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Approach and Withdrawal Behavior in Pavlovian Aversive Conditioning in the Pigeon[1]

Aproximación y retiro en condicionamiento pavloviano aversivo en palomas

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ABSTRACT

Groups of pigeons were exposed to several types of correlations between keylight and shocks, the pigeons' behavior was measured as approach or withdrawal from the keylight. Experiment 1 showed that a signalled avoidance task is learned faster when the instrumental response is to withdraw from the signal than when it is to approach the signal. Experiment 2 showed withdrawal behavior from the keylight in a purely Pavlovian procedure, but failed to show the approach towards a Pavlovian inhibitor. Experiment 3 showed approach to a keylight between-sessions negatively correlated with shocks, whereas such a behavior was not observed in control groups. Thus, both Pavlovian exciters and inhibitors can elicit behavior which reflect the hedonic consequences of the presentation and omission of a reinforcer.

DESCRIPTORS: Approach and withdrawal, Signalled avoidance, Pavlovian aversive conditioning, shocks, pigeons.

RESUMEN

Se expusieron grupos de palomas a varios tipos de correlaciones entre la luz de la tecla y choques eléctricos, y se midió la aproximación o retiro de la techa. El Experimento 1 mostró que una tarea de evitación señalada se aprende más rápidamente cuando la respuesta instrumental es retirarse de la luz que cuando la respuesta es de aproximación a la luz. El Experimento 2 demostró la provocación de la conducta de retiro por la luz en un procedimiento Pavloviano, pero no demostró la provocación de aproximación por el inhibidor Pavloviano. El Experimento 3 mostró aproximación a la luz cuando está negativamente correlacionada entre sesiones con los choques, y que ese comportamiento no se observó en el grupo control. Por lo tanto, tanto los excitadores como los inhibidores Pavlovianos pueden provocar respuestas que reflejan la naturaleza hedónica de la presentación u omisión del reforzador.

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For over a decade a great deal of attention has been given to the general question of what a freely-moving animal does when exposed to a stimulus which occurs at a specific and identificable location and is related to the ocurrence of some reinforcer. However, this problems has very largely been studied in experiments employing only positive reinforcers. As various reviews of auto-shaping or sign-tracking have indicated (e.g., Hearst & Jenkins, 1974; Schwartz & Gamzu, 1977; Terrace, 1981), relatively little is known about conditioned behavior that may be directed towards or away from stimuli signalling the presence or absence of aversive events. Available evidence suggests the existence of effects which are the reverse of those found with positive reinforcement; that is, just as an excitatory stimulus (CS+) for food or water comes to elicit approach movements and a corresponding inhibitory stimulus (CS—) produces withdrawal, an animal may move away from a stimulus signalling the delivery of shock and move towards one signalling the absence of shock. Although this possibility was first raised some years ago (Hearst & Jenkins, 1974; Mowrer, 1960), until quite recently the evidence bearing on it was wither indirect or otherwise unsatisfactory.

One source of evidence is from experiments involving conditioned suppression of a baseline instrumental response. Karpicke, Christoph, Peterson & Hearst (1977) varied the distance between the CS+, a light followed by shock, and the manipulandum used for the food-reinforced instrumental response. They found that rates of either chain-pulling or lever-pressing were more suppressed when the CS was close to the manipulandum than when at some distance. The explanation they offered was that decreased instrumental responding resulted from the animal moving away from the CS and thus from the manipulandum. Periodic observations of their subjects were in agreement with this idea, but no direct measures of such movement were taken.

Green and Rachlin (1977) came to a similar conclusion from an experiment which measured conditioned suppression of food-reinforced key-pecking by pigeons. In their experiment a concurrent schedule was used to maintain responding to two response keys so that the differential effect of presenting the visual CS for shock on only one key could be assessed. Their results were quite variable, but there was some indication that with mild shock response rates to the signal key were suppressed more than those to the unchanged key. This was interpreted as due to a shift away from the signal for shock. Such shifts were directly measured by Karpicke and Dout (1976) in two experiments employing a tilt-floor to register on which side of the chamber a pigeon was standing at a given moment. Subjects were given baseline instrumental training using key-pecking and the exposed to pairing of one of two lamps with shock. On each trial the lamp on the side on which the pigeon was standing was illuminated and in general subjects moved across to the other side. However, as in Green and Rachlin, the absense of a random control condition meant that the possibility of some non-associative effect could not be assessed. Karpicke and Dout refer to some subsequent preliminary data suggesting that this possibility was unlikely.

A different source of evidence has been the study of avoidance learning under conditions employing a discrete trial procedure and manipulation of the position of the warning signal. McAdam (1964), Whittleton, Kostansek and Sawrey (1965) and Baker and Ziegelbauer (1969) have all reported that avoidance behavior develops more rapidly when it involves withdrawal from the warning signal than when it involves approaching the signal. Their experiments used shuttle boxes, whereas Biederman, D'Amato and Keller (1964) obtained a similar result using a lever-press response. These findings were obtained before Brown and Jenkins' (1968) discovery of the autoshaping phenomenon focussed attention on the possible directional properties of classically conditioned behavior. Nevertheless one ready explanation for these results in that early in training pairing of the warning signal with shock produce withdrawal movement which facilitates acquisition of avoidance behavior under one condition, but competes with it under the other.

The studies described so far have all involved instrumental contingencies, of one kind or another and, with the exception of Karpicke and Dout (1976), have not directly measured the subjects' reaction to the CS. One aim of the present experiments was simply to check that withdrawal from an aversive CS+ can occur in the absence of any instrumental contingency and under conditions which rule out the possibility of non-associative processes such as sensitization. After they were completed LeClerc and Reberg (1980) reported two experiments with the same aim. They used the presentation of a platform, obtained by retracting part of one of the chamber walls to form an alcove, as the conditioned stimulus. It was found in one experiment that rats for whom the appearance of this platform preceded shock jumped up to the platform less frequently than animals given appropriate control conditions. This result was clear and unambiguous. However, it can be argued that it demonstrates suppression of movement towards a place now associated with shock rather than initiation of movement away from an excitatory stimulus.

The other main concern of the present experiments was also shared by LeClerc and Reberg, but not by any previous study; this was the question of whether an equivalent inhibitory stimulus has direct behavioral effects. One very important aspect of Wasserman, Franklin and Hearst's (1974) discovery that pigeons move away from a light signalling the absence of food is that it seems to represent a rare instance of behavior elicitation by a conditioned inhibitor; as often pointed out, inhibitors are generally behaviorally silent. LeClerc and Reberg (1980) found that rats given a backward conditioning procedure, which presumably established the platform as an inhibitory stimulus, jumped up to the platform much more than control animals. At the very least this result provides a potentially powerfull tool for studying inhibitory learning in the context of aversive reinforcement.

