

PAVLOVIAN APPETITIVE CONTINGENCIES AND APPROACH VERSUS WITHDRAWAL TO CONDITIONED STIMULI IN PIGEONS¹

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Three experiments investigated the directed skeletal movements of pigeons toward signals of food or no food. Pigeons approached and pecked an illuminated key that was positively correlated with food delivery and positioned themselves relatively far from an illuminated key that was negatively correlated with food delivery. Key illuminations alone, random presentations of key illuminations and food, and backward pairings of key illuminations and food did not produce keypecking or consistent approach/withdrawal. Therefore, directed skeletal behavior—often believed to be conditioned and maintained primarily or exclusively by “operant” procedures—also emerges on “Pavlovian” procedures. Several kinds of alternative explanations (e.g., conditioned reinforcement effects, stimulus substitution) for these phenomena were considered, and some potential implications for operant discrimination learning were briefly explored.

Pavlovian conditioning involves the presentation of stimulus events independently of an animal's behavior. Most research with this procedure has employed restrained subjects and types of responses (e.g., glandular, visceral, and some skeletal responses like eye blinks and knee jerks) that cannot be directed toward or away from stimuli in the environment. Recently, however, several studies have examined the directed skeletal behavior of freely moving subjects in situations that otherwise fulfill the usual defining criteria of Pavlovian conditioning. For example, in their work on autoshaping, Brown and Jenkins (1968) found that pigeons approached and pecked a small circular key whose brief illumination (conditioned stimulus, or CS) signaled the imminent presentation of grain (unconditioned stimulus, or

US), even though these behaviors had no effect on grain delivery.

We were principally interested in whether there was a negative counterpart to the approach behavior evoked by food-predictive stimuli (Pavlovian positive stimuli, CS+*s*). Would pigeons withdraw from a signal (CS−) that reliably indicates grain is *not* coming? Aside from the symmetry one might intuitively expect between CS-US contingency (positive vs. negative) and locomotor behavior (approach vs. withdrawal), there are several other grounds for suspecting that subjects will be repelled by a signal of non-reinforcement. Asratian (1972) and workers in Pavlov's laboratory reported that conditioned inhibitors established with a food US come to evoke motor reactions antagonistic to the reaction to the CS+. In operant discrimination situations, several researchers (see Coughlin, 1972, for a review) have found that subjects will acquire a response that merely terminates a negative cue (S−). Furthermore, we have frequently noticed that birds which are mastering operant discriminations usually look away or walk away from the location of S− rather than merely displaying highly variable behavior or “waiting” quietly in its presence.

The usual key-pecking measures would not directly help us in determining whether the CS− evokes active withdrawal, because

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the mere absence of key pecking to a CS—fails to distinguish between a lack of behavioral control and a conditioned repulsion from the cue. Therefore, we quantitatively recorded not only pecks at CS but also the subject's physical proximity to the CS. A pivoted floor was constructed to detect whether the bird was standing on the left or right side of the chamber (see Brown, 1968, who used a situation similar to the present work). Two response keys were used and on a given trial either the left or the right key was illuminated.

We thought it likely that the birds would positively track the CS when illumination of the key signaled imminent grain delivery, i.e., they would remain on or shuttle to the side with the lighted key and peck that key. On the other hand, we expected the birds to negatively track the CS when it signaled a relatively long food-free interval, i.e., they would remain on or move to the opposite side of the chamber from the key light and probably not peck the key.

In 3 experiments we investigated the tracking behavior of pigeons as a function of various CS-US contingencies and control procedures (Hearst, 1972; Rescorla, 1967). In none of these experiments did any behaviors of the subjects—key pecking, approach or withdrawal responses, other movements around the chamber—have any programmed effect upon CS or US presentation. Nevertheless, clear acquisition of locomotor and manipulative behavior was obtained to the CSs. These findings seem particularly interesting because such directed skeletal behavior is often believed to be conditioned and maintained primarily or exclusively by means of response-contingent (operant) procedures.

EXPERIMENT 1

In Experiment 1 the sensitivity and validity of our technique for measuring approach and withdrawal movements to Pavlovian CSs were evaluated. Some subjects (positive correlation) received training in which key illumination signaled the imminent delivery of grain, whereas for other subjects (negative correlation) key illumination signaled the beginning of a relatively long period during

which grain was never presented. Two additional groups received other treatments in which USs never occurred or in which the correlation between CS and US differed from that of the 2 main groups.

Method

Subjects. The subjects were 10 experimentally naive female White Carneaux pigeons, 5-7 yr. old, maintained at 75% of their free-feeding weights. Water was always available in their individual home cages. Subjects were tested only when they were within ± 10 gm. of their 75% weights. If that criterion was met, subjects were tested daily except for the birds in the backward pairing group, which were tested 6 days a week.

Apparatus. A standard Lehigh Valley Electronics 3-key pigeon chamber was employed, but the middle key was never used (it was covered with gray tape). The 2.6-cm.-diam. left and right keys, which were 16.6 cm. apart (center to center) on the front panel of the chamber and 22.5 cm. above the floor, appeared dark when not illuminated by white light projected from individual miniature display units mounted behind each key. Only one key was illuminated on a given trial. The key lights were adjusted with a photometer for approximately equal luminance. To count as responses, pecks on either key required a minimum force of 10 gm.

