

Pigeons and rats observe signals of when but not where food will occur

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Pigeons and rats were exposed to a mixed variable-time extinction schedule of reinforcement. During the variable-time component of the schedule, response-independent food was delivered at either a left or a right feeder. The animals were allowed to perform observing responses to produce either stimuli paired with the component of the mixed schedule that was in effect (temporal information) or stimuli paired with the feeder that might deliver food (spatial information). Only stimuli conveying temporal information reinforced observing. This result contradicts a prediction of the "information hypothesis" of observing, but is consistent with various conditioned-reinforcement interpretations of observing.

Recent research dealing with the "spatial memory" of animals (e.g., Menzel, 1978; Olton, 1978, 1982; Shettleworth & Krebs, 1982; Wilkie, 1983) has led to a renewed interest in the effects of spatial relations on learning and behavior. Most of this research and the resultant interest has been focused on the way in which animals acquire and maintain information about the spatial features of the environment for more efficient procurement of reinforcers. In other words, the study of spatial memory has been basically concerned with issues of stimulus control.

An area of research in animal learning that has largely ignored the effects of spatial relations is represented by those who investigate conditioned reinforcement. One exception to this generalization is a study by Bowe and Dinsmoor (1983) in which they provided some evidence suggesting that a spatial relation between a stimulus and a primary reinforcer does not affect the establishment of that stimulus as a conditioned reinforcer. In two experiments, they showed that stimuli providing "spatial information" about which of two keys could be pecked to produce occasional food deliveries did not reinforce observing responses, whereas stimuli providing "temporal information" about which component of a multiple variable-interval extinction schedule of reinforcement was operating did reinforce observing responses. Bowe and Dinsmoor interpreted their results in terms of a "reinforcement density analysis," similar to Fantino's (1977) "delay-reduction hypothesis," in which the spatial rela-

tions between stimuli and primary reinforcers play no role. The analysis posits that a stimulus becomes a conditioned reinforcer as a result of the greater proximity in time to primary reinforcement that is signaled by the onset of the stimulus in question, or as a result of the higher density of reinforcement in its presence. In contrast to the delay-reduction and reinforcement-density analyses, the "information hypothesis" of observing (e.g., Berlyne, 1957; Bloomfield, 1972; Lieberman, 1972; Schrier, Thompson, & Spector, 1980) holds that information is generally reinforcing, so that animals should behave (e.g., observe) so as to produce information of nearly any kind about primary reinforcement. The information hypothesis was contraindicated by the failure of Bowe and Dinsmoor's pigeons to observe spatial information.

Despite fairly convincing evidence that the spatial information in their two-key situation did not support observing and so was not reinforcing, Bowe and Dinsmoor's (1983) more general claim about the ineffectiveness of spatial information in the establishment of conditioned reinforcers requires further empirical tests. One of their suggested tests (p. 237) was to determine whether spatial information about where to go to *receive* food, as opposed to where to go to *produce* food by pecking on keys (Bowe and Dinsmoor's experimental situation), would prove reinforcing as measured by the acquisition and maintenance of an observing response that produced such information. In the present experiments, therefore, pigeons and rats were allowed to perform observing responses that produced stimuli conveying spatial information about which of two feeders might deliver response-independent food. According to the information hypothesis, the animals should make observing responses in such a situation since the stimuli so produced provide information (or reduce uncertainty) about where food may oc-

Preparation of this paper was supported by Program Project Grant NS 03856 from the National Institute of Neurological and Communicative Disorders and Stroke awarded to the Central Institute for the Deaf. We thank J. D. Miller for his comments on the manuscript and members of the Psychonomy Cabal for their assistance in running the experiments. Reprints may be obtained from Leonard Green, Department of Psychology, Washington University, St. Louis, MO 63130.

cur. On the other hand, the reinforcement-density hypothesis predicts that observing responses will not be emitted since there is no difference in the density of reinforcement in the presence of such spatial stimuli. As a comparison condition, in other sessions the animals were allowed to perform observing responses to produce stimuli conveying temporal information about which component of a multiple variable-time extinction schedule of reinforcement was in effect. This latter condition has been shown to result in the establishment of a conditioned reinforcer (i.e., the stimulus correlated with the variable-time component) that supports an observing response (Browne & Dinsmoor, 1974; Dinsmoor, Bowe, Green, & Hanson, 1988).