The present study may be viewed as complementary to that of LeClerc and Reberg. It had one further aim, that of relating autoshaping phenomena to the earlier findings, mentioned above, that avoidance behavior may be affected by the location of the warning signal. We began by examing whether this was the case for pigeons.

EXPERIMENT 1

This experiment sought to determine whether the position of a warning signal (WS) in an avoidance task would affect the development of avoidance learning, and whether such effects would be in a direction consistent with a notion of interactions of either a facilitating or interfering kind arising from presumed directed responses to an aversive stimulus. The procedure was modelled on that of McAdam (1964), in which a group of cats was trained, using a 2-way shuttle paradigm, to move away from a warbling tone source to avoid (or escape) shocks, while a second group was trained to move towards the source or the warbling tone. For the first group, group A, the warning signal, WS, was delivered to the compartment in which the subject was located; whereas for group C it came from a speaker in the unoccupied compartment. In either case the shocks could be avoided and the WS terminated if the cat crossed the barrier dividing the shuttle box during the WS-US interval, or could escape shocks and terminate the WS by crossing the barrier once the shock has started. McAdam reported that the cats in group A learned to avoid faster than the cats in group C. Essentially similar results have been reported by Whittleton, Kostansek and Sawrey (1965) using rats and shocks, and by Baker and Ziegelbauer (1969) using monkeys and air-blasts as reinforcers.

In the present experiment three groups of pigeons were presented with trials in which a response key mas illuminated and the birds could avoid the shocks by crossing a chamber early in the trial or escape from pulsating shocks late in the trial. Birds in the Approach group were required to approach the keylight to avoid or escape shocks and birds in the Withdraw group were required to move away from the keylight. A third, unsignalled avoidance group was included to assess the level of crossing responses to the absence of any warning signal.

METHOD

Subjects

Eighteen naive pigeons obtained from the University of Sussex breeding colony were used. They were taken from a communal aviary at the approximate age of one year and individually caged three months prior to the start of the experiment. They had continuous access to mixed grit and grain, and water in their home cages throughout the experiment.

Implantation of the electrodes

About a week prior to the start of the experiment, the birds were implanted with 0.065-cm stainless steel electrodes around the pubic bones under

Diethyl ether anesthesia as suggested by Azrin (1959). A small amount of cotton wool was impregnated with 10 ml of ether and then placed inside a 100 ml calibrated cylinder, the head of the bird was then inserted in the cylinder until the neck's muscles were no longer able to support the head. The electrodes were about 5-cm long with a sharpened tip, and a flexible cable soldered to the other end. The electrodes were inserted just beneath the pubis bone, then bent to make a loop around the bone and joined together with the other end; finally the sharp tip was cut off and the external part of the electrodes were covered with insulating tape. The cables were connected to a 'male' two-pin nonreversible socket that was attached to a suede harness every pigeon wore throughout the experiment.

Apparatus

Two identical chambers were used; they measured 70 × 30 × 30 cm. All walls in the chambers were of alluminium painted flat grey, except for the clear Plexiglas ceiling and entrance door. One 3.8 × 3.8 cm opaque Plexiglas response key was mounted at each end of the chamber; they were placed 19 cm from the floor and 10 cm from the entrance door. They could be transilluminated by a single 2.8 W 24 VDC bulb and required a force of about 0.1 N to be operated. A 8 ohm 0.3 W speaker was mounted to the side of each response key, 20 cm from the entrance door. At the center of the wall opposite to the entrance door a 5.5 × 4.5 aperture with the lowest edge 5 cm from the floor could give access to a Gerbrands grain hopper. When the hopper was operated a 2.8 W 24 VDC bulb illuminated the grain. This aperture was blocked by an aluminium sheet in Experiments 1 and 2. The floor of the chamber was made of two 30 × 30 cm pads supported at the edges by four microswitches each; these pads required a weight of about 200 g to be operated. The pads and the 10 cm wide strip separating them were covered by coarse grain sandpaper. A 40 W 200 VAC striplight mounted on the ceiling provided general illumination. The ceiling contained a rotating mercury swivel to which a 20 cm lenght of a flexible cable was attached; the cable terminated in a female two-pin non-reversible socket compatible with the one mounted on each pigeon's harness. Shocks produced by Campden Instruments shock generators could be delivered to the pigeon via the mercury swivel and connecting cable. Continuous white noise (80 db SPL) was delivered through a 8 ohm 0.3 W speaker mounted on the ceiling of the chamber. Controlling and recording equipment was located in an adjacent room.

Procedure

After allowing the pigeons to recuperate from electrode implantation for approximately 7 days they were randomly assigned to three groups and were exposed to avoidance-escape trials. A trial consisted in the illumination of a response key for 20 sec at variable times averaging 2 min (VT 2 min), range 1.3 to 4.5 min, and by the delivery of up to five 2 mA 0.5 sec shocks at a frequency of 1 Hz if the required response was not produced. The subjects could avoid shocks and terminate the trial by responding during the first 15 sec of key illumination, and escape only, during the final 5 sec of the trial. For the Withdraw group the keylight was presented on the side of the chamber currently occupied by the subject and a withdrawal response was defined as depressing the pad opposite to that occupied at the start of the trial. For the Approach group the keylight was always presented on the side of the chamber opposite to the one occupied by the bird at the start of the trial and an approach response was defined as depressing the pad close to the keylight. The subjects in the No-signal group never experienced the keylight, althought they could avoid or escape shocks by moving to the pad opposite to the one occupied at the start of the trial. When neither pad was depressed at the start of a trial because the birds stood in the middle of the chamber, the pad last depressed prior to the trial onset was used to determine which side of the chamber the keylight was presented for each of the groups. All groups received ten sessions and in each session there were twenty trials.

Statistical Analysis

All statistical analysis of the data from this and following experiments reported here involved comparisons using non-parametric statistics such as Kruskal-Wallis analysis of variance. When significant differences between groups were found the critical groups were compared using the Mann-Whitney U-test or Wilcoxon matched-pairs signed-ranks. The rejection level for a Type I error was set at $p < .05$.

RESULTS

Figure 1 shows the median percentage of trials with an avoidance response for each group in blocks of 20 trials. Throughout the experiment, the Withdrawal group showed better avoidance performance than either of the other groups. The group medians represent individual performance fairly well, since by the end of training all subjects from the Withdraw group were avoiding in more than fifty percent of the trials, while in the Approach group five out of six birds never avoided shocks on more than fifteen percent of the trials.

