%, and 50% of the total reinforcers in green. The remainder (10%, 30%, or 50%) were delivered following red. These conditions are designated by the percentage of reinforcers delivered in green and called the 100% green condition,

90% green condition, *etc.* The percentage of reinforcers delivered following the two stimuli was the only variable changed in this part of the experiment. Reinforcers always occurred on half of the total trials. Eighty trials were given per session so that 40 reinforcers were delivered per session. Each bird went through the sequence of percentages of reinforcers delivered following green in a different order. Birds II-1 and II-2 were returned to the 100% green condition following exposure to the other conditions. Due to the breakdown of the response key, this was not possible for Bird II-3. Table I shows the sequence of conditions for each bird and the number of sessions each bird was exposed to that condition.

Following the procedures given above, Birds II-1 and II-2 were given further training in which reinforcement occurred on each trial, regardless of the color of the delay stimulus. This condition is called the 100% reinforcement condition, not to be confused with the 100% green, in which only 50% of the trials ended with reinforcement. The number of trials was decreased from 80 to 40 per session. Twenty sessions were given in this condition.

RESULTS

The results of Experiment II are shown in Figure 4. The response rate is plotted as a function of information in bits. The amount of information transmitted is calculated by the formula:

$$T_{(L,F)} = H_{(L)} + H_{(F)} - H_{(L,F)} \quad (1)$$

where $T_{(L,F)}$ stands for the information transmitted by the light about food; $H_{(L)}$ stands for the uncertainty of the light; $H_{(F)}$ the uncertainty of the food, and $H_{(L,F)}$ the uncertainty of the light/food combination. $H_{(L)}$

Table 1
Conditions, Number of Sessions, and Rate of Responding for Each Subject

| Bird II-1 | | | Bird II-2 | | | Bird II-3 | | |
|-------------|----------|--------------------|-------------|----------|--------------------|-----------|----------|--------------------|
| Condition | Sessions | Rate (Resp/min) | Condition | Sessions | Rate (Resp/min) | Condition | Sessions | Rate (Resp/min) |
| 100% Gr* | 20 | 73.76 | 100% Gr | 25 | 121.54 | 100% Gr | 20 | 99.72 |
| 90% Gr | 18 | 52.39 | 50% Gr | 15 | 41.23 | 70% Gr | 20 | 63.81 |
| 50% Gr | 24 | 43.45 | 70% Gr | 23 | 47.63 | 90% Gr | 29 | 77.68 |
| 70% Gr | 27 | 51.57 | 90% Gr | 26 | 69.73 | 50% Gr | 33 | 47.85 |
| 100% Gr | 20 | 84.72 | 100% Gr | 20 | 125.00 | | | |
| 100% reinf. | 20 | 61.61 | 100% reinf. | 20 | 52.56 | | | |

*Green

and $H_{(F)}$ are kept at 1 since $p(\text{red}) = p(\text{green}) = 0.50$ and $p(\text{food}) = p(\text{timeout}) = 0.50$. Both of these quantities are calculated by $\sum p_i \log 1/p_i$, where p_i equals the probabilities of red and green or food and timeout. $H_{(L,F)}$ is calculated by the same formula where p_i is equal to the joint probability of each light-food combination, *i.e.*, green-food, green-timeout, red-food and red-timeout. With all reinforcers occurring in green and none in red, one bit is transmitted. Where there is no correlation, zero bits

is transmitted. The other two values are 0.531 bits (90% green) and 0.119 bits (70% green).

The data plotted in Figure 4 are the average response rates for the last four sessions in a given condition. For both Birds II-1 and II-2, which were returned to the condition where all reinforcers were delivered in green, the average of the two values is plotted. These data are also given in Table I. For Birds II-1 and II-2, the response rate for the condition in which all delays were followed by reinforcement is plotted on the graph at zero bits of information by an "X". The reason for plotting this data point at zero bits is that the stimulus does not reduce uncertainty about whether reinforcement will follow the delay, since it always does.