EXPERIMENT 1

Method

Subjects

Four female White Carneaux pigeons, approximately 1-1.5 years old, were maintained at 80% of their caged free-feeding weights via supplementary feedings that followed experimental sessions. Water and grit were continuously available in each bird's home cage. Before they began the present experiment, the birds had participated in a discrete-trials discrimination experiment in which red and green signal lights served as the stimuli and pecking an amber key served as the response.

Apparatus

During experimental sessions, the birds were placed in a Coulbourn Instruments pigeon chamber measuring 25 cm across the front panel, 27.5 cm from front to back, and 30 cm in height. The chamber was housed in a sound-attenuating enclosure located in a room separate from the one containing electromechanical equipment that controlled and recorded experimental events. The front panel included two response keys, a houselight, and two openings, each providing access to a food hopper. The response keys were 2.5 cm in diameter and aligned vertically, 8 cm apart, center to center, with the center of the lower key 14 cm from the floor. Each key could be transilluminated with red, green, blue, white, or amber light. The houselight was contained in a metal housing located 2 cm from the ceiling; the light was directed toward the ceiling. Each rectangular opening to a food hopper measured 5.5 cm high and 5 cm across. The food hoppers (hereafter called the "left feeder" and the "right feeder") were located on either side of the front panel such that 14 cm separated the centers of the openings, each opening was 3 cm from its nearest side wall, and the lower edge of each opening was 2.5 cm above the floor. Food deliveries were 3 sec in duration and were accompanied by illuminations of a Type 1829 bulb located within the opening of each hopper. All other sources of illumination were extinguished during food deliveries.

Procedure

Pretraining. Two birds, 21 and 28, were initially assigned to the SI (spatial-information) condition and the other two, 26 and 32, were assigned to the TI (temporal-information) condition. The birds were then exposed to five 30-min daily sessions in which stimuli conveying either spatial or temporal information were presented to the appropriate birds. During each of these sessions, the two components of a multiple variable-time (VT) 30-sec extinction schedule of reinforcement (mult VT 30-sec EXT) alternated quasi-randomly such that each component was in effect for variable periods of time averaging 30 sec. In addition, whenever the VT 30-sec component of the multiple schedule produced a food delivery, the food

could occur at either the left or right feeder. Which feeder would operate at such times (hereafter called the "correct feeder") was determined by the quasi-random alternation of a dual-state programming device that switched states on the average of every 30 sec.

For birds in the SI condition, the stimuli conveying spatial information were green and red illuminations of the lower (hereafter called "signal") key that were differentially correlated with the correct feeder. The signal key was green during periods when the left feeder was correct and red during periods when the right feeder was correct. For birds in the TI condition, the stimuli conveying temporal information were green and red illuminations of the signal key that were differentially correlated with the component of the multiple schedule in effect at the time. The signal key was green during periods when the VT component was in effect and red during periods when the extinction component was in effect. Pecks on the signal key were recorded but had no scheduled consequences throughout the experiment and are not reported in the data below. The upper (hereafter called "observing") key was dark and inoperable during the first five sessions of pretraining.

The final two sessions of pretraining involved training all the birds to peck the observing key. During these sessions, the observing key was amber. Pecks on this key produced food deliveries at the correct feeder according to variable-interval (VI) schedules of reinforcement: VI 15 sec for the first session and VI 30 sec for the second session. Sessions ended after the 20th reinforcer. None of the birds required shaping because all had been trained to peck amber response keys with food as a reinforcer in a previous experiment. The signal key was dark throughout both of the final sessions of pretraining.

Observing. During the 40 daily sessions in this part of the experiment, pecks on the observing key could produce the stimuli conveying spatial information and temporal information for birds in the SI and TI conditions, respectively. The scheduling of times and locations for food deliveries was accomplished in the same manner during each 30-min session of the observing phase as it had been during the first five sessions of pretraining. Furthermore, the stimuli conveying either the spatial information or the temporal information were the same for the observing phase as those during the first five sessions of pretraining. For birds in the SI condition, green occurred during periods when the left feeder was correct and red occurred during periods when the right feeder was correct. For birds in the TI condition, green occurred during periods when the VT component was in effect and red occurred during periods when the extinction component was in effect. Note that for the SI condition, the stimuli indicated which feeder was correct but *not* which component of the multiple schedule was in effect, whereas for the TI condition the reverse was true.