The median percentages of avoidance trials over all 200 trials were 53.5, 12.5, and 3.5 for the group Withdrawal, No-signal, and Approach respectively. Analysis of variance revealed a reliable difference between groups, Kruskal-Wallis $H(2) = 14$ and subsequent tests indicated that all groups differed reliably from one another, Mann-Whitney Us $(6,6) < 3$.

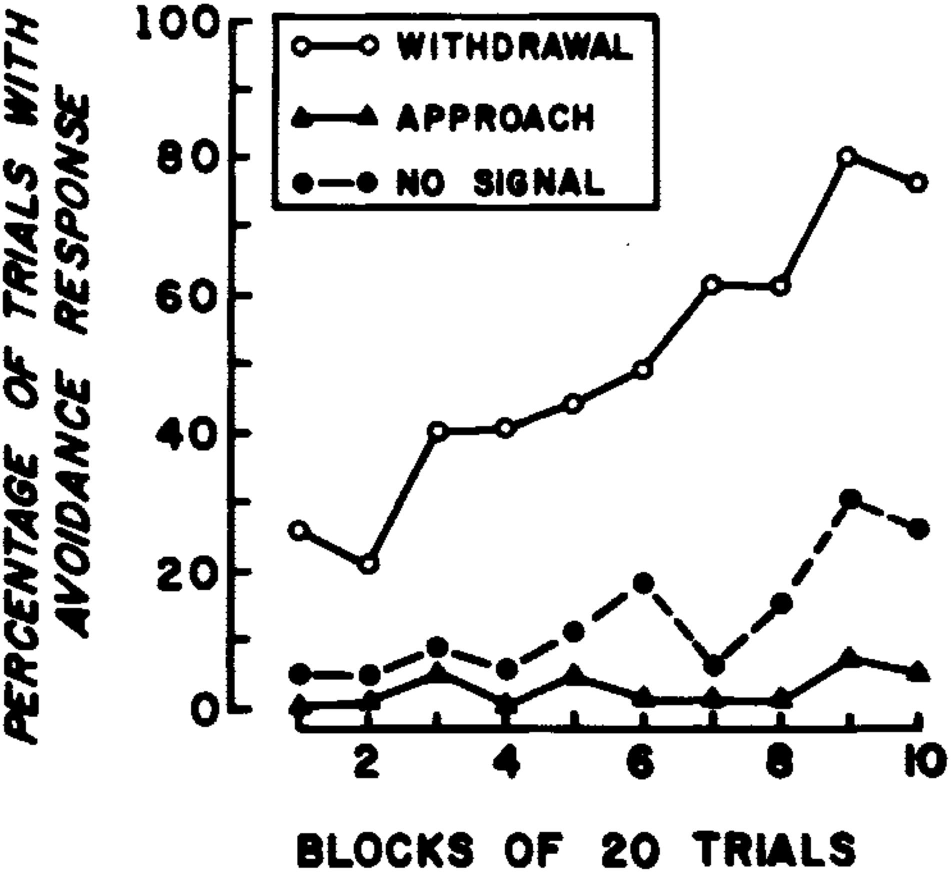

Figure 1. Median porcentage of trials with an avoidance response for each group in Experiment 1. Each session consisted of 20 trials.

DISCUSSION

The results from Experiment 1 demonstrated that signalled shock avoidance is facilitated if the instrumental response requires the birds to move away from the WS, but that it is disrupted when the avoidance response involves approaching the WS. These observations agree with those previously reported in other species by McAdam (1964), Whittleton *et al.* (1965) and Baker and Ziegelbauer (1969). The very poor learning by the group Approach in the present experiment is surprising, since in the published studies referred to above the equivalent groups successfully avoided on at least fifty percent of the trials. Although species and parametric differences preclude any firm conclusions, it is plausible that the internally delivered shock was a crucial factor in the present situation.

The present results are consistent with an interpretation based on an interaction between Pavlovian and instrumental conditioning. This view suggests that the difference between the groups was due to Pavlovian contingencies implicit in the signalled avoidance procedure; that is, due to the pairing of the keylight with shocks early in training and during the escape trials, the former acquired the ability to induce responses that conflicted with the requirements of the instrumental task. For the Approach group this only served to enhance even further the Pavlovian properties of the light, whereas in the Withdrawal group the Pavlovian reaction not only was compatible, but may have encouraged the operation of the instrumental contingency.

McAdam (1964) and Whittleton *et al.* (1965) offered a similar interpretation of their results, but based on Mowrer's (1960) two-process theory of avoidance. According to their view, because of the implicit Pavlovian contingency the WS comes to elicit a state of fear and this generates competing responses; as the elimination of fear and of stimuli associated with it is reinforcing, an avoidance response leading to a decrease in proximity with the WS will be strengthened. Note this assumes that withdrawal from an aversive CS+ is instrumentally conditioned, and not a purely Pavlovian conditioned response.

Finally, the results of the present experiment could be interpreted as yet another example of "misbehavior" (Breland and Breland, 1961). In this situation the Pavlovian contingency implicit in instrumental training generates particular expectations and/or responses that disrupt instrumental learning and performance. Among well known examples are the studies of omission training (Sheffield, 1965; Williams and Williams, 1969), species specific defense reactions (Bolles, 1978), and the studies of token reinforcement in rats (Boakes, Poli, Lockwood and Goodall, 1979).

EXPERIMENT 2

The interpretation favoured in the preceding discussion assumes that even when there is no avoidance contingency, an aversive exciter should produce withdrawal if localized. To check this assumption Experiment 2 assessed whether a keylight positively correlated with shock induces withdrawal in the absence of any instrumental contingency. In addition a second group was exposed to a negative correlation between keylight and shocks in an attempt to detect approach towards an aversive inhibitor. These two groups were compared with a third group which was exposed to uncorrelated presentations of keylight and shocks. The procedure was purely Pavlovian, since in all groups the presentation of both keylight and shocks was independent of the subject's behavior.

Subjects

Eighteen pigeons, maintained and implanted in the same manner as in Experiment 1, were used. The apparatus was the same as in Experiment 1.

Procedure

All pigeons were first given two 1-hr sessions of familiarization to the chamber, to white noise and to being connected to the mercury swivel through the cable. Then they were given two 1-hr sessions in which twenty 20-sec keylight presentations per session occurred according to a VT 3-min schedule (range 1.2 to 5.1 sec).