The response rate is a function of the amount of information transmitted by the delay stimuli. Whether it is a linear function or not is not entirely clear from the data. The data of Bird II-2 most closely approximate a straight line. Both Birds II-1 and II-3 show a fairly sizeable increase in response rate between zero bits (50% in green) and 0.119 bits (70% in green). For Bird II-1, the response rate does not change much between 0.119 bits and 0.531 bits, but the response rate for Bird II-3 increases fairly substantially and is reasonably linear between 0.119 bits and 1.0 bits.

The response rates for the condition where all delays preceded reinforcement (100% reinforcement) are lower than the response rates for the 100% green condition (1.0 bit) but higher than the 50% green (0 bits) condition. This finding confirms earlier results of Wilton and Clements (1971a). It is difficult to tell whether the rate in the 50% green condition was lower than in the 100% reinforcement condition for some of their birds, however.

DISCUSSION

The results of Experiment I support the findings of Hendry (1965), McMichael *et al.* (1967), McMillan (1970), and Wilton and Clements (1971b). They do not support the results of Eckerman (1970) and Hendry (1969b). Eckerman found that observing behavior remained strong across a wide range of probabilities of the brief fixed-interval of a pair of fixed intervals. Hendry (1969b) found no change in observing behavior when the probability of a short fixed-ratio of a pair of

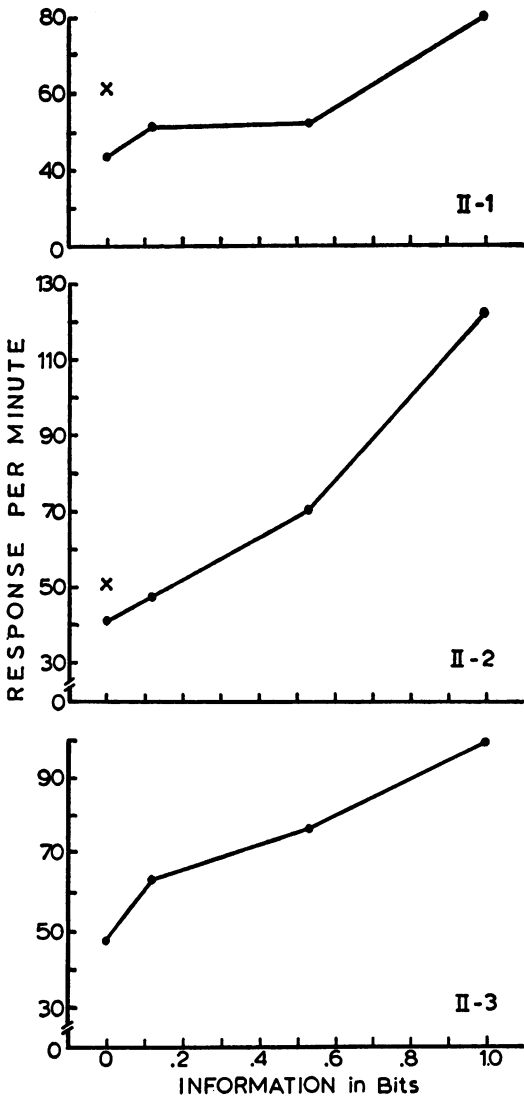


Fig. 4. Response rate for Birds II-1, II-2, and II-3 as a function of the average amount of information in bits transmitted by the two stimuli. The "X" for Birds II-1 and II-2 is the response rate in the 100% reinforcement condition.

fixed ratios was altered. In addition, Bower, McLean, and Meacham (1966) found no change in observing behavior when the probability of a brief fixed-interval of a pair of fixed intervals was changed from 0.50 to 0.20.

There are two differences between the group of studies that have found an effect of varying schedule probability and those that have not. One is that the studies finding an effect have used a schedule of positive reinforcement and extinction as the pair of conditions that were signalled by the stimuli produced by the observing response. Those that have not found an effect of varying probability have used two schedules of positive reinforcement, either two fixed-interval schedules (Eckerman, 1970; Bower *et al.*, 1966) or fixed-ratio schedules (Hendry, 1969*b*). The other difference is that the studies finding an effect of varying schedule probability have used a procedure that allows the rate of observing responses to be measured on one operandum while explicit food responses were either not required or occurred on a concurrently available operandum. (An exception is McMichael *et al.*, who used the concurrent procedure described below). Those studies not finding an effect have used a choice or concurrent chains procedure, Bower *et al.* (1966) and Hendry (1969*b*) used a concurrent chains procedure and Eckerman (1970) used a procedure called "sequential choice", in which the options were presented successively. In a concurrent chains procedure, the subject has the option of responding on one of two levers or keys. Responses on one operandum are defined as the observing response and produce the reinforcement schedule currently arranged and its correlated stimulus. Responses to the other operandum produce the reinforcement schedule currently arranged, but the stimulus produced does not reliably correlate with either of the schedules that might occur.