Pecks on the observing key produced, according to a VI 15-sec schedule, 20-sec displays of the red or green lights on the signal key, during which time the observing key became dark. In the absence of such displays, the observing key was amber and the signal key was dark. Besides the production of displays, pecks on the observing key within 2 sec of a scheduled food delivery postponed that delivery until 2 sec had elapsed without a peck.

Retraining. Between the observing phase and the next part of the experiment, each of the birds was exposed to seven daily sessions that were nearly identical to those of pretraining, except that each bird received a different type of information than before. During each of the first five sessions, Birds 21 and 28 were presented stimuli conveying temporal information and Birds 26 and 32 were presented stimuli conveying spatial information. For temporal information, the signal key became blue if the VT component was in effect or white if the extinction component was in effect, and for spatial information, the signal key became blue if the left feeder was correct or white if the right feeder was correct. The final two sessions of retraining were identical in procedure and purpose to the final two sessions of pretraining: Each bird was trained to peck

the observing key for food that was delivered on the first session according to a VI 15-sec schedule and on the second session according to a VI 30-sec schedule. Each session ended after the 20th reinforcer had been delivered.

Interchange. During the 60 daily sessions in this part of the experiment, birds that had been in the SI condition from the observing phase were exposed to the TI condition (21 and 28) and birds that had been in the TI condition from the observing phase were exposed to the SI condition (26 and 32). The only change in the SI and TI conditions (other than bird assignments) from the observing phase to the interchange phase was that the signal key became blue or white rather than green or red.

Results and Discussion

The mean number of pecks on the observing key as a function of session blocks (four sessions per block) is shown for each of the birds in Figures 1 and 2. These data are shown in Figure 1 for birds that were first exposed to the SI condition (21 and 28) and in Figure 2 for birds that were first exposed to the TI condition (26 and 32).

The general result of Experiment 1 was that the pigeons observed stimuli conveying temporal information about when food was likely to occur, but they did not observe stimuli conveying spatial information about where food was likely to occur. Inspection of Figures 1 and 2 reveals that this was true in all but one instance (i.e., Bird 21 during interchange; see below for a possible explanation of this exception). The data to the left of the broken lines

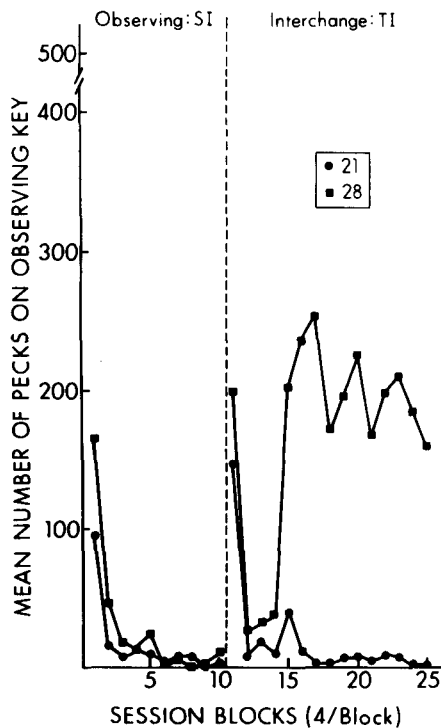


Figure 1. Mean number of pecks on the observing key as a function of session blocks (four sessions per block) for Birds 21 and 28. Data to the left of the broken line are from the observing phase; data to the right of the broken line are from interchange. SI = spatial information; TI = temporal information.