The Pavlovian conditioning procedure was imposed during the next fifteen sessions. The subjects were assigned to three equal groups. For the Positive correlation group each session consisted in the presentation of twenty 20-sec key illumination terminating with a 2.0 mA, 0.5 sec shock. The trials were initiated according to the VT 3-min schedule used in the two pretest sessions. For the Random correlation group each session consisted of twenty keylight presentations and twenty shock deliveries, but they were programmed by two independent VT 3-min schedules. The Negative correlation group received twenty 20-sec keylights presented according to the VT 3-min, and twenty shocks delivered according to a VT 2-min schedule. The VT 2-min timer was stopped during each of the keylight presentations and for the 40-sec following its offset.

For each subject the same key was illuminated during the first nine sessions, with half of the birds starting on the left and for the others on the right. Then, the keylight position was reversed for all birds for a further six sessions.

Throughout the experiment the measure of interest was the time spent on the right and left pads during CS presentation and during an equivalent interval preceding the CS (the pre-CS interval). From these measures an approach-withdrawal score was calculated for each subject. Assuming that the left key was illuminated, the score was defined as $(A - B) - (C - D)$, where A is the time on the left pad during CS presentation; B is the time on the left pad during the pre-CS interval; C is the time on the right pad during CS; and D is the time on the right pad during pre-CS interval. This calculation yields a positive score when approach to the light occurs, a negative score for withdrawal from the light and zero when neither approach nor withdrawal occurs.

RESULTS

The median pre-CS times were analysed in succesive blocks of three sessions in order to detect a possible bias towards one of the pads. Kruskal-

Wallis analyses indicated that the groups did not differ reliably in the pre-CS time on the left pad nor in pre-CS times on the righ pad in any of the blocks, Hs < 3.89. Subsequently the pre-CS times on the left pad were compared with those on the right pad for each of the blocks; Wilcoxon's matched pair signed tests indicated that pre-CS times on either pad did not differ reliably in any of the block, Ts(17) > 52.

During the two keylight pretest sessions (not shown), twelve out of eighteen birds moved away from the keylight, while the six remaining birds approached it. The median approach-withdrawal scores per trial over the pretest sessions were –1.7, –0.04, and –0.10 sec for the groups Positive, Random and Negative respectively. These scores did not differ reliably between groups, H(2) = 1.74.

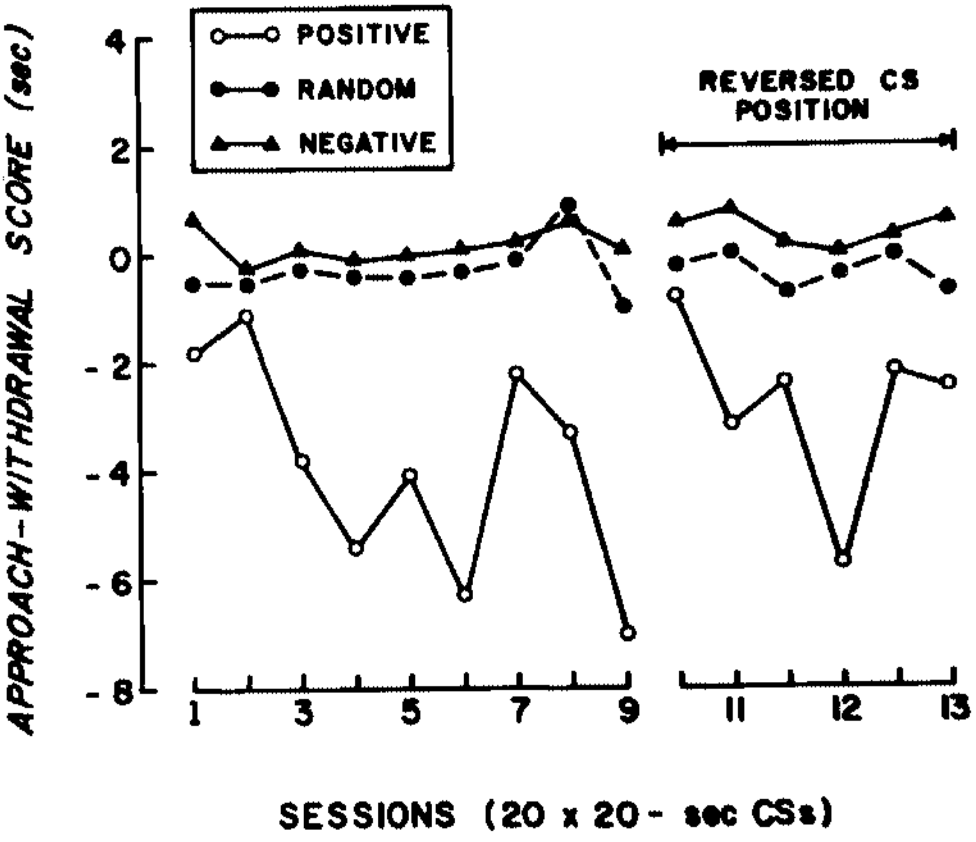

Figure 2. Median approach-withdrawal scores for each group in Experiment 2. Positive scores indicate approach and negative scores indicate withdrawal.

As Pavlovian training continued, the scores of the Positive group became increasingly negative, whereas the scores of the other two groups remained close to zero, as seen in Figure 2. Five out of six birds in the Positive group consistently withdrew from the keylight; four out of six birds in the Negative group withdrew from the keylight and the other two consistently approached it. The performance of the birds in the Random group was more variable, and none of the birds showed any consistent approach or withdrawal tendency towards the light.

On the first nine training sessions, 49 out of a total of 54 data points were negative in the Positive group, 31 were negative in the Random group and 26 were so in the Negative group. An analysis of the median overall scores indicated a reliable difference between groups, $H(2) = 8.47$. Subsequent tests indicated that the Positive group differed reliably from the Random group, $U(6,6) - 5$ but that the latter did not differ from the Negative group, $U(6,6) = 14$. Session by session analyses of these data indicated that the differences between groups emerged early in training and was observed in all but the second and fourth sessions, $Hs(2) > 6.49$. The positive group differed reliably from the Random group in Sessions 3, 5, 7, 8 and 9, $Us(6,6) < 3$. The latter group differed reliably from the Negative group only in the first session, $U(6,6) = 4$.

Following reversal of the position of the keylight most of the subjects that were responding reversed the direction of their behavior, although there was more individual variability. Analyses of the overall scores revealed a reliable group difference, $H(2) = 8.92$, $p. < .02$. Subsequent comparisons indicated that the Positive group differed reliably from the Random group, $U(6,6) = 3$, $p = .004$; but the latter group did not differ reliably from the Negative group, $U(6,6) = 12$. Session by session analyses of these data showed that the groups' differences were less consistent since the groups only differed significantly in the second and fourth light position reversal sessions, $Hs(2) > 6.49$, $p < .05$. The Positive group differed reliably from the Random group in both of these sessions, $Us(6,6) < 4$, $p. < .01$. The latter group did not differ reliably from the Negative group in any of the sessions, $Us(6,6) = 15$.