The first of the above-mentioned variables correlates perfectly with the finding of some effect when a schedule probability is varied. All studies using a schedule of positive reinforcement and extinction as the two conditions of the experiment have yielded results similar to those of the present Experiment I. Observing responses are strongest when the probability of the schedule of positive reinforcement is less than 0.50. The exact location of the peak of this function is not known.

Hendry found a peak when the probability of a variable-ratio schedule was about 0.35 (Hendry, 1965). The location of the peak might vary depending on various particulars of the experiment, however.

Why has not the other group of studies employing chain and concurrent chains procedures revealed a difference in observing response strength when schedule probability is varied? One reason could be that the use of two schedules of positive reinforcement does not yield any effect. McMichael *et al.* (1967) found an effect with a concurrent chains procedure when fixed interval and extinction were used. Another reason might be because of the use of the chain procedure. Concurrent schedules have proved to be a powerful tool for the analysis of several variables, some of which have very little effect on a single schedule of reinforcement (Catania, 1963). Concurrent variable-interval schedules are preferred, apparently for their sensitivity. The studies of Bower *et al.* (1966), and Hendry (1969*b*) used concurrent fixed-ratio schedules, however. Bower *et al.*, used FR 1 and Hendry used FR 10. While concurrent variable-interval schedules may be sensitive to schedule probability in an observing response procedure, fixed-ratio schedules may not be. Hendry (1969*b*) reported that his birds rarely switched between keys once responding in the initial link had begun. It is possible that a slight difference in value between the two options is sufficient to lead to exclusive preference for that option where fixed-ratio schedules are used.

To what extent do the present results support the information hypothesis of observing responses? One prediction is clearly not supported by Experiment I. This is that the strength of observing responses is maximal when the probability of the positive stimulus is equal to 0.50. No experiment directed at this hypothesis has yet supported it, and it seems clear that maximal observing response strength is obtained when the probability of the positive stimulus is less than 0.50.

Wilton and Clements (1971*b*) suggested that the results of their experiment and others that have found an effect of manipulating schedule probabilities may be explained by considering the amount of information that the positive stimulus contributes to the average amount transmitted by the positive and negative stimuli. The function relating this quan-

tity ($p \log 1/p$) to the probability of occurrence of the positive stimulus (p) is maximal at a probability value of 0.37 (Garner, 1962). Observing responses should obtain maximal strength at this value, assuming that the reinforcer for the observing response is the positive stimulus. This explanation will not fit Experiment I, however. The average amount of information contributed by the positive stimulus when its probability is 0.50 is identical to the average amount contributed when its probability is 0.25. In both cases, $p \log_2 1/p = 0.50$. Therefore, Wilton and Clements' hypothesis predicts equal responding when the probability of the positive stimulus is either 0.50 or 0.25.

In a recent paper, Wilton (1972) proposed that the observing response is reinforced by the amount of information in the positive stimulus and punished by the information from the negative stimulus. He has also assumed that the amount of punishment by the negative stimulus is small relative to the reinforcement delivered by the positive stimulus. That they cannot be equal is obvious because this would predict no observing responses when the probability of the positive and negative stimuli were equal to 0.50. If it is assumed that the punishment by the negative stimulus is some constant fraction of the information in the negative stimulus ($q \log_2 1/q$, where q is the probability of the negative stimulus), then the direction of the results in Experiment I is predicted. This can be done by considering the amount of information in the positive stimulus at the three probability values in Experiment I. The values are 0.50 bits, 0.50 bits, and 0.31 bits when the probability of the positive stimulus is 0.25, 0.50, and 0.75. The values for the negative stimulus are 0.31 bits, 0.50 bits, and 0.50 bits when the probability of the positive stimulus is 0.25, 0.50, and 0.75. Thus, multiplying the information in the negative stimulus by some fraction and subtracting that amount from the information in the positive stimulus will yield the prediction that responding will be maximal when the probability of the positive stimulus is 0.25.