Centered above the unused middle key was the house light, which remained continuously illuminated during experimental sessions. It was located in a chrome housing that directed its light toward the ceiling. Sixteen centimeters below the house light and 8 cm. above the floor was an aperture (5.6 \times 5 cm.) containing a solenoid-operated grain magazine which, whenever a US was scheduled, was lighted and raised into an accessible position for 3 sec. A ventilating fan and a white noise (coming from a speaker located 2 cm. above and slightly to the left of the grain magazine) remained on during sessions to mask extraneous sounds from the programming circuitry and recording equipment in an adjoining room.

A specially constructed Bakelite floor was installed and pivoted so as to record the pigeon's position in the experimental chamber. The fulcrum of this "teeter-totter" floor was in a plane perpendicular to the key-magazine panel and bisected the chamber into left and right halves (17.5 cm. on each half) at the midline of the grain magazine. The normally open and normally closed contacts of a small microswitch beneath the right side of the floor detected whether the bird was standing on the right or left side of the chamber. Thus, the pigeon's location in the box was partitioned into mutually exclusive and exhaustive categories, "on left side" and "on right side."

Procedure. Preliminary (magazine) training was the same for all subjects except those in the CS-

only group. Each bird was placed in the test chamber with the magazine lighted, accessible, and filled with grain. After the subject had eaten for approximately 20 sec., the magazine was lowered. Thereafter, grain was accessible for 3-sec. periods at irregular intervals. If a bird failed to eat during 3 successive grain presentations, the magazine was held in its raised position until the subject had eaten for 3 sec. This preliminary session ended when the bird had eaten grain efficiently during 20 3-sec. presentations.

Experimental training began on the following day and differed for subjects placed in each of the 4 conditions. For all subjects, however, each session included 20 10-sec. illuminations of the left key and 20 10-sec. illuminations of the right key (total CSs = 40). The sequence of left and right key illuminations was nonsystematic, with the constraint that no more than 3 trials in a row could involve the same key. During intertrial intervals both response keys remained dark. The intertrial intervals varied in length around a mean of 86 sec. (range: 20-152 sec.).

For all subjects except those in the CS-only condition, 40 3-sec. grain presentations also occurred each session. The relationship between CS (key light) and US (grain) was varied in the different groups as follows:

1. Explicitly paired: For the 3 birds in this condition, the 40 daily grain presentations immediately followed the 10-sec. illuminations of either the left or right key. Because of the positive correlation between CS and US in this group, the key light should become a signal for the occurrence of food.

2. Explicitly unpaired: For the 3 birds in this condition, the 40 daily grain presentations occurred in the intertrial interval when the keys were dark, and were scheduled so that they never followed key illumination by less than 33 sec. and never preceded key illumination by less than 20 sec. Because of the negative correlation between CS and US in this group, the key light should become a signal for the nonoccurrence of food.

3. CS only: The 2 subjects in this group received 40 daily key illuminations, but grain presentations never occurred. This group permits assessment of any possible unconditioned tendency of pigeons to approach or withdraw from lighted keys.

4. Backward pairing: Each of the 40 key illuminations in this group of 2 birds was immediately preceded by a 3-sec. grain delivery. Some investigators (e.g., Siegel & Domjan, 1971) consider the backward conditioning paradigm to produce an inhibitory CS (it initiates a relatively long period during which the US will not occur), and therefore such a procedure might produce withdrawal from the CS.

Experimental sessions on the above procedures lasted slightly over 1 hr. and continued for 20-21 days. During the remainder of the experiment, most birds were tested on several of the other

conditions. Subjects in the CS-only group were given a standard session of magazine training before placement on another procedure. Details of the subsequent treatment of individual birds will be described in the results section.

In addition to measures of key pecking during trials and intertrial intervals, we recorded (in tenths of a second) the cumulative amount of trial time that the pigeon stood on the same side of the chamber as the lighted key and the amount of time the bird stood on the opposite side of the chamber. An approach/withdrawal ratio was derived from these measures and indicated whether the pigeon was attracted to or repelled by the lighted key. This ratio was calculated by the formula: total time on the same side as the key light ÷ total trial time. A ratio of .50 would indicate that the bird's movements were not controlled by the key light. Ratios near 0.0 or 1.00 would indicate very strong withdrawal or approach, respectively.

Results and Discussion

Although our presentation of the results focuses on approach vs. withdrawal behavior under the different experimental treatments, the key pecking results of each group will first be described, and their similarity to prior observations concerning conditioning in a single-key situation will be pointed out.

