OBSERVING STIMULUS SOURCES THAT SIGNAL FOOD OR NO FOOD¹

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Pigeons were given a choice between observing a stimulus source that was uncorrelated with food or one that was informative. The informative source was either positive, in which a stimulus change signalled food, or negative, in which change signalled no food. If observing is supported by the reduction of uncertainty, the negative as well as the positive source should be preferred to the uncorrelated source. On the other hand, if observing requires support by conditioned reinforcement, the negative source should not be preferred to the uncorrelated source. Two keys served as stimulus sources in a discrete trial procedure. The keys were lighted together, remained on for a variable length of time, and went off together. A key could change color 1 sec before going off. In the uncorrelated source, the change occurred equally often on trials ending with or without food. In the positive information source, the change occurred only on food trials, whereas in the negative information source, it occurred only on no-food trials. All stimulus changes and food delivery were response independent. As measured by orientation and auto-shaped pecking, the positive information source was preferred to the uncorrelated source. However, the uncorrelated source was preferred to the negative information source. The latter result does not support the view that observing behavior is reinforced by the reduction of uncertainty. The positive and negative information sources reduced uncertainty equally but only the positive source provided a signal that could act as a conditioned reinforcer by virtue of its relation to food.

It is well established by the experiments of Wyckoff (1952, 1969), Prokasy (1956), Bower, McLean, and Meacham (1966), and by more recent work (see Hendry, 1969a), that animals work to observe informative stimuli in preference to uninformative stimuli, even though the informative stimuli do not allow for an improvement in the objective conditions of reinforcement. Two interpretations of this preference have been advanced. One is that observing is maintained by the conditioned reinforcing effect of the stimulus value associated with the more favorable condition of reinforcement (positive value). The other is

that observing is maintained by reduction of uncertainty about whether the more or less favorable condition of reinforcement is in effect, or in other words by both the positive and negative values of an informative source. In common language, the conditioned reinforcement hypothesis holds that the animal is interested only in seeing the signal for food (or some other relatively positive event), while the uncertainty reduction hypothesis holds that the animal is interested in seeing whether the signal is for food or non-food². The conditioned reinforcement hypothesis has been favored by Wyckoff (1952, 1969), Perkins (1955), Prokasy (1956), Bower *et al.* (1966), and Kendall (1973), among others. The uncertainty reduction hypothesis has been fav-

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²The concepts of uncertainty, and reduction of uncertainty are defined and discussed by Garner (1962). For present purposes, it would suffice to consider that the uncertainty of an event is inversely proportional to its probability of occurrence. When the event in question actually occurs, or fails to occur, uncertainty is reduced to zero. The amount of information transmitted by occurrence of nonoccurrence is directly related to the amount of uncertainty reduced and therefore inversely related to the probability of occurrence or nonoccurrence.

ored by Berlyne (1957), Hendry (1969*b*), Schaub (1969), and Schaub and Honig (1967), among others.

A decisive test of the hypotheses has proved difficult to arrange. One result, which at first appears to be a basis for rejecting the conditioned reinforcement hypothesis, turns out on closer examination to be equivocal. If negative values and negative outcomes are eliminated so that the observing response produces only the positive value, observing behavior diminishes or ceases (Hendry, 1969*b*; Kendall, 1973), or fails to develop (Wilton and Clements, 1971). Since the positive stimulus value is still in temporal conjunction with the positive outcome, one might suppose that, on the conditioned reinforcement hypothesis, observing behavior should not diminish. This result can, however, be given an interpretation that is consistent with the conditioned reinforcement hypothesis of observing behavior. One can suppose that in order for the positive value to become or to remain a conditioned reinforcer, a negative stimulus value must also occur so that the positive value transmits information about the reinforcer (Egger and Miller, 1962, 1963). Observing behavior could still be maintained entirely by the conditioned reinforcing effects of the positive value, even though the negative value was necessary to render the positive value a conditioned reinforcer. In other words, one can accept an information hypothesis for conditioned reinforcement without accepting an uncertainty reduction hypothesis of observing behavior.