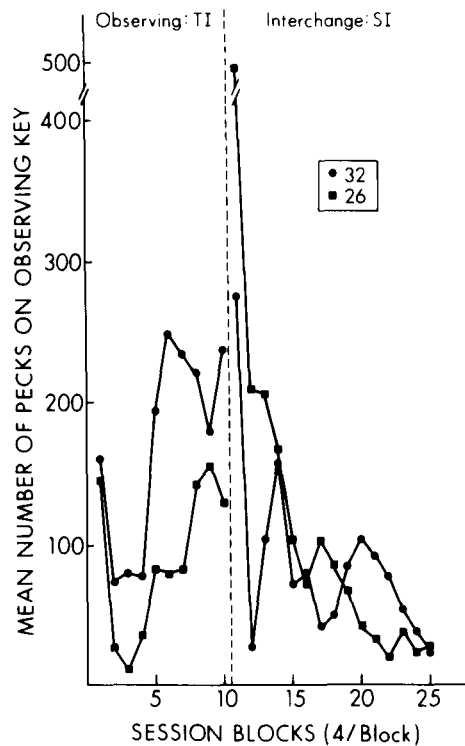


Figure 2. Mean number of pecks on the observing key as a function of session blocks (four sessions per block) for Birds 26 and 32. Data to the left of the broken line are from the observing phase; data to the right of the broken line are from interchange. SI = spatial information; TI = temporal information.

(i.e., during the observing phase) show that temporal information reinforced substantial levels of pecking on the observing key by Birds 26 and 32 (see Figure 2), but spatial information did not reinforce such observing by Birds 21 and 28 (see Figure 1). Similarly, the data to the right of the broken lines (i.e., during interchange) show that spatial information failed to reinforce observing (Birds 26 and 32; see Figure 2), whereas temporal information came to reinforce the observing of one of the two birds (Bird 28; see Figure 1). The high levels of observing exhibited by all birds during the first few session blocks of both the observing and interchange phases were largely the result of the training received by each bird just prior to those session blocks, as opposed to an exclusive result of a reinforcing effect of either kind of information. That is, each bird had produced a primary reinforcer—food—by pecking the observing key during the two sessions immediately preceding the observing and interchange phases (i.e., during pretraining and retraining, respectively). Thus, any reinforcing effectiveness of information was manifested in the present experiment by the maintenance of a substantial number of pecks on the observing key across session blocks in the observing and interchange phases.

It is important to note that the failure of Bird 21 to observe temporal information during interchange is not unusual. Some failures to acquire and/or maintain observing responses that produce such information occur in most

observing experiments (see Dinsmoor, Mueller, Martin, & Bowe, 1982), and may be expected because the observing response is reinforced by a conditioned, not a primary, reinforcer. The key feature of the present results is that temporal information reinforced observing in three of four cases and that spatial information *failed* to support any appreciable observing in four of four cases.

The present results are inconsistent with an information hypothesis of observing, but they are compatible with various conditioned-reinforcement interpretations of observing. A reinforcement-density interpretation (e.g., Bowe & Dinsmoor, 1983; Dinsmoor, 1983) predicts that the sort of temporal information employed in the present experiment will establish a conditioned reinforcer to support observing because there exists a stimulus correlated with a discriminably greater reinforcement density than is correlated with any other stimulus in the TI condition. That is, in the TI condition, the green and the blue signal-key colors (i.e., S+) from their respective parts of the experiment were correlated with a density of two reinforcers per minute. Two reinforcers per minute is greater than the reinforcement density correlated with either the dark signal key (one reinforcer per minute; i.e., the mixed stimulus on the amber observing key) or the red and the white signal-key colors (zero reinforcers; i.e., S-). Thus, according to the reinforcement-density interpretation, the birds in the TI condition performed the observing response to produce the green or blue colors that had become conditioned reinforcers via their correlation with the greatest density of primary reinforcement. Furthermore, the reinforcement-density interpretation predicts that the sort of spatial information employed in the present experiment will not establish a conditioned reinforcer to support observing, because no stimulus in the SI condition is correlated with a discriminably greater reinforcement density than is any other stimulus. All the signal-key colors in the SI condition, including the dark signal key, were correlated with the same reinforcement density: one reinforcer per minute. According to the reinforcement-density interpretation, therefore, the birds in the SI condition did not perform the observing response because no conditioned reinforcer could be produced.

EXPERIMENT 2

The results from Experiment 1 and from Bowe and Dinsmoor's (1981, 1983) experiments imply that spatial information does not reinforce the observing behavior of pigeons. Nevertheless, one could argue that observing responses of species more specially adapted to the use of spatial information than pigeons should be reinforced by the spatial information employed in these experiments. Rodents, especially rats, are thought by many to be highly attuned to the spatial relations in their environments (see, for example, Olton, 1978, or Small, 1901), and so it might be expected that their observing behavior would be rein-

forced via spatial information. Experiment 2 sought to determine whether this expectation is justified by using rats rather than pigeons as subjects in a procedure basically identical to that employed in Experiment 1.