All the birds in the explicitly paired group began pecking the lighted key by the second session of training, and during the fourth session each of the 3 subjects in that group pecked the key on more than 87% of the trials, regardless of whether the right key or the left key was illuminated. Responding to the lighted keys generally remained at this high level throughout the rest of the 21 days that subjects stayed on this procedure. Subjects in the explicitly unpaired, backward pairing, and CS-only groups almost never pecked the lighted key. No bird in the explicitly unpaired group ever pecked it during 21 days of training (840 trials), nor did any bird in the backward pairing group (20 days, 800 trials). In the CS-only group, one bird pecked on one of its 840 trials and the other bird pecked on only 3 trials.

It is clear, therefore, that the contingency between CS and US is responsible for the large amount of key pecking in the explicitly paired group. This behavior is not due to any unconditioned tendency of birds to peck intermittently lit keys, nor due to simple stimulus generalization from pecking at grain

in the white-lighted magazine to pecking at any other white-lighted, relatively brief stimulus (thus invalidating the suggestion about autoshaping made by Logan, 1971, p. 51). These findings also suggest that conditioned approach-and-contact behavior develops as readily in a situation in which 2 keys are used and each lit in a random sequence, as it does in the conventional single-key situation.

Figure 1 presents group data summarizing approach/withdrawal behavior under the 4 different initial treatments. The groups fall into 3 distinct categories. The CS-only and backward pairing subjects performed similarly and showed ratios near .50. Explicitly paired subjects consistently approached the CS, and explicitly unpaired subjects kept away from the CS. After the first training block (Sessions 1-4), there was no overlap in individual mean ratios between birds in the explicitly paired group, the explicitly unpaired group, and the combined group of CS-only and backward pairing subjects.

Table 1 presents approach/withdrawal ratios from individual subjects exposed to one or more experimental treatments. These data provide convincing confirmation of the differences in locomotor behavior to positive and negative Pavlovian CSs indicated in the group curves in Figure 1. All 7 birds trained under both explicitly paired and explicitly unpaired conditions evidenced consistent ap-

TABLE 1
MEAN APPROACH/WITHDRAWAL RATIOS OVER
LAST FIVE DAYS OF VARIOUS TREATMENTS

Bird	Explicitly paired	Explicitly unpaired	Conditioned stimulus only	Backward pairing
7760	.96(1, 21)	.33(2, 8)	—	—
4024	.96(1, 21)	.32(2, 21)	—	—
2844	.90(1, 21)	—	—	—
2818	.67(2, 21)	.25(1, 21)	—	—
1877	.55(2, 21)	.35(1, 21)	—	—
7102	.96(2, 21)	.27(1, 21)	—	—
750	.92(2, 10)	.29(3, 16)	.48(1, 21)	—
263	.94(2, 10)	.42(3, 16)	.50(1, 21)	—
2886	—	—	—	.44(1, 20)
2748	—	—	—	.49(1, 20)
<i>M</i>	.86	.32	.49	.47

Note. The first number in parentheses denotes the ordinal position of that treatment; the second number denotes the number of training sessions on that particular treatment.

proach and withdrawal over the last 5 sessions on each treatment (mean ratios of .85 and .32, respectively).

The order of presentation of the various treatments appeared to influence approach/withdrawal behavior as well as key-pecking behavior. After explicitly unpaired training, placement on the explicitly paired procedure did lead to consistent approach behavior. However, in 2 of the 3 birds, approach ratios never reached the high levels achieved by pigeons initially placed on the paired procedure or by birds placed on the paired procedure following CS-only training. Initially unpaired subjects also showed a retardation in the emergence of key pecking on the paired procedure. Eventually 2 of the 3 birds attained a high level of pecking; however, it took Bird 2818 15 sessions and Bird 7102 17 sessions before they responded on 75% of a day's trials. The other subject (Bird 1877) generally pecked on only one trial per session even after a 3-wk. exposure to the paired procedure. No such proactive interference effects were obtained when CS-only training preceded paired training. By Day 3 each of the 2 birds responded on more than 87% of a day's trials. Previous experience with nonpositively correlated CS and US thus interferes with approach and key pecking when CS and US are later positively

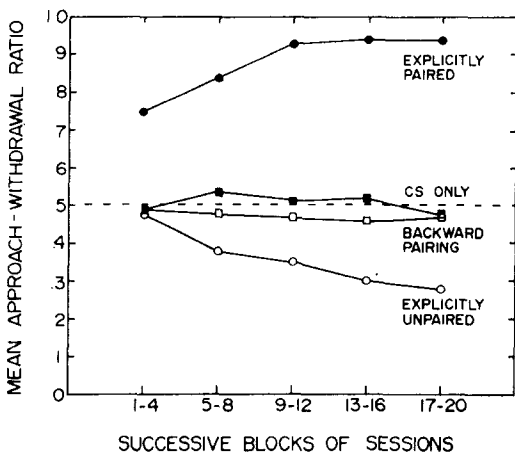


FIGURE 1. Mean approach/withdrawal ratios over successive blocks of sessions on the 4 initial experimental treatments of Experiment 1.

correlated (see Gamzu & Williams, 1971, as well as Experiment 2 here).