The assertion that the negative value as well as the positive value of the informative stimulus variable reinforces the observing response is what distinguishes the uncertainty reduction hypothesis from the conditioned reinforcement hypothesis of observing behavior. Schaub and Honig (1967) and Schaub (1969) attempted to demonstrate a reinforcing effect of the negative value. They arranged for the observing response in pigeons to produce a signal only during nonreinforced periods. Three observing responses (key pecks) produced a momentary flash of color on the prevailing white key if the extinction component of the schedule was in effect. Their results suggested that observing responses were receiving reinforcement despite the fact that the signal was always "bad news".

On closer examination of the method used

in the Schaub and Honig experiments, it becomes apparent, however, that one cannot state that observing responses produced only the negative stimulus value. As Wilton and Clements (1971) pointed out, the nonoccurrence of the flash of color following three pecks could serve as a signal that the positive component of the schedule was current. Consequently, observing responses may have been reinforced by the absence of a stimulus change after three responses in positive periods, rather than by the presence of a change in negative periods. The experiment does not, therefore, provide strong support for the uncertainty reduction hypothesis of observing behavior. The interpretation of these experiments has also been questioned by Dinsmoor, Browne, and Lawrence (1972).

It is impossible to use a stimulus as a signal for one event without having the absence of the stimulus transmit some information about the other event. One can, however, devise a situation in which the absence of a stimulus following a response transmits very little information. Suppose that in the Schaub and Honig experiment, observing responses produced a signal after a variable number of responses (a variable-ratio or VR schedule) rather than after a fixed number. If the mean number of responses required to produce a signal were large, the absence of a stimulus would be the highly probable result of an observing response in both positive and negative (or extinction) components of the schedule of food reinforcement. The absence of a stimulus would therefore transmit very little information. In that case, one can have a single stimulus value, either the positive or negative value, transmit almost all of the information.

A strategy of this kind was used by Dinsmoor *et al.* (1972) in order to learn whether the appearance of the negative stimulus value alone is sufficient to maintain observing responses, as would be expected on the uncertainty reduction hypothesis. Pigeons pecked an observing-response key to produce positive or negative stimulus values. The stimuli were produced on a variable-interval schedule so that the absence of a stimulus was the highly probable consequence of a peck on the observing response key.

Observing responses continued undiminished when the negative stimulus value was removed. Removing the positive value, on

the other hand, caused the birds to stop responding on the observing key. These results showed that the negative value was not serving as a reinforcer of observing responses. They were consistent with an account of observing based on conditioned reinforcement.

The present experiment used a related approach to examine the possibility that a stimulus source that produces a definite signal only when food is not available is observed in preference to a stimulus source that produces a signal not correlated with the availability of food.

The present experiment differed in a number of ways from the experiment by Dinsmoor *et al.* and from operant experiments on observing behavior in general. The pigeon was presented with a choice between two simultaneously available stimulus sources. A discrete trial procedure was used. The stimulus sources were turned on together after irregular off periods. One of the sources provided information about whether food would or would not arrive at the termination of the trial, while the other source provided no information about the outcome of the trial. Responses had no effect on the stimulus sources or on the delivery of food. A record was kept of which stimulus source the bird oriented towards during each trial. The birds were not required to make any response, other than simply "looking", in order to make the positive and negative stimulus values available. As it turned out, the procedure resulted not only in orientation towards the stimulus sources but also in auto-shaped pecking at the sources. Pecks were recorded, along with orientation, and served as a major dependent variable. The present experiment may be thought of as one concerned with the control of auto-shaped pecking by stimuli of varying informational properties, as well as an experiment on the reinforcement of observing behavior.

A stimulus source in this experiment had the following characteristics. Intermittently the source came on (lighted up), and stayed on for a variable length of time. On half the trials, it went off without changing color. On the other half of trials, it showed a brief flash of color just before it went off. These are called signal trials. The trials without change are called no-signal trials. The variable duration of trials ensured that the absence of a flash at any time transmitted little informa-

tion as to whether the trial would ultimately end with or without a signal. Variable duration served the same purpose as did the variable-interval schedule of presenting positive and negative stimulus values in the experiment by Dinsmoor *et al.* (1972).