Figure 3 shows the temporal distribution of approach-withdrawal scores during keylight presentation in five bins of 4 sec each. These data were collected during the last session prior to CS position reversal. As time elapsed within a keylight period the birds in the Positive group were more likely to move away from the light than either of the other two groups. The groups differed in all bins except the first one, $Hs(2) > 8.03$, $p. < .02$. The Positive group differed reliably from the Random group during the second, third and fourth bins only, $Us(6,6) < 5$, $p. < .02$. The latter group differed reliably from the Negative group during the last bin, $U(6,6) = 2$, $p = .004$.

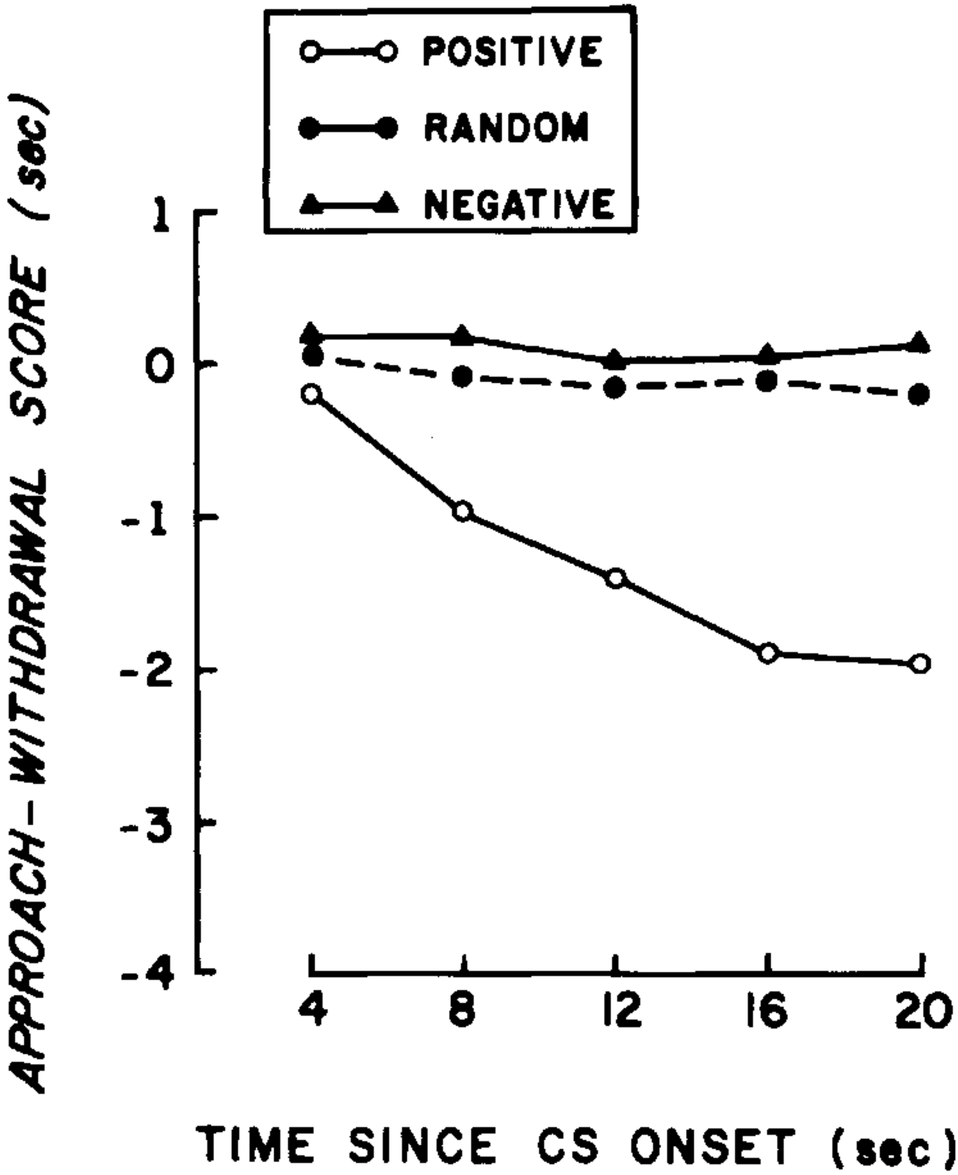

Figure 3. Median approach-withdrawal scores as a function of time since keylight onset in Experiment 2.

DISCUSSION

The results of Experiment 2 showed the development of withdrawal from a localized aversive exciter, but there was only slight evidence for an approach tendency to the presumed inhibitor. The existence of the withdrawal behavior induced by the aversive exciter is consistent with the expectations derived from Experiment 1, where it was assumed that a Pavlovian contingency embedded in the avoidance procedure was responsible for the facilitated acquisition of withdrawal responding. Comparisons between the Positive group and the other groups suggest that the differences found between them should be attributed to the signalling functions of the keylight in that group. This conclusion is strengthened by the observation that withdrawal behavior in the Positive group was under the temporal control of the CS onset to US delivery interval.

The failure to observe consistent approach behavior in the Negative group was surprising. However, the fact that two birds consistently approached the keylight supported the hope that a more judicious selection of procedure and parameters would produce more approach behavior.

EXPERIMENT 3

The aim of this experiment was to assess the effect of a between-sessions negative correlation between keylight and shock deliveries on approach behavior to the keylight. This procedure was chosen aftter initial attempts were made with the conditioned inhibition procedure (Pavlov, 1927), but without success (Nieto, 1981).

The between-sessions negative correlation procedure was introduced by Baker (1977). In Baker's study hungry rats were first trained to press a lever for food. In a second, off-the-baseline stage the experimental group was exposed to two types of sessions: on even days the CS was presented on its own and on odd days brief shocks were delivered. Thus, this procedure creates a negative correlation between CS and shocks, but it is between- rather than within-sessions, as is more usually the case. Baker reported that such a procedure endowed the CS with inhibitory properties as compared with groups exposed to uncorrelated presentations of CS and shocks. This procedure was chosen here in an attempt to reduce the magnitude of freezing by pigeons observed in preliminary experiments, since shocks are never delivered in sessions in which the CS is presented. As a control condition a between-sessions uncorrelated procedure was used instead of the uncorrelated control employed by Baker (1977), in which sessions containing uncorrelated presentations of CS and US alternated with uneventful sessions. The latter procedure arranges a between-sessions positive correlation between the CS and US that could endow the CS with excitatory properties. Although Baker considered and rejected the possibility that such a factor played a role in his study, pseudo-excitatory conditioning is known to develop as a result of chance pairings in uncorrelated procedures (*cf.*, Kremer and Kamin, 1971; Quinsey, 1971).