Thus, Experiment 1 showed that birds not only approach and peck a spatially shifting signal which indicates that food reinforcement is imminent, but they also position themselves relatively far away from a signal that food reinforcement is not coming. Our approach vs. withdrawal measure was much more sensitive to changes in CS-US contingency than were measures of key pecking. Brown (1968) also reported that on a paired procedure, approach to CS occurs prior to and sometimes in the absence of consistent key pecking, and H. M. Jenkins (personal communication, November, 1972) has remarked on the reliability of approach behavior even in birds that fail to peck the key very frequently or directly in some of his autoshaping situations.

No clear-cut withdrawal from CS was observed in birds on the backward pairing treatment, although 28/40 ratios (2 subjects, 20 sessions each) did fall below .50. Therefore, little support was provided in this experiment for the hypothesis that backward pairings produce a negative CS.

EXPERIMENT 2

Experiment 1 showed that the type of CS-US contingency controls the spatial proximity of a subject to CS. In the explicitly paired condition of that experiment the illumination of the key light signaled that a grain presentation would occur in exactly 10 sec. Rescorla (1969) and Gamzu and Williams (1971) have preferred to use conditioning procedures in which there is a fixed probability of US occurrence at any given time during the periods when USs are potentially available. We based Experiment 2 on the probabilistic treatments of this kind used by Rescorla. Under a positive contingency programmed on such a basis, USs can occur only during or shortly after the CS, but they may be triggered during any brief (4 sec. in Experiment 2) interval of that time span; each CS is not a signal of inevitable and impending US delivery as in Experiment 1, but simply indicates a period during which USs may occur. Under a negative contingency, USs cannot occur

during or shortly after CS presentation; however, they may occur in any other 4-sec. period of the session. Under a random contingency, USs occur with the same probability during each 4 sec. of the experimental session, regardless of CS presentation. The inclusion of a random contingency group in this experiment allowed us to compare the effects of positive and negative CS-US contingencies with a control procedure (see Rescorla, 1967) not run in Experiment 1.

Experiment 2 involved 2 further procedural modifications. In addition to recording the total amount of trial time spent close to and away from the CS, we also measured approach/withdrawal behavior as a function of the pigeon's location in the box at trial onset. Such data would permit more precise interpretation of the overall approach/withdrawal ratios. For instance, do subjects on an explicitly unpaired procedure not only passively avoid approaching the CS when they happen to be standing on the opposite side at CS onset, but also actively withdraw from CS when they happen to be standing on the same side at CS onset? Furthermore, in Experiment 2, all subjects were exposed to each of the 3 CS-US contingencies, which allows a between- and within-subject assessment of treatment effects.

Method

Subjects. The subjects were 7 experimentally naive female White Carneaux pigeons, 5-7 yr. old, maintained under the same motivational and housing conditions as the birds in Experiment 1. The subjects were tested 6 days a week.

Apparatus. The same conditioning chamber and accessory equipment were used as in Experiment 1.

Procedure. Unless mentioned below, the procedure was the same as Experiment 1.

Presentation of key lights and grain began on the day following magazine training. For all subjects in the 3 treatment groups there were 30 key light presentations daily, 15 of the left key and 15 of the right key, occurring in a nonsystematic order. Each key was lit for 10 sec. per trial; the intertrial interval averaged 120 sec. (range: 90-150 sec.). All grain presentations lasted 3.5 sec.

The 3 treatment groups differed in terms of the correlation between the illumination of the key and the delivery of grain. A random probability generator was periodically activated when grain delivery was possible (never during USs). The

output of the generator was sampled every 4 sec. and the probability of a positive pulse from the generator was set at .06 for each such sample. Whenever a positive pulse occurred, grain was immediately delivered. Thus, during the periodic pulsing of the generator, USs occurred about once every 67 sec.

The treatment of the 3 groups was as follows:

1. Positive contingency: The probability generator was sampled only during the 10-sec. key-light periods and during the 30-sec. interval immediately following CS offset. The 2 birds in this group received an average of 18 reinforcements per session.

2. Negative contingency: The probability generator was sampled during the intertrial interval but never during the 40-sec. period initiated by CS onset (i.e., 10 sec. of key light and 30 sec. of post-CS time). The 3 birds in this group received approximately 40 reinforcements per session.

3. Random contingency: The probability generator was sampled throughout the entire session. Reinforcements were thus equiprobable during CSs, the 30-sec. post-CS interval, and the remainder of the intertrial interval. The 2 birds in this group received approximately 60 reinforcements per session.

All subjects remained on the above procedures for 14 sessions. Thereafter, the birds were placed on each of the other 2 procedures. Details of these subsequent manipulations will be described in the results section.