Method

Subjects

Eight Wistar rats were maintained at 85% of their free-feeding weights via supplementary feedings that followed the experimental sessions. Water was continuously available to each rat in its home cage. Before they began the present experiment, the rats had been trained to press a lever for food delivered according to various VI schedules.

Apparatus

During the experimental sessions, the rats were placed in the same Coulbourn Instruments chamber and sound-attenuating enclosure that had been used for the pigeons, except for some changes in the front panel of the chamber. The front panel for the rats included a response lever, a houselight, a Sonalert, three red jeweled lamps, and two openings, each giving access to a pellet dispenser. The response lever was a piece of metal 3.5 cm long that extended 2.0 cm into the rat's working space from the front panel. The lever was centered on the front panel 6.5 cm above the grid floor of the chamber. The houselight was a Type 1829 bulb contained in a metal housing located 2 cm from the ceiling; the light was directed toward the ceiling. The Sonalert could deliver a 4.5 kHz tone. The three lamps were aligned horizontally and were 2.5 cm apart from one another. These lamps, which were located 8.0 cm above the response lever, provided illumination of the chamber throughout the experimental sessions. Each rectangular opening to a pellet dispenser measured 4.0 cm high and 3.0 cm across. The dispensers (hereafter called the "left feeder" and the "right feeder") were located on either side of the front panel such that 19.0 cm separated the centers of the openings, each opening was 1.5 cm from the nearest side wall, and the lower edge of each opening was 1.5 cm above the floor. Each reinforcement consisted of the delivery of a single 45-mg Noyes pellet to the appropriate feeder and was accompanied by a 0.5-sec illumination of a Type 1829 bulb located within the feeder opening. All other sources of illumination and sound were extinguished during the 0.5-sec feeder illuminations.

Procedure

Pretraining. Four rats (J6, D6, J7, and D7) were assigned to the SI (spatial-information) condition and the other four (J3, D4, J4, and D5) to the TI (temporal-information) condition. The rats were then exposed to 10 30-min daily sessions in which stimuli conveying either spatial or temporal information were presented to the appropriate rats. During each of these sessions, the two components of a mult VT 30-sec EXT schedule of reinforcement alternated quasi-randomly such that each component was in effect for variable periods of time averaging 30 sec. In addition, whenever the VT 30-sec component of the multiple schedule produced a pellet delivery, it could occur at either the left or right feeder. The feeder that would operate at such times (hereafter called the "correct" feeder) was determined by the quasi-random alternation of a dual-state programming device that switched states on the average of every 30 sec.

For rats in both conditions, the stimuli conveying information were illuminations of the houselight and occurrences of the tone. For the SI condition, the houselight was illuminated during periods when the left feeder was correct; the tone occurred during periods when the right feeder was correct. For the TI condition, the houselight was illuminated during periods when the VT component was

in effect; the tone occurred during periods when the extinction component was in effect. The response lever was not in the chamber during these first 10 sessions of pretraining.

The final three sessions of pretraining involved training all the rats to press the response (hereafter called the "observing") lever. During the first of these sessions, presses produced 10 pellets delivered according to a VI 15-sec schedule of reinforcement. On the average, each rat received an equal quantity of pellets from each feeder during this and all subsequent sessions of the experiment. During each of the last two sessions of pretraining, presses produced 30 pellets delivered according to a VI 30-sec schedule of reinforcement.

Observing: Information present. During the 60 daily sessions in the first part of the experiment, presses on the observing lever could produce the stimuli conveying spatial information and temporal information for rats in the SI and TI conditions, respectively. The scheduling of times and locations for pellet deliveries was accomplished in the same manner during each 30-min session of the observing phase as it had been during the first 10 sessions of pretraining. Furthermore, the stimuli conveying either the spatial information or the temporal information were the same for the observing phase as those during the first 10 sessions of pretraining: For rats in the SI condition, the houselight was illuminated during periods when the left feeder was correct, and the tone occurred during periods when the right feeder was correct. For rats in the TI condition, the houselight was illuminated during periods when the VT component was in effect, and the tone occurred during periods when the extinction component was in effect. Note that for the SI condition, the stimuli indicated which feeder was correct but *not* which component of the multiple schedule was in effect, whereas for the TI condition, the reverse was true.