In addition, the present experiment attempted to induce stronger approach behavior by using birds with prior autoshaping experience in one of the two groups. The present experiment also attempted to identify more precisely what subjects did in the presence of the signal of the absence of shocks. Consequently, the behavior of the birds was videotaped during the pre-CS and CS interval and was subsequently classified into several response categories.

METHOD

Subjects and Apparatus

Twenty-four pigeons weighing 504 g on average, range 324 to 524 g, were used. Half of the birds were experimentally naive and the remainder had been exposed to an autoshaping procedure which consisted of the pairing of a 4-sec keylight with delayed access to grain. The pretrained birds were maintained at approximately 80% of their initial weights during the first three sessions of the experiment, and then were given free food in their home cages of the remainder of the experiment.

All birds were implanted with electrodes under ether anesthesia as described for Experiment 1. The apparatus used in aversive conditioning was described in Experiment 1, and the pretrained birds were autoshaped in three standard conditioning chambers measuring 30 X 30 X 30 cm, with a 2 cm diameter response key centrally mounted on one of the walls and 18 cm from the floor.

Procedure

During the first three sessions the pretrained birds were given autoshaping training with food reinforcement. Each session consisted of thirty 10-sec keylight presentations paired with 5-sec grain access. This coincided with the keylight offset and was signalled by switching the houselight off and the hopper light on. The keylight was illuminated according to a VT 1-min schedule. Then, the birds were ranked by the number of trials with a peck during the last autoshaping session, and were allocated to two matched groups: Negative-pretrained and Uncorrelated-pretrained. The naive birds were also assigned to two groups: Negative-naive and Uncorrelated-naive.

The main part of the experiment lasted 24 sessions in which Pavlovian aversive conditioning was carried out. For two groups the aim of this training was to establish the keylight as an inhibitor, while leaving it neutral in the two uncorrelated groups.

The Negative groups were exposed to a between-sessions negative correlation procedure involving two types of session. On even sessions one 60-sec keylight occurred every 10 min, four times per session. On odd sessions twelve 2.0 mA, 0.5 sec shocks were presented on a VT 6-min schedule, range

1,5 to 15 min. The Uncorrelated groups were exposed to a between-sessions uncorrelated procedure involving four types of sessions. First, sessions in which the key was illuminated according to the procedure described for the Negative groups; second, sessions in which shocks occurred according to the procedure described for the Negative groups during odd sessions; third, sessions in which both keylight and shocks were presented in an uncorrelated fashion; fourth, uneventful, neither keylight nor shock. This sequence was repeated six times, and for keylight-shock sessions the position of the keylight was alternated across sessions.

The keylight was always presented on the same side of the chamber for the first twelve sessions and then its position was reversed. For half of the birds the light was presented initially on the left, and for the other half on the right. All sessions lasted 50 min.

Recording of behavior

As in Experiment 2, times spent on the right and left pads during CS presentation and during the pre-CS interval were recorded every session. In addition, the sessions when the keylight was presented were videotaped and the behavior of the birds was subsequently analyzed by an observer using a manually operated keyboard connected to a multi-channel event record. Tapes were observed blind, that is, the observer did not know the identity of the bird or the group it belonged to until the analyses were completed.

The following categories of behavior were employed: *a*) Pecking keylight wall; *b*) Pecking the other walls and the floor; *c*) Preening, defined as movements involving care of feathers and pecking directed to the body; *d*) Inactive, defined as being stationary either standing or with the breast on the floor.

RESULTS and DISCUSSION

All trained birds pecked the keylight during the last autoshaping session. The number of trials with a peck varied from 3 to 18 out of 30.

The median pre-CS times were analysed in blocks of three sessions throughout the experiment in order to detect biases towards one of the pads. In both naive groups and in the Uncorrelated-pretrained group the pre-CS times did not differ reliably between pads in any of the blocks, $Ts(6) > 1$. In the Negative-pretrained group the pre-CS times did not differ between pads during the first two blocks, $Ts(6) = 9$, but the birds spent more time on the right pad in the last two blocks after CS position reversal, $Ts(6) = 0, p < .02$.

Both of the negatively correlated groups displayed some approach towards the keylight, as shown in Figure 4. The left side of this figure presents the median scores per trial for the two naive groups and the right side those of the pretrained groups. Considering the naive groups first, four of the

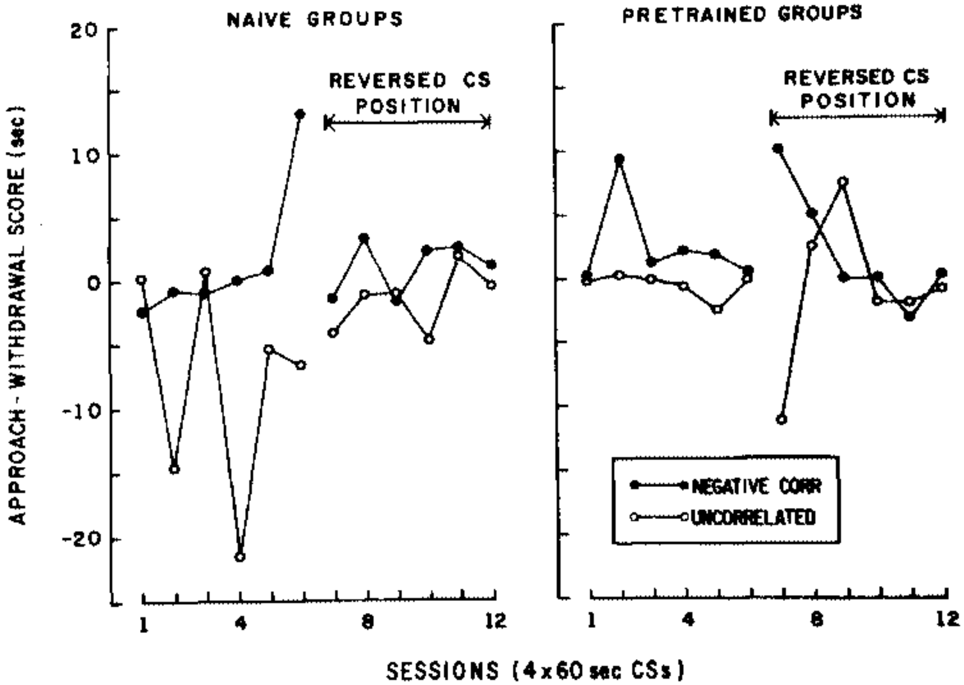

Figure 4. Median approach-withdrawal scores for each group in Experiment 3. The left-hand panel shows the data for the naive groups, the right-hand panel for the two groups with prior autoshaping experience.