Results and Discussion

During initial training (Sessions 1-14), key pecking emerged and continued only in birds exposed to a positive CS-US correlation. By Session 7 each of the 2 subjects given the positive contingency had pecked the CS on 90% or more of a day's trials (pecks at the unlit key during the intertrial interval and post-CS period were quite infrequent). However, pecking at the CS generally occurred less often and was more erratic in Experiment 2 than in Experiment 1. This outcome is probably due to the way in which the positive CS-US correlations were defined in the 2 experiments: in Experiment 1 CS onset was always followed 10 sec. later by US delivery, whereas in Experiment 2 some trials passed without US delivery and the exact time of occurrence of the US was unpredictable. None of the 3 subjects given the negative contingency ever pecked the lighted key (14 sessions, 420 trials). One of the random contingency subjects pecked the CS on 2 trials, but the other subject never pecked the CS during the 2 wk. of

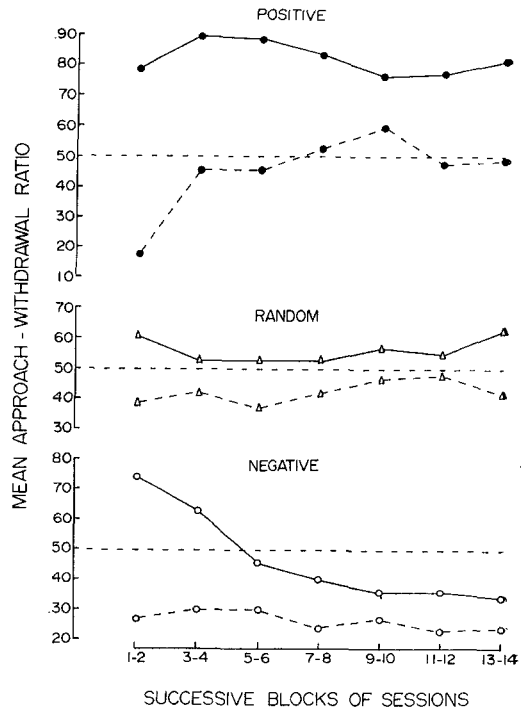


FIGURE 2. Mean approach/withdrawal ratios over successive blocks of sessions on the 3 initial experimental treatments of Experiment 2. (Solid lines connect ratios obtained on trials initiated when the subject happened to be standing on the same side of the chamber as the CS; broken lines connect ratios on trials initiated when the subject happened to be standing on the opposite side.)

initial training. Post-CS and intertrial pecks were very infrequent in random and negative contingency pigeons.

Figure 2 shows group data summarizing approach/withdrawal behavior under the 3 different initial treatments. As can be seen, the 3 treatment groups differed greatly in their behavior. The random contingency subjects tended to respond unsystematically to the lighted key; overall ratios ranged at or near .50. Ratios slightly greater than .50 were obtained when a trial started with the bird on the same side of the box as the CS and ratios slightly less than .50 were obtained when a trial began with the subject on the side of the chamber opposite the CS.

Positive and negative contingency subjects displayed effects opposite to each other. Over the 2 wk. of initial training, positive subjects tended to remain on the same side

TABLE 2
MEAN APPROACH/WITHDRAWAL RATIOS OVER
LAST FIVE DAYS OF VARIOUS TREATMENTS

Bird	Positive	Random	Negative
844	.66(1, 14)	.40(3, 10)	.43(2, 10)
585	.66(1, 14)	.44(3, 10)	.39(2, 10)
885	.63(2, 10)	.51(1, 14)	.39(3, 10)
762	.60(3, 10)	.56(1, 14)	.33(2, 10)
875	.58(2, 10)	.54(3, 10)	.27(1, 14)
1100	.61(2, 10)	.59(3, 10)	.26(1, 14)
503	.53(2, 10)	.41(3, 10)	.34(1, 14)
<i>M</i>	.61	.49	.34

Note. The first number in parentheses denotes the ordinal position of that treatment; the second number denotes the number of training sessions on that particular treatment.

of the box as the CS, and negative subjects tended to remain on the opposite side of the box from the CS. When a trial began with the subject on the side opposite to CS, positive contingency subjects showed an increased likelihood of approaching the CS throughout initial training; on the other hand, negative contingency subjects showed an increased likelihood of withdrawing from the CS as initial training progressed. Thus subjects administered the negative CS-US contingency not only passively avoided approach to the CS, but also actively moved away from the CS when they were near to it at trial onset.

In the present experiment, withdrawal from CS under the negative contingency was somewhat stronger than approach toward CS under the positive contingency. Over the last 5 days of initial training, the positive group had a mean ratio of .66 (.16 above chance) and the negative group had a mean ratio of .29 (.21 below chance). The reverse direction of effects had occurred in Experiment 1: the paired group had a mean ratio of .94 (.44 above chance) and the unpaired group had a mean ratio of .29 (.21 below chance). Therefore, the magnitude of approach vs. withdrawal effects is contingency dependent; one is not invariably larger than the other.

Table 2 presents approach/withdrawal ratios from individual subjects exposed to the 3 experimental contingencies. With high consistency, the behavior of the subjects

changed according to the different reinforcement contingencies. Six out of the 7 birds evidenced ratios ordered positive > random > negative.

As in Experiment 1, the presentation order of the various treatments seemed to influence approach and key pecking behavior on the positive-contingency procedure. A mean ratio of .66 was obtained when subjects were first placed on the positive contingency, but the ratio was only .59 if either random or negative training had occurred earlier. Moreover, only 1 of the 5 birds (885) placed on the positive contingency subsequent to random and/or negative training pecked the CS on more than one trial (10 days, 300 trials).