The behavior of the source can be represented by a Markov process as schematized in Figure 1. The information transmitted by the absence of a signal about whether the trial will eventually end with or without a signal can be readily calculated for a system of this sort. Assume that signal and no-signal trials occur equally often so that their *a priori* probabilities are $\frac{1}{2}$. A straightforward application of Bayes' theorem shows that the absence of a change after the first instant, or small time unit, increases the probability that the trial is a no-signal trial from $\frac{1}{2}$ to $1/1 + q$, where q is the probability of the source remaining in the prevailing or c state. The probability that the trial is a no-signal trial remains at $1/1 + q$ until the trial actually terminates without change or until a flash in the pre-termination state indicates that this is a signal trial. It is apparent that the higher the probability, q , of remaining in the prevailing state, the less the probability of a no-signal trial is increased over its *a priori* value of $\frac{1}{2}$ by the absence of a stimulus change. In other words, the information transmitted by the absence of a signal is inversely proportional to the probability that the source is still in its prevailing state, rather than in the pretermination state.

In the present experiment, signal and no-signal trials were related to the arrival or non-arrival of food at the termination of the trial in three different ways. We refer to the source as a positive information source when all signal trials terminated with food and all no-signal trials terminated without food. It is a negative information source when the reverse assignment was made, so that all signal trials terminated without food and all no-signal trials terminated with food. Finally, we refer to the source as uncorrelated or uninformative when half the signal trials and half the no-signal trials terminated with food.

The experiment involved measuring preference between the positive information source and the uncorrelated source or, in a separate group, between the negative information source and the uncorrelated source.

Fig. 1. Markov representation of the behavior of a stimulus source on signal trials and on no-signal trials. The probability of remaining in the prevailing or common state, c , at each instant is q . The probability of an exit to the preterminal state is $1-q$. On signal trials, the preterminal state is marked by a brief flash. On no-signal trials, the preterminal state, c' , is indistinguishable from the prevailing c state so that the source goes off without a perceptible change in the preterminal state.

The critical question for the uncertainty reduction hypothesis is whether the bird will observe the negative source, which provides advance information that no food will be delivered at the termination of the trial, in preference to the uncorrelated source, which provides no information about whether food will or will not be delivered at trial termination.

Orienting behavior was monitored and scored with the aid of closed-circuit television. Auto-shaped pecks were recorded by means of a contact-sensitive transducer on each stimulus source. Orientation and pecks were recorded only during the prevailing, or c state of the stimulus source, not during the pretermination state. Therefore, any systematic preference for a source of one type must result from the way in which the pretermination states, in relation to the arrival or non-arrival of food, affected responding to the prevailing state of the source.

In the design of the experiment, the question arose of whether it would be preferable to place a divider between the light sources so that only one could be seen by the bird at a time, or to allow both sources to be visible at once. A divider would make the orientation of the bird more evident, but it might also reduce exposure on a trial to the alternative

source. It was decided to alternate sessions with and without a divider in order to assess its effect.

METHOD

Subjects

Adult, male homing pigeons with no experimental experience were maintained at 80% of their free-feeding weights throughout the experiment. They were randomly assigned to two groups of six subjects.

Apparatus

In a chamber measuring 42 by 33 by 32 cm (16.5 by 13 by 12.5 in.) one wall, painted light gray, contained the light sources and the magazine aperture. The opposite wall was transparent and through it an externally mounted TV camera could view the inside of the chamber. The two side walls were plain and painted matte black. The sources consisted of two halves of ping-pong balls, which projected into the chamber and were mounted at a height of 20 cm (8 in.) with a center-to-center distance of 15 cm (6 in.). The left source contained a white panel lamp and an amber lamp; the right source a white lamp and a red lamp. The same wall contained the magazine

aperture, whose center was 11 cm (4.25 in.) above the floor and equidistant from the two sources. A removable barrier made of thin sheet metal could be mounted halfway between the sources and normal to their plane. The shape of this barrier was such as to remove one source from the view of a pigeon that was within about 10 cm (4 in.) of the other source without impeding access to the magazine aperture. A diffuse source of illumination was mounted on the ceiling in the rear of the chamber to illuminate the compartment.