Before Wilton's hypothesis is wholeheartedly endorsed, one confounding factor should be eliminated as a potential source of the effect observed in Experiment I. When the probability of the positive trial is 0.25, the amount

of time spent in negative trials occupies more of the experimental session. Time spent in the negative trial will be less when the probability of positive trials is 0.75. Suppose that the strength of observing responses was a function of several variables including (1) reinforcement factors in the positive trial (delay, amount, *etc.*), (2) intermittency of reinforcement for the observing response, and (3) the amount of time spent in negative trials. If the value of the positive stimulus increases as the amount of time spent in negative trials increases, the results of Experiment I could be predicted, although a quantitative prediction is not easily arrived at. Wilton's position would seem to be that increasing the time spent in negative trials without changing the probability of either type of trial would add to the amount of punishment delivered by the negative trial stimulus. Since a change in the probability of the positive trial does add to the amount of time spent in negative trials, it is not possible to rule out this as a factor leading to the results of Experiment I.

Experiment II was designed to manipulate only one variable: the correlation between the stimuli and reinforcement. This correlation may be expressed quantitatively by information theory. Neither the probability of either stimulus nor the probability of reinforcement was varied. The procedure was similar to the one previously reported by Wilton and Clements (1971a, b), in that a delay period followed responding and preceded either reinforcement or timeout. The delay period was dependent on responding so that there was no non-observing response option. The response rate was fairly close to being a linear function of the amount of information transmitted by the stimuli. Had the procedure of Experiment II not required responding to produce reinforcement, the observing response rate would probably have been close to zero in the zero-bit conditions. The birds in Wyckoff's original observing response experiment pressed the pedal (the observing response) very little when the resulting stimuli were not systematically correlated with reinforcement (Wyckoff, 1969).

Although the response rate between zero and one bits was a function of the information measure, uncertainty reduction by the stimuli would not account for the fact that the animals responded in the conditions in the experiment in which the stimuli transmitted zero

bits. There were two such phases. In one, reinforcement was given on half of the trials, but the stimuli were not correlated with its delivery. In the other, reinforcement was delivered on each trial so that the delay stimuli reduced no uncertainty about the ultimate delivery of reinforcement. The response rate in the first of these two conditions was lower than in the second. It might be argued that the onset of any stimulus in a chain procedure provides some sort of information. In the present procedure, the onset of a stimulus indicates that the fixed-ratio is completed and that the delay period is in effect. The onset of a stimulus more reliably signals reinforcement when the reinforcer is delivered on each trial than when only on half of the trials. This proposal is similar to one made by Egger and Miller (1962, 1963).

Although the information delivered by the stimuli in both the 50% green and the 100% reinforcement conditions is zero bits, there are two differences between these conditions. One is the overall rate of reinforcement in the presence of the stimuli; it is twice as high in the 100% reinforcement condition as in the 50% green condition. Another relates to information. In the 50% green condition the terminal events in a trial, *i.e.*, reinforcement and timeout, are informative; there is uncertainty about the outcome until it occurs. In the 100% reinforcement condition, the act of pecking, the stimuli, and the delivery of food form a redundant sequence, so that there is no initial uncertainty, at least about the ultimate outcome of the trial. Whatever value may lie in the information delivered by food or timeout in the 50% green condition is obviously not sufficient to outweigh the effects of the greater rate of reinforcement.

Information theory terminology often seems to imply that, in addition to stimuli and responses, there is something called "information" which stands apart, as it were, and is only "transmitted" by the stimuli. In this sense it may be objected to on the same grounds as the term "meaning" as something that is conveyed by words (Skinner, 1957). In another sense, which is the one intended here, information is a way of summarizing certain relationships, such as correlations between stimuli and reinforcers, or between responses and stimuli. Information theory has formulated quantitative ways of describing such

procedures. An information theory leads, then, to certain quantitative predictions, some of which are substantiated in the present report. This theory is not totally unambiguous, however. Wilton's recent restatement of the theory includes the supposition that information may be punishing as well as reinforcing, a view not included in earlier statements of the information hypothesis (Berlyne, 1960; Hendry, 1969).