These findings provide a systematic replication of many of the results of Experiment 1. They indicate that conditioned approach and withdrawal also occur in a situation in which CSs are probabilistically related to US presentation; subjects approach and contact a CS which indicates a period of relatively high reinforcement probability (Experiment 2) as well as a CS which signals inevitable reinforcement x seconds after CS onset (Experiment 1). In addition, conditioned approach and withdrawal occur both within individual subjects and between separate groups of subjects when viewed in relation to the behavior achieved under a random correlation of CS and US. Such directed skeletal behavior obviously depends on CS-US contingencies and thus is "associative" in nature.

EXPERIMENT 3

In the first 2 experiments we found that subjects approached and pecked a signal of US presentation and positioned themselves relatively far away from a signal of non-reinforcement. Subjects were exposed to these 2 kinds of signal either in separate treatments given different groups or in separate phases of work with a particular subject. Standard Pavlovian discrimination training can be considered a procedure that includes both types of signal during each session, one (CS+) a reliable signal of US presentation and the other (CS-) a reliable signal that the US will not occur for a rela-

tively long time (if one includes the inter-trial interval that follows every stimulus presentation). Therefore, in Experiment 3, individual birds received daily trials of both CS+ and CS-, a procedure which permits a within-subject, session-by-session analysis of the kinds of effects previously obtained in the separate treatments of Experiments 1 and 2. On the basis of the prior work, we expected birds to approach and peck CS+ and to move away from CS-.

Because Experiment 3 was the first study of this kind to employ a discrimination procedure, and we did not know in advance what the optimal conditions would be for obtaining consistent and substantial results, we placed different birds on visual discriminations of ostensibly different difficulty (*easy*: a vertical black line on an otherwise white key vs. a blank white key; *hard*: a vertical line vs. a line tilted 45° clockwise). After an extended period of discrimination learning, the discrimination was reversed and changes in approach/withdrawal measures and key pecking were examined over 15 sessions on the reversal of the original discrimination.

Method

Subjects. The subjects were 4 experimentally naive female White Carneaux pigeons, 5-7 yr. old, maintained under the same motivational and housing conditions as the birds in Experiments 1 and 2. All subjects were tested 6 days a week.

Apparatus. The same chamber and accessory equipment were used as in the first 2 experiments. Besides the blank white key lights presented as stimuli in Experiments 1-2, on certain trials the miniature display units behind each key presented either a black vertical line (0°) or a black line tilted 45° clockwise from vertical. These lines (.32 cm. wide) bisected the response keys and appeared on a white background. All stimuli were initially adjusted as closely as possible for equal luminance and were rechecked occasionally for approximate equality. For the US, birds received 4-sec. opportunities to eat grain.

Procedure. After magazine training, subjects received 60 10-sec. key illuminations per session, 30 of the right key and 30 of the left key. The inter-trial interval averaged 40 sec. (range: 16-64 sec.). Thirty of the daily trials (15 left key and 15 right key illuminations) were CS+ presentations, all of which were immediately followed by the US. The other 30 trials (15 left, 15 right) were CS- presentations, none of which was ever followed by the US. Two of the birds received presentations of either the vertical line on the key or a blank white

key; for one bird the vertical line was CS+ and the blank key was CS-, whereas for the other bird the functions of the 2 stimuli were reversed. The other 2 birds were presented with stimuli that were presumably harder to discriminate than those in the first subgroup: a vertical line vs. a 45° line. For one bird the vertical line was CS+ and the 45° line was CS-, and for the other bird the functions of the 2 line tilts were reversed. Sequences of right and left key illuminations, and CS+ and CS- presentations, were nonsystematic, with the constraint that no more than 4 stimuli in a row could be CS+ or CS-, and no more than 2 in a row could appear on the left or right key.

The subjects stayed on their respective discrimination procedures for 20 sessions. Immediately after termination of that phase, the discrimination was reversed for each bird; its original CS+ became CS- and its original CS- became CS+. Discrimination reversal continued for 15 sessions.

Measures of key pecking and time spent on the same and opposite sides of the chamber as the lighted key were separately tabulated for CS+ and CS- trials throughout the experiment.

Results and Discussion

Within 3 days of initial discrimination training, each of the 4 birds had begun pecking both CS+ and CS-. As training progressed, pecking became limited to CS+ periods only. As an index of discriminative performance, a discrimination ratio was computed each day and was of the form: CS+ pecks ÷ (CS+ pecks + CS- pecks). Discrimination ratios of .90 and 1.00 were achieved after means of 5.75 and 9.50 sessions, respectively, indicating that the visual discriminations were quickly and completely mastered. There was no obvious difference in the relative difficulty of the 2 discriminations (see Figure 3).

The approach/withdrawal performance of all 4 subjects during both initial discrimination training (Days 1-20) and discrimination reversal (Days 21-35) is shown in Figure 3. Subjects initially approached both CS+ and CS-. At or shortly after reaching the .90 (key pecking) discrimination ratio, approach toward CS- gave way to withdrawal. This withdrawal behavior was consistent and persistent in 3 of the 4 birds, and ranged .30-.40 over the last 5 days of initial training.