Experimental events were arranged on conventional electromechanical equipment. Temporal spacing was controlled by variable-interval film timers. Randomization was provided by two independent Lehigh Valley probability generators. Mechanical impulses to the sources were detected by phonograph cartridges, the outputs of which were amplified to drive relays. The sensitivity of these systems was balanced and set to a level so that pecks, but no other events such as the operation of the magazine, would cause the relays to operate.

Procedure

Subjects were first trained to eat from the hopper by presenting it for periods of 8 sec at variable intervals with a mean of 100 sec. The barrier was absent when the birds were first placed in the chamber. Each subject was removed when it was eating consistently from the hopper. In the next session, the barrier was again absent and a total of 50 hopper presentations was given. During this session, the time of presentation of the hopper was progressively reduced to 3 sec. In the next session, the barrier was present and again 50 hopper presentations were given. In this, and all subsequent sessions, presentation time remained at 3 sec. Throughout magazine training, the compartment light was the only source of illumination.

On completion of magazine training the following conditions were introduced and maintained for nine sessions. Six daily sessions were given per week and each session contained 100 trials. At variable intervals averaging 40 sec (range, 12 to 120 sec) a trial began with both sources illuminated by the white lights. Both lights remained on for a variable time averaging 9 sec (range, 2 to 30 sec). At the end of this time there was always

a further period of 1 sec, the pretermination state, before the end of the trial. During this period a signal could occur in either or both the sources. The signal consisted of a change in illumination from white to amber or to red. When a signal did not occur in the pretermination state on a given trial, the source simply remained white and there was no change to indicate that the final 1-sec period had begun. The statistical properties of the trial duration would be approximated by assuming a discrete Markov process that can change state once per second and having a value for q , the probability of remaining white, of 0.89.

Six pigeons were randomly assigned to Group P and six to Group N. For nine sessions, Group P was presented with a positive information source and the uncorrelated source. Group N was presented with a negative information source and the uncorrelated source. At the end of nine sessions, the informative sources were changed from positive to negative in Group P and from negative to positive in Group N. The positions of the informative and uncorrelated sources remained fixed for individual subjects but were counter-balanced within groups.

A random half of the trials were followed by operation of the hopper. The remaining trials ended with a return to the intertrial conditions. The houselight remained on throughout the session except during hopper presentations.

In the uncorrelated source, the signal occurred with equal probability on food and no-food trials. In the positive information source, the signal occurred only on trials that terminated with food. In the negative information source, the signal occurred only on trials that terminated without food.

The barrier was present on alternate sessions, being absent during the initial session for all subjects and thus present for the first session in which conditions were changed. Throughout Sessions 8 and 9 of the initial phase *i.e.*, the two sessions before reversal, the behavior of each subject was monitored systematically on closed-circuit television. The experimenter closed hand-held switches connected to clocks for as long as the pigeon's beak pointed to one or the other of the sources during the trial. Comparable measurements from pilot experiments had suggested that nothing was gained from observations during

Table 1

Distribution of responses in the first session in which at least 10 responses were made. The barrier was absent on odd-numbered and present on even-numbered sessions.

	Subject	Session Number	Infor- mative Source	Uncor- related Source
<i>Group P</i>				
(Informative source is positive)	P113	1	308	25
	P119	1	19	1
	P129	1	404	0
	P117	1	64	5
	P121	1	65	852
	P124	3	85	3
<i>Group N</i>				
(Informative source is negative)	P114	3	0	11
	P118	3	0	12
	P123	1	82	501
	P115	1	6	32
	P120	2	5	46
	P125	1	10	191

the intertrial intervals because subjects rarely oriented towards the sources unless they were illuminated.

RESULTS

All subjects began to peck at the sources within the first few sessions. As shown in Table 1, very strong preferences were apparent as soon as responding began: in Group P, all subjects but one responded more to the positive information source than to the uncorrelated source, whereas in Group N, all subjects responded more to the uncorrelated source. These preferences were maintained for the first nine sessions, but were more pronounced in sessions without barrier than in sessions when the barrier was present. This is apparent in Figure 2, where the median percentage of responses to the informative source for each group is plotted separately for ses-

Fig. 2. Median percentages of responses to the informative source for Groups P and N. Sessions without the barrier are shown in the left-hand panel and those with the barrier in the right-hand panel. Medians were calculated for sessions in which a subject responded at least 10 times.

sions with and without the barrier. It can be seen that when the values of the informative source were reversed following the ninth session, these preferences were no longer maintained. They were not, however, clearly reversed.