Schneider (1972) has questioned the assumption that the immediate stimulus consequences of responding in earlier components of chain schedules reinforce responding in those components. The results of the present Experiment II indicate that changes in the correlation between the stimuli and reinforcement affect the value of the stimuli when the probability of reinforcement on a trial is not affected. The rate of reinforcement does change, but as a function of changes in the response rate. Observing response experiments in general argue for the importance of immediate stimulus changes in concurrent arrangements, since animals prefer stimuli consistently correlated with their respective reinforcement schedules, even though this choice may result in a lowered frequency of reinforcement (Hendry, 1969b).

REFERENCES

- Attneave, F. *Applications of information theory to psychology*. New York: Holt, 1959.
- Berlyne, D. C. *Conflict, arousal and curiosity*. New York: McGraw-Hill, 1960.
- Bower, G., McLean, J., and Meacham, J. Value of knowing when reinforcement is due. *Journal of Comparative and Physiological Psychology*, 1966, 62, 184-192.
- Catania, A. C. Concurrent performances: a baseline for the study of reinforcement magnitude. *Journal of the Experimental Analysis of Behavior*, 1963, 6, 299-300.
- Eckerman, D. A. *Information transmission and conditioned reinforcement*. Paper presented at the meetings of the American Psychological Association, Miami Beach, 1970.
- Egger, M. D. and Miller, N. E. Secondary reinforcements in rats as a function of information value and reliability of the stimulus. *Journal of Experimental Psychology*, 1962, 64, 97-104.
- Egger, M. D. and Miller, N. E. When is a reward reinforcing?: An experimental study of the information hypothesis. *Journal of Comparative and Physiological Psychology*, 1963, 56, 132-137.
- Garner, W. R. *Uncertainty and structure as psychological concepts*. New York: John Wiley & Sons, 1962.
- Hendry, D. P. *Reinforcing value of information*.

- NASA Technical Report 65-1. Space Research Laboratory, University of Maryland, 1965.
- Hendry, D. P. Introduction. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Illinois: Dorsey, 1969. Pp 1-33 (a)
- Hendry, D. P. Reinforcing value of information: Fixed-ratio schedules. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Illinois: Dorsey, 1969. Pp. 300-341. (b)
- Kelleher, R. T., Riddle, W. C., and Cook, L. Observing responses in pigeons. *Journal of the Experimental Analysis of Behavior*, 1962, 5, 3-13.
- Kendall, S. B. The distribution of observing responses in a mixed FI-FR schedule. *Journal of the Experimental Analysis of Behavior*, 1965, 8, 305-312.
- McMichael, J. S., Lanzetta, J. T., and Driscoll, J. Infrequent reward facilitates observing responses in rats. *Psychonomic Science*, 1967, 8, 23-24.
- McMillan, J. C. *Uncertainty reduction and the maintenance of observing behavior*. Paper presented at the meetings of the Psychonomic Society, San Antonio, 1970.
- Schneider, J. W. Choice between two-component chained and tandem schedules. *Journal of the Experimental Analysis of Behavior*, 1972, 18, 45-60.
- Skinner, B. F. *Verbal behavior*. New York: Appleton-Century-Crofts, 1957.
- Wilton, R. N. The role of information in the emission of observing responses and partial reinforcement acquisition phenomena. *Learning and Motivation*, 1972, 3, 479-499.
- Wilton, R. N. and Clements, R. O. Observing responses and informative stimuli. *Journal of the Experimental Analysis of Behavior*, 1971, 15, 199-204. (a)
- Wilton, R. N. and Clements, R. O. The role of information in the emission of observing responses: a test of two hypotheses. *Journal of the Experimental Analysis of Behavior*, 1971, 16, 161-166. (b)
- Wyckoff, L. B., Jr. The role of observing responses in discrimination learning. In D. P. Hendry (Ed.), *Conditioned reinforcement*. Homewood, Illinois: Dorsey, 1969. Pp. 237-260.

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