During discrimination reversal, the key-pecking and approach/withdrawal behaviors to former CS+s and CS-s were corre-

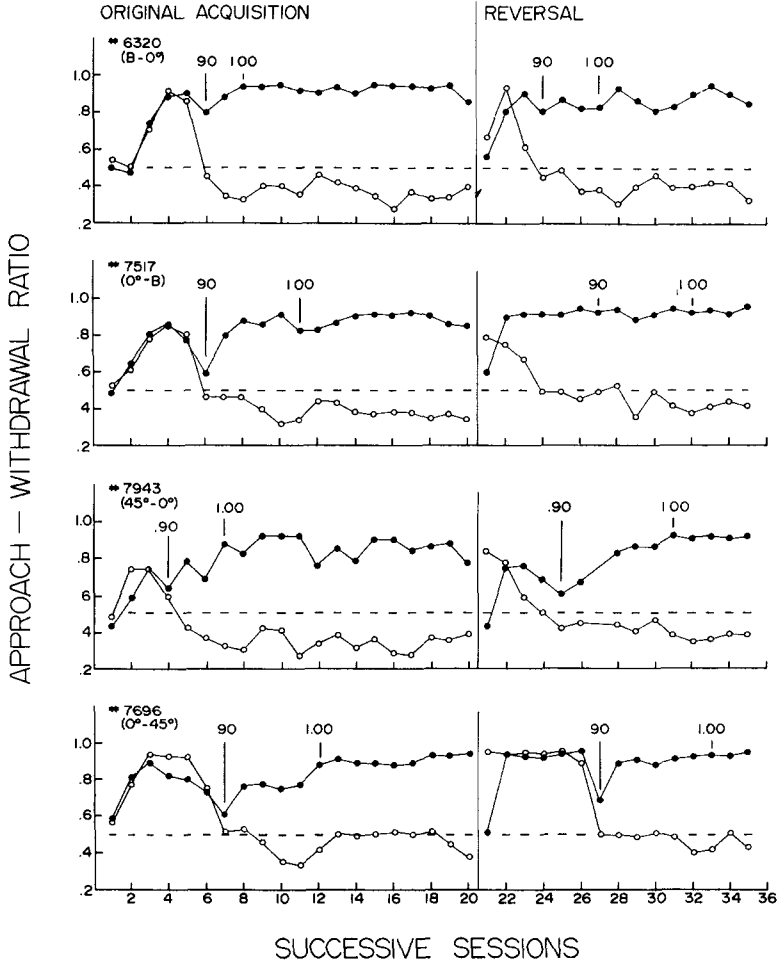


FIGURE 3. Approach/withdrawal ratios obtained on CS+ (closed circles) and CS- (open circles) trials from 4 individual subjects undergoing discrimination training (20 sessions) and subsequent discrimination reversal (15 sessions). (Indicated on each record are [a] the points at which the subject first achieved .90 and 1.00 discrimination criteria [derived from keypecking measures], and [b] the specific discrimination [0° vs. blank; 0° vs. 45°] assigned to the subject during the first 20 sessions of training [the first named value was CS+].)

spondingly reversed. Means of 5.75 and 10.75 sessions were required to reach .90 and 1.00 discrimination ratios for key pecking. Once again, movement away from CS- developed in 3 of the 4 birds at or just after the .90 ratio for key pecking was met. Those 3 subjects that did display consistent withdrawal from CS- tended to perform slightly worse during discrimination reversal than during original discrimination training, although asymptotic approach levels to CS+ appeared unaffected.

Therefore, approach and withdrawal be-

havior toward Pavlovian CS+s and CS-s also occurs in a situation in which subjects receive a mixed sequence of both such stimuli. These effects are manifested during the initial formation of a successive visual discrimination and during the discrimination's subsequent reversal.

GENERAL DISCUSSION

The present set of experiments demonstrates that despite the absence of any programmed contingency between behavior and US delivery, subjects may acquire consistent

and relatively permanent locomotor and manipulative responses to initially neutral stimuli that predict the presentation or nonpresentation of US. Specifically, pigeons will approach and peck a discrete visual stimulus that signals food delivery and will remain away or move away from the same stimulus when it signals a relatively long period without food. These conditioned skeletal movements are a result of what are usually considered Pavlovian associative procedures (positive or negative contingencies between CS and US: Hearst, 1972; Rescorla, 1967); they do not develop reliably in subjects exposed to CSs only, or to CSs and USs presented independently of each other.

Our floor-position measure of proximity to the CS proved to be a simply implemented and rather sensitive index of one aspect of this conditioned tracking behavior. The technique may be useful in future research on the conditioning of locomotor behaviors with both operant and Pavlovian training procedures. It might also help experimenters to determine in a variety of contexts whether consistent behaviors do develop to stimuli which may (wrongly) be judged ineffective if only a single response measure (e.g., key pecking) is taken (see Jensen, 1970).