Results for individual subjects in Group P are shown in Figure 3. It is apparent that, except for Subject P121, the median functions in Figure 2 are typical of the performance of individual subjects before reversal, but that, following reversal, there is considerable variability. Also shown in Figure 3 is the total number of responses per session for each subject. Similar data for individual subjects in Group N are shown in Figure 4.

As some subjects made few pecks during the

first three sessions, and as in the final phase there appeared to be no consistent differences between the groups, statistical analysis was confined to the final six sessions of the first phase. It should be noted that since, as shown in Figure 2, there was a slight tendency for the differences between the groups to decrease with continued exposure, estimates of the reliability of the results based on these sessions are conservative. For each subject, the percentage of total responses made to the informative source (positive or negative) was calculated for Sessions 5, 7, and 9 (no barrier), and separately for Sessions 4, 6, and 8 (with barrier).

The results of the experimenter-measured orientation in Sessions 8 and 9 showed that

Fig. 3. Distribution of responses and total number of responses within a session for individual subjects in Group P. The percentage of responses to the positive informative source (on the left-hand scale) are shown only for sessions in which at least 10 responses occurred. Both these percentages and the total number of responses (on the right-hand scale) are based on responses before the 1-sec pretermination state. For subjects shown at the left, the informative source was on the left.

Fig. 4. Distribution of responses and total number of responses within a session for individual subjects in Group N. These data were calculated as in Figure 3. For subjects shown on the left, the informative source was on the left.

These scores were compared using a Wilcoxon Matched Pairs Test, which showed that there was a significant tendency ($p < 0.02$, two-tail) for subjects to distribute their responses more equally between the sources when the barrier was present than when it was absent. Differences between the groups were tested by a two-way analysis of variance (Groups $\times$ Position of Informative Source) of the arc-sine transformation of the scores. This was carried out separately for the scores obtained on no-barrier sessions and on barrier sessions. With the barrier absent, a significant Group effect was obtained ($F_{1,8} = 11.5$, $p < 0.01$) and, although there was a slight position preference for the left, this effect ($F_{1,8} = 1.6$) and the interaction term were small ($p > 0.05$).

The error term from this analysis was used as an estimate of variance in t-tests that showed the mean scores of each group to be reliably different from 50% ($p < 0.05$, two-tail, for each group). A similar analysis for the scores based on barrier sessions revealed no significant differences, although the position preference for the left was greater than with the barrier absent and just failed to reach the 0.05 level of significance ($F_{1,8} = 5.3$).

In all the above results, only responses that occurred during a trial before the last 1-sec period were taken into account. Although data on responses to the terminal signal might be of considerable significance in experiments of this general design, they were not available in a useful form in the present case.

the number of pecks was closely related to orientation. There was a high correlation between the proportion of time spent with the beak pointing towards a source and the percentage of responses to that source. This is illustrated in Figure 5, where the per cent of total orientation time (either source) to the informative source is plotted against the percentage of responses (pecks) to that source. The results from Session 8 (with barrier) are on the left-hand side of the figure and those from Session 9 (no barrier) on the right. Almost every point is close to the diagonal representing perfect correspondence between the two measures.

DISCUSSION

Two matters of secondary importance may be commented on briefly. The first is that the preferences could be reliably detected only under "No-Barrier" conditions. Observations showed that subjects typically approached the nearer source when the trial started. Subsequently, if this source was not the preferred one, they would switch to the other side within a few seconds if no barrier were present. However, with the barrier present, crossovers during a trial were infrequent. This meant that subjects that spent time equally on both sides of the chamber during the intertrial periods

would tend to respond equally to both sources during trial periods and subjects with a tendency to spend intertrial periods on a particular side would respond mostly to the source on that side. In neither case would the nature of the source be an important determinant of orientation.