Presses on the observing lever produced, according to a VI 15-sec schedule, 20-sec displays of either the houselight or the tone. In addition, presses on the observing lever within 2 sec of a scheduled pellet delivery postponed that delivery until 2 sec had elapsed without a press.

Observing: Information absent. During the 75 sessions in the second and final part of the experiment, all information was removed from the experimental situation. This was accomplished by eliminating the correlation between the stimuli produced via observing responses and the feeder locations or components of the multiple schedule for rats in the SI or TI conditions, respectively. Thus, for all rats, houselight illuminations and tone occurrences had no correlation with either the correct feeder location at the moment or the component of the multiple schedule in effect at the moment.

Results and Discussion

The mean number of presses on the observing lever as a function of session blocks (four sessions per block) is shown for each of the rats in Figures 3 and 4. These data are shown to the left of the line in Figure 3 for rats exposed to the SI condition during the information present phase and in Figure 4 for rats exposed to the TI condition during the information present phase. These data are also shown to the right of the line in Figures 3 and 4, when all the rats were exposed to a condition of no information during the information absent phase.

The general result of Experiment 2 was essentially identical to that of Experiment 1: Rats, like pigeons, observed stimuli conveying temporal information about when food was likely to occur but did not observe stimuli conveying spatial information about where food was likely to occur. Inspection of Figures 3 and 4 reveals that this was the case for each rat (with the possible exception of J3). Generally, rats in the TI condition pressed the observing lever much more frequently during the information present part of Experiment 1 than did those in the SI condition.

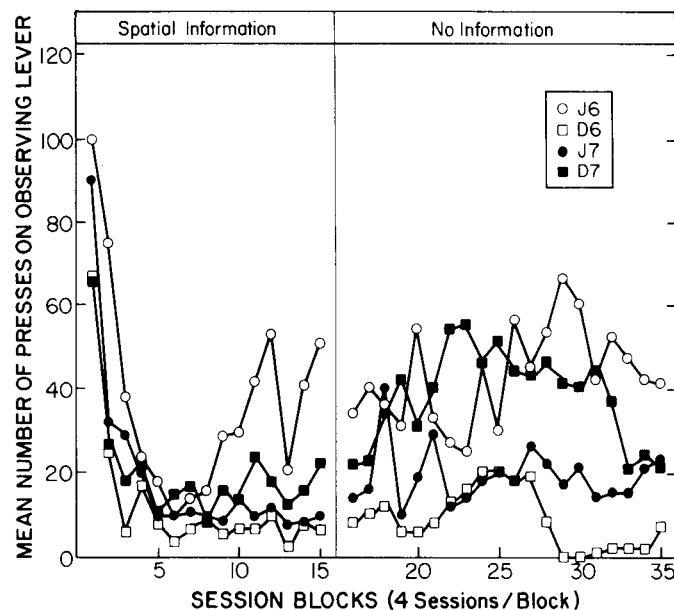


Figure 3. Mean number of presses on the observing lever as a function of session blocks (four sessions per block) for rats initially studied on the SI (spatial information) condition. Data to the left of the line are from the SI condition; data to the right of the line are from the no information condition.

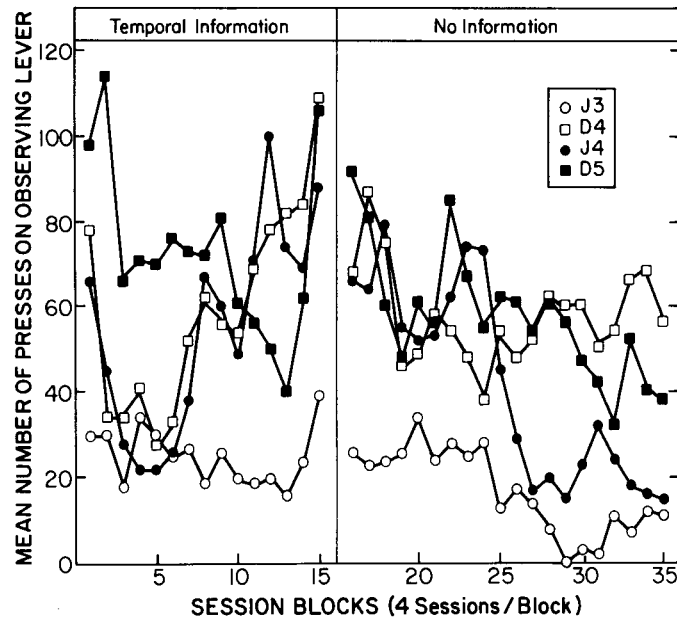


Figure 4. Mean number of presses on the observing lever as a function of session blocks (four sessions per block) for rats initially studied on the TI (temporal information) condition. Data to the left of the line are from the TI condition; data to the right of the line are from the no information condition.