Some Possible Mechanisms

So far in this report, our approach to the problem of CS tracking (or "sign-tracking," as E. Hearst and H. M. Jenkins, in preparation, call it) has been largely atheoretical. However, the question ultimately arises as to the mechanism(s) responsible for this phenomenon. At least 3 possible types of explanation, not mutually exclusive or sometimes even easily distinguishable, have occurred to us. We will state these possibilities and comment briefly upon them.

Evolutionary approach/withdrawal. One possible explanation of positive and negative tracking behavior is an elaboration of the idea that because of obvious survival value, adaptive life forms instinctively approach and contact appetitive stimuli and flee from aversive stimuli (Glickman & Schiff, 1967). After association with pleasant (food) or unpleasant (no food) events, CSs

also evoke innate approach and withdrawal responses. These locomotor behaviors are likely to be importantly influenced by the localizability of such events and signals (see Marler & Hamilton, 1966). Only spatially discrete stimuli would be expected to give rise to behavior aimed at or directed away from CSs.

This emphasis on the spatial characteristics of a stimulus adds a relatively novel dimension to the list of stimulus attributes generally stressed in the control of conditioned responses. However, whether appeal to rather vague instinctive approach/avoidance tendencies is necessary to account for tracking behaviors might be questioned.

Conditioned reinforcement. Rather than calling upon instinct as the mechanism which brings animals in contact with or pushes them away from CSs, a learning account might invoke the concept of conditioned reinforcement. The correlation of formerly neutral stimuli with positive reinforcers and with the absence or removal of positive reinforcers may produce positive and negative conditioned reinforcers, respectively. Positive and negative tracking behaviors may therefore arise and be strengthened in operant fashion, because such responses bring animals into closer contact with positive conditioned reinforcers and move them away from negative conditioned reinforcers.

To us, this kind of explanation seems to beg the question of why subjects approach and withdraw from CSs in the first place, especially in situations like ours where such behaviors have no effect on US delivery. Indeed, in the case of the positive CS-US contingencies which we studied, approach and contact of CS actually removed the pigeon from the magazine opening and thereby delayed the bird's receipt of food and decreased the duration of food availability (see also the relevant comments of Brown, 1968, on observing responses, and Williams & Williams, 1969, on negative automaintenance effects and "superstitious conditioning" explanations of autoshaping).

Stimulus substitution. A Pavlovian account of tracking behavior could consider approach, withdrawal, or contact responses as components of unconditioned response pat-

terns to the presentation and removal (or absence) of appetitive USs. With positive CS-US correlations, the subject may respond to the CS as if it were the US—in our case by approaching and pecking it and in other cases by approaching and exhibiting CRs bearing a marked similarity to URs (Jenkins & Moore, 1973; Peterson; Ackil, Frommer, & Hearst, 1972). With negative CS-US correlations, the subject should respond to the CS as it would to the nonoccurrence of food—presumably by retreating from it.

This explanation is not without its problems, however. For example, it is unclear to what extent the nonoccurrence of food can be considered an unconditioned stimulus. An event such as the absence of the US is not a stimulus that experimenters can easily present to an organism in a brief and discrete manner, and thus actual unconditioned responses to such a stimulus are especially difficult to measure.

At the empirical level, recent studies cast some doubt on the stimulus-substitution account. Animals may approach and contact CSs even though the appetitive USs they precede do not themselves evoke approach and contact (hypothalamic brain stimulation, Peterson et al., 1972; heat reinforcement in Wasserman, 1973).

The 3 possible mechanisms we have mentioned, considered either singly or in combination, do not seem to provide a completely adequate explanation of conditioned tracking behavior. Further analytic experiments should be performed before any of these possibilities is excluded or any different account is accepted.

An Extension

In addition to the possible behavioral mechanisms controlling conditioned tracking behavior, we have been interested in the possibility of extending our findings to other effects observed in operant discrimination situations. For example, after non-differential reinforcement of 2 successively presented stimuli, the programming of extinction during one stimulus (S⁻) leads to a reduced frequency of operant response to that stimulus and an increased frequency of response to the reinforced stimulus (S⁺).

Since operant discrimination training inevitably establishes positive and negative correlations of S⁺ and S⁻ with reinforcement, then effects paralleling those observed in the present experiments with response-independent reinforcement may play an important role in the emergence of the operant discrimination. Positive tracking would serve to amplify S⁺ responding, whereas negative tracking would take the subject out of close physical contact with S⁻ and correspondingly attenuate S⁻ responding.

This interpretation would not, of course, provide a complete explanation of operant discrimination learning. However, by relating these effects to possible Pavlovian origins, we may be able to derive some novel implications, explainable in operant terms with great difficulty (if at all). These implications would relate primarily to the physical arrangement of cue and response. For example, behavioral contrast (the response-rate increase to S⁺ in operant discrimination learning) should be maximal with localized cues to which responses are directed (like visual cues projected upon pigeon pecking keys). Furthermore, response reduction to S⁻ should be faster with cues localized on the response manipulandum rather than on other environmental features or with cues (like tones) diffusing throughout the whole environmental space.

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