six birds in the Negative group started to approach the keylight regularly, while none of the birds in the Uncorrelated-naive group showed similar behavior. The median approach-withdrawal scores over the six sessions were –0.19 and –5.25 sec for these groups respectively. The scores differed reliably between groups, U(6,6) = 1, $p < .002$. However, the scores of the Negative-naive group were not different from zero, T(5) = 5, and the scores of the group Uncorrellated-naive were reliably smaller than zero, T(6) = 0, $p < .05$.

Session-by-session analyses of the naive groups' performance revealed that their median scores differed only in the sessions 4, 5, and 6, Us(6,6) < 4, $p < .01$. In these sessions (4,5,16) the scores of the Negative-naive group were greater than zero, Ts(6) = 0, $p < .02$, only in sessions 5 and 6. The group Uncorrelated-naive had scores that were always smaller than zero, Ts(6) = 0.

Considering the two pretrained groups next (see right side of Figure 4), only two of the six birds in the Negative-pretrained group consistently approached the light, and two of the six birds in the Uncorrelated-pretrained group displayed approach during the first six sessions. The median scores over these sessions were 1.22 and –0.28 sec for the above groups respectively. The scores did not differ between groups, U(6,6) = 11, nor were they different from zero, $Ts(5) > 3$. Session-by-session comparisons of the groups' performance revealed no significant differences in any of the sessions, $Us(6,6) > 8$.

During sessions with reversed CS position four birds in the Negative-naive group approached the light with some consistency and the performance of the Uncorrelated-naive birds was very variable. The group median scores over these sessions were 2.5 and −0.4 sec respectively and they did not differ reably, $U = 13$. Session-by-session analyses also failed to reveal any group difference.

Two birds in the Negative-pretrained group consistently approached the key-light and only one of the birds in the Uncorrelated-pretrained group did so. The median scores over the six sessions were 2.4 and −0.16 sec respectively; These scores did not differ reliably, $U = 14$. Session-by-session analyses also failed to reveal any group difference.

Table 1 shows the number of keypecks for each birds. As can be seen, the number of birds that pecked the key at least once was higher in the Negative than in the Uncorrelated groups. As within-group comparisons showed that the number of keypecks did not differ prior and after the CS

TABLE 1

Number of keypecks per trial in Experiment 3

GROUPS

	NEGATIVE-NAIVE	UNCORRELATED-NAIVE
	0.9	0.3
	3.3	3.6
	2.3	0.1
	1.5	1.0
	0.4	0.3
	20.8	0.2
Median:	1.9	0.3

	NEGATIVE-PRETRAINED	UNCORRELATED-PRETRAINED
	5.9	4.1
	9.7	0.0
	0.2	0.0
	0.2	0.0
	0.0	1.3
	0.3	0.8
Median:	0.3	0.4

position reversal, Ts(6) = 3, the median number of pecks per session over all twelve sessions was calculated. These were 1.9, 0.3, 0.3, and 0.4 for the groups Negative-naive, Uncorrelated-naive, Negative-pretrained, and Uncorrelated-pretrained. The only significant difference was that between the two naive groups, U(6,6) = 7, p < .05.

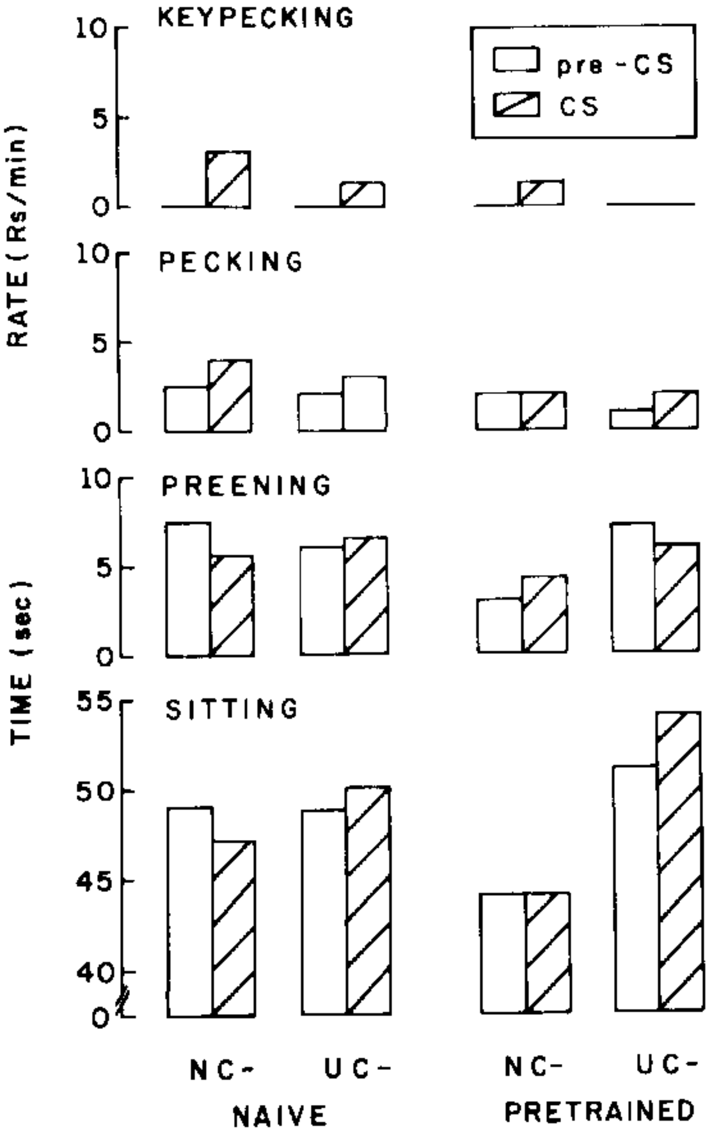

Figure 5. Median rates of keypecking and pecking other areas of the chamber during pre-CS and CS intervals (top two rows) for each group in Experiment 3. The two bottom rows show median times spent preening and inactive during equivalent periods.