Furthermore, when information of either type was removed from the situation during the information absent phase, rats in the TI condition substantially decreased their levels of pressing on the observing lever, whereas those in the SI condition did not. This can be seen more clearly in Table 1, which shows the mean number of presses on the observing lever for each rat during the last five session blocks in each part of the experiment (information present and information absent). This finding implies that (1) rats in the TI condition pressed the observing lever frequently during the information present phase because the temporal information thereby produced was reinforcing, and (2) rats in the SI condition pressed the observing lever infrequently during the information present phase because the spatial information thereby produced was not reinforcing.

Table 1
Mean Number of Observing Responses for Each Rat During the Last Five Session Blocks in Each Part of Experiment 2

Condition	Rat	Information Present	Information Absent
Spatial Information	J6	42	45
	D6	7	3
	J7	10	18
	D7	19	29
	Mean		20
Temporal Information	J3	24	9
	D4	84	59
	J4	80	21
	D5	63	41
	Mean		63

The results from Experiment 2, like those from Experiment 1, are best explained via a conditioned-reinforcement interpretation of observing (e.g., Dinsmoor, 1983), as opposed to an information hypothesis of observing. Again, in the TI condition, there existed a stimulus correlated with a greater density of reinforcement than any other stimulus in that condition (i.e., the houselight). Thus, the rats in the TI condition acquired and maintained observing during the information present phase. On the other hand, in the SI condition, there was no stimulus correlated with a greater density of reinforcement than any other stimulus in that condition. Thus, the rats in the SI condition did not acquire observing during the information present phase.

GENERAL DISCUSSION

The present results, in combination with those reported by Bowe and Dinsmoor (1981, 1983), strongly suggest that spatial information about where food can be produced or received will not reinforce the observing behavior of animals. Nevertheless, one might argue that the spatial information in all of these experiments was somehow minimal or "unimportant," so that the failure to acquire and maintain observing responses that produced spatial information was to be expected. Under both information conditions, the animals were essentially faced with a two-alternative situation in which observing responses produced one "bit" of information with respect to the state of their world. For temporal information, the stimulus displays reduced uncertainty about whether a VI or VT component versus an extinction component was oper-

ating. For spatial information, the stimulus displays reduced uncertainty about whether responding on a left key versus responding on a right key might produce food or whether food might be delivered from a left feeder versus a right feeder. Using vague notions like "worth" or "importance" of information to explain why the animals in the spatial-information conditions failed to observe begs the question of why those in the temporal-information conditions did observe. Conditioned-reinforcement accounts answer both questions with precise specifications of the conditions under which observing is and is not acquired and maintained. Furthermore, their predictions have now held across species, including humans (Case & Fantino, in press; Fantino & Case, 1983; Fantino, Case, & Altus, 1983), and one (the rat) for which spatial cues are known to be of particular importance. Information hypotheses, at best, will require further precision in specifying just what information is and is not "worthwhile" before they can again be considered viable alternatives to conditioned-reinforcement interpretations of observing.

More research than is represented by these studies is needed to determine whether the establishment of conditioned reinforcers is completely unaffected by spatial relations between stimuli and primary reinforcers, as the basic effect from these experiments has suggested. In particular, other assays for conditioned reinforcement than the observing procedure are necessary to test the generality of the effect. Under some situations, spatial cues may well maintain observing behavior, but we suggest that they would do so only when they in turn affect more fundamental variables, such as delay to or amount of primary reinforcement. And, finally, the potential significance of the effect for those who study spatial relations in areas of animal learning and behavior other than conditioned reinforcement needs further investigation.

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(Manuscript received July 13, 1987;
revision accepted for publication November 23, 1987.)