The second matter concerns the failure of the preference to be clearly reversed in the second phase of the experiment, when the informative source was changed from positive to negative or *vice versa*. While several factors may be involved, it seems likely that once responding has converged on a source, stimuli that played no role in determining the preference may become conditioned to the response by virtue of repeated reinforcement in their presence. Stimuli associated with the position of the source in the chamber would be an example. Conditioning to such stimuli could result in resistance to subsequent changes of preference.

The finding of principal interest was that although the positive information source was preferred to the uninformative source, the uninformative source was preferred to the negative information source. These results rule out some accounts of how observing behavior (orienting to a source and pecking at it) is supported.

Fig. 5. Correlational plot of the per cent of total orientation time to the informative source against the per cent of total pecks to the informative source. Measures are based on trial periods in two sessions in which the direction of the beak was systematically monitored: Session 8 (left) and Session 9 (right).

It is clear that preference was not determined by the temporal conjunction of the white, or prevailing stimulus, with food. If that account were correct, the negative source would be preferred (oriented to and pecked at) more than the uncorrelated source. The negative source is always white at the moment of food delivery, whereas the uncorrelated source is white at the moment of food delivery on only half of the trials. Moreover, the uncorrelated source should be preferred to the positive source because in the positive source, the light is never white at the moment of food delivery. The results, of course, showed just the opposite pattern of preferences. We must conclude that the temporal conjunction of the white light with food is not the cause of pecking at or orienting to the stimulus source while the key is white. It is clear that the relation of the signal to the trial outcomes determined systematic orienting and pecking preferences.

The results also allow the rejection of one form of the uncertainty reduction hypothesis. Specifically, it is not the case that the bird prefers to orient towards and peck at a stimulus source that gives advance notice that the trial will end without food over a stimulus source that provides no advance notice about how the trial will end. In fact, the results showed a strong preference for the uncorrelated source over the negative source.

In all of the previous discussion, we have been concerned with the role of the signal in reducing uncertainty about *whether* the trial will end with food or no food. With that as a reference, the uncorrelated source provides no reduction of uncertainty while the negative source provides as much reduction of uncertainty as does the positive source. There is, however, another dimension of uncertainty that may be more relevant to the bird's behavior; namely, uncertainty about the *time* of arrival of food.

The positive source transmits the most information about the time of arrival of food. The signal is always followed immediately by food. But, the uncorrelated source also provides information about the time of arrival of food because the signal is followed immediately by food on half of the trials. Although the signal is unreliable, the probability of receiving food in the next second is much greater after a signal than before. The signal

in the negative source provides the least information about when food will arrive. The arrival of food in the next instant is a low probability event during the prevailing (white) state. Thus, even though the probability of food drops to zero on the signal, it is a relatively small change in probability. For that reason the signal in the negative source transmits little information about food delivery in the next instant.

In view of these considerations, the present results do not rule out the possibility that observing is supported by any signal that transmits information about the time of arrival of food, including a signal that anticipates a reduction in the probability of food in the next instant. The preference for the positive over the uncorrelated source, and for the uncorrelated over the negative source, is consistent with differences in the amount of information transmitted about arrival time in these sources. Perhaps the negative source would be preferred over one that was uninformative about *when* the trial will end as well as *how* the trial will end. Such a source would be one in which no stimulus change ever occurred to mark the pretermination state.

The present results are also consistent with the more traditional account of observing behavior in terms of conditioned reinforcement, although here the conditioned reinforcer is not contingent on responses. Pecking at white receives non-contingent conditioned reinforcement to the extent that the signal predicts an increase in the probability of food. This generalization would account for the observed preference between sources: the positive source over the uncorrelated source and the uncorrelated source over the negative source. The generalization is also consistent with the results obtained by Dinsmoor *et al.* (1972). Those results failed to demonstrate a reinforcing effect of a signal that predicted the nonavailability of food.

In summary, the present experiment provided no support for an uncertainty reduction hypothesis of observing behavior. It allowed the rejection of one version of that hypothesis: namely, that observing is supported by a reduction of uncertainty about the outcome of the trial. The untested possibility remained that in an arrangement of the present kind, observing behavior can be supported by a

signal that changes the probability that food will arrive in the next instant, even where the change is a decrease.

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