Observational data

As approach behavior seemed stronger during the last two sessions prior to CS position reversal, the videotapes from these sessions were analysed. The upper two rows of figure 5 show the median rates of pecking the key and other areas of the chamber and the two bottom rows show the median time spent preening or being inactive during both pre-CS and CS periods. In all groups the most prominent class of behavior was Inactive; this occupied about 80% of the pre and CS intervals. The next most frequent class of behavior was Preening which occupied 8% of the recorded intervals. This behavior did not seem to be under the control of the CS presentation since comparisons of pre-CS and CS times did not show reliable differences, $Ts(6) > 3$.

Pecking occurred in all groups, but at a low level. Although the number of keypecks and keywall pecks seemed smaller than the number of pecks to other areas of the chamber, this was not confirmed by statistical analyses, $Ts(6) > 3$.

Pecking occurred in all groups, but at a low level. Althought the number of keypecks and keywall pecks seemed smaller than the number of pecks to other areas of the chamber, this was not confirmed by statistical analyses, $Ts(6) > 4$.

GENERAL DISCUSSION

In general the results obtained from these experiments confirm the suggestion made by Hearst and Jenkins (1974) that animals withdraw from a CS+ and approach a CS— when conditioning is based on aversive reinforcement. In doing so, they complement the similar findings of LeClerc and Reberg (1980) with rats. In the latter study clear evidence of a CS+ effect was found only in one experiment, whereas marked approach to the CS— was obtained in both experiments. In contrast, it was found relatively easy in the present research to obtain withdrawal from a CS+, but approach to a CS— proved to be more elusive. The small, though significant, effects found in Experiment 3 were also seen in related experiments carried out in this laboratory (Nieto, 1981). The general conclusion from this research is that, at least in pigeons, it is difficult to find behavior directly elicited by an aversive CS—, but that when it does occur one component consists of approach towards the stimulus.

The fact, which was noted at the beginning of this paper, that relatively little is known about sign-tracking in aversive conditioning may be due to the use of procedures that are far from optimal. Evidence from sign-tracking in appetitive conditioning has shown that this phenomenon depends on several environmental factors for its expression. One major factor is that some types of stimuli used as CSs support behavior much better than other despite equal correlation with food: small and localizable visual stimuli support pecking and approach whereas diffuse stimuli does not (e.g., Blanchard & Honig, 1976; Schwartz, 1973). Other factors may also be important but obvious; for example, the dramatic form of signtracking pigeons display in a long box occurs only with conventional traylight arrangement (Boakes, 1979).

Similarly, studies of avoidance learning have shown that the kind of reaction to aversive stimuli displayed by an animal, and in fact the success in learning an avoidance task vary greatly with contextual factors (e.g., Bolles, 1978). Thus, when fleeing is prevented the next most likely reaction is freezing. As suggested by the analysis of subjects' behavior in Experiment 3, the major problem in the present research was that pigeons tend to remain immobile in any place associated with shock. A possible reason why the withdrawal response was quite clear in Experiment 2, whereas Karpicke and Dout (1976) failed to find a similar effect in pigeons prior to introducing baseline instrumental training, was the use of a large chamber; in the confined space of a standard chamber 'freezing' is a much more likely reaction to fear than 'fleeing''. The use of an even larger chamber than here might further increase pigeons' levels of activity. As for rats, Reberg (personal communication) has reported that a variety of arrangements were tried with little success before the procedures adopted in LeClerc and Reberg (1980) were found to work.

So far we are suggesting that vigorous sign-tracking with respect to aversive reinforcers is only likely to occur when the general context does not encourage freezing. This does not indicate why it proved more difficult to detect the effects of a CS− than those of a CS+ . There seem to be at least two possibilities. First, it is simply a further example of a common finding that inhibitory effects are more difficult to obtain than excitatory ones; thus, in Experiment 2 subjects probably could more readily learn that the keylight is followed by shock than that is followed by a 40-sec period free of shock. The second possibility follows from some indication that any tendency to approach the CS− may be opposed by a non-associative effect in the opposite direction. A tendency for pigeons to move away from a keylight even when it is unrelated to shock delivery is suggested by the results from the uncorrelated subjects in Experiment 3 and, although there is little sign in the results from the Random condition of Experiment 2, this tendency was also seen in other experiments in these series (Nieto, 1981). In analysing the video recordings quite pronounced startle reaction, which some times culminated in withdrawal, were seen to occur to the outset of the keylight in both the negatively correlated and control subjects of Experiment 3. This may well be an example of general sensitization, but a further possibility is second-order conditioning, in that simply because the keylight is occasionally presented against a background associated with shock it may acquire fear eliciting properties. Tests involving the presentation of equivalent stimuli that were previously novel in this context would be required to distinguish between these possibilities.

Turning to an issue of more theoretical than methodological interest, one reason for studying the effects of a CS– stemmed from theories of inhibition which have stressed the similarities between an aversive CS– and an appetitive CS+, and *vice versa* (Dickinson & Dearing, 1979; Konorski, 1967; Mowrer, 1960). In an extreme form such an approach would predict that, as long as performance factors allowed, keylight signalling the absence of shock might acquire similar hedonic properties to one signalling the occurrence of food and, as a consequence, a pigeon might well peck, as well as approach, such a stimulus. There was a slight suggestion from the Naive pigeons in Experiment 3 that this can occur, but clearly the rate of keypecking was negligible in comparison to that typical for any appetitive procedure, and why no such effect was found in the pre-trained pigeons remains a mystery. Further exploration of this possibility would require the development of a procedure which reduced the general level of inactivity.

A final issue requiring discussion is the connection between the behavior produced by stimulus-reinforcer contingencies alone in Experiments 2 and 3 and the different rates of avoidance learning found in Experiment 1. By showing that these different effects can occur within the same context the present results strongly support the idea that the position of a warning signal affects avoidance acquisition because of facilitation or interference from behavior generated by stimulus-shock contingencies. They do not decide between the assumption that this behavior is a direct effect, as is normally made in the analysis of appetitive sign-tracking, or the earlier suggestion stemming from Mowrer's two-factor theory (Mowrer, 1960; McAdam, 1964) that such behavior is instrumentally conditioned, since withdrawal from an aversive CS+ has the consequence of decreasing an animal's fear, while approaching an appetitive CS+ is correspondingly assumed increase the effectiveness of a positive conditioned reinforcer. To test between these alternatives would mean the use of an arrangement whereby an animal's tendency to approach a CS+ did not in fact bring it any closer to the stimulus. Until such a study is carried out, it is probably safe to assume that approach and withdrawal movements of the kind studied here are not a result of instrumental conditioning by a conditioned reinforcer.

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