COLLATERAL BEHAVIOR OF THE PIGEON DURING CONDITIONED SUPPRESSION OF KEY PECKING¹

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Ethological recording procedures measured collateral behavior in pigeons whose key-pecking performance was suppressed during a tone that ended with unavoidable electric shock. Independent recordings of gross behavior were made by two observers throughout 60-sec intervals immediately before, during, and after tone presentation. Results indicated significant reductions in the frequency of collateral movements and an increase in the time between successive movements during tone presentations. These effects were observed in all subjects, despite differences in the sequential patterns of behavior. Only partial recovery of the behavior evidenced before tone presentation was found during a 60-sec interval following shock. It was concluded that conditioned suppression procedures caused the bird to "freeze" during tone presentation and in this fashion produced a general inhibitory effect on ongoing overt activity, including key pecking.

A stimulus that repeatedly precedes an inescapable noxious event can acquire the capacity to reduce the rate of responding maintained by positive reinforcement (Estes and Skinner, 1941). This effect is known as conditioned suppression and has been suggested as a quantitative index of conditioned emotional behavior (Brady and Hunt, 1955).

The conditioned suppression effect is frequently explained in terms of the elicitation of conditioned respondents during the pre-shock stimulus. Thus, Brady and Hunt (1955) characterized the conditioned suppression phenomenon as the result of a generalized or non-specific inhibitory effect of the pre-shock stimulus on all overt behavior. They noted that when a rat trained to press a lever for food is subjected to the Estes-Skinner procedure, the disruption in lever pressing during the pre-shock stimulus is accompanied by characteristic crouching, immobility, and defecation. These reactions were subsumed under the term "freezing" and employed, in part, as evidence for an emotional state. Alternatively, Dinsmoor (1954, 1955) and Weiskrantz (1968)

suggested the possibility that reductions in base rate responding during the pre-shock stimulus may result from an increase in the frequency of other behaviors (operants and respondents) that are incompatible with the baseline responses. For example, Weiskrantz (1968) proposed that movements that minimize the noxious qualities of a stimulus such as electric shock may increase in frequency during a pre-shock stimulus and physically prevent the subject from maintaining the baseline behavior. Thus, according to this view, to suggest that the pre-shock stimulus controls a conditioned emotional state that disrupts the rate of large classes of behavior through an inhibitory influence may be inappropriate or, at best, incomplete.

The present study was designed to assess the behavioral changes produced by the Estes-Skinner procedure in pigeons trained to peck a key under a schedule of food presentation. Specifically, the study was to determine whether the conditioned suppression phenomenon is characterized by a reduction in the rate of all ongoing behavioral movements (*i.e.*, freezing) or whether, alternatively, subjects engage in other movements that increase in frequency during a pre-shock stimulus and prevent a maintenance of baseline responding. In the present research, ethological methods of observation were combined with the more or less standard recording techniques of the operant conditioning laboratory in an effort to

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identify the behaviors before, during, and after pre-shock stimulus presentations. In this way, we hoped to extend the analysis of conditioned suppression to components of the subject's general activity other than key pecking.

METHOD

Subjects

Five male homing pigeons, maintained at 80% of their free-feeding body weights were used. They were approximately 3 yr old at the start of this research.

Apparatus

The apparatus consisted of a Foringer pigeon chamber in a sound-resistant chest, equipment to schedule reinforcers and tone presentations, cumulative recorders, printout counters, and special purpose connectors to deliver shock via a pair of permanently worn wing bands (Hoffman, 1960). Shock was generated by an Applegate constant current stimulator with shock intensity set at 2 mA. A 1000-Hz tone preceded and accompanied shock delivery and was set at an intensity of 90 db, re: 0.0002 dynes/cm² (2×10^{-9} N/cm²). The tone was presented through a speaker mounted on the wall of the chamber opposite the response key and food hopper. General illumination was provided by houselights on the top wall of the chamber. When the response key was transilluminated by an orange light, a force exceeding 25 g (0.245 N) applied to the key was sufficient to register a peck.

The bird's behavior was observed through a television camera mounted on a tripod approximately 4 in. (10 cm) from a 4 by 6 in. (10 by 15 cm) window on the side of the pigeon chamber. A split coaxial cable from the camera transmitted identical pictures to two 11-in. (28 cm) television monitors located in separate and acoustically isolated rooms. A tape recorder in each room recorded comments from trained observers and recorded the clicks from relays activated by the operation of the response key. Concurrently, key pecks, reinforcers, tones, and shocks were recorded on a Gerbrands cumulative recorder and on an Esterline Angus operations recorder.

Procedure

The procedures employed for the development of conditioned suppression are presented

in detail elsewhere (Hoffman and Fleshler, 1964). Briefly, all subjects were maintained at 80% of their free-feeding body weight, magazine trained, and then trained to key peck. Throughout, a reinforcer consisted of a 3.5-sec access to mixed grain. In conditioning the key peck, each subject was exposed to fixed-ratio (FR) schedules, gradually progressing from reinforcements presented after two successive key pecks (FR 2), to an FR 10, to an FR 30. Thereafter, a variable-interval 2-min schedule (VI 2-min) served as the baseline for the assessment of conditioned suppression. When the cumulative records indicated that the response rate was stable (resulting in approximately 56 responses per minute for each subject), a series of adaptation trials to the 1000-Hz tone was conducted. In each of the next 10 sessions, there were five presentations of the 1000-Hz tone while the birds continued to peck the key. The duration of each tone presentation was 60 sec, with an interval of approximately 10 min between successive tone presentations.

After adaptation to the 1000-Hz tone was completed, procedures to establish conditioned suppression were initiated. In each of the next 20 sessions, there were five presentations of the 1000-Hz tone. The duration of each tone presentation was set at 67 sec, with the last 7 sec consisting of tone plus pulsating electric shock. Each shock pulse was presented for approximately 1 sec, with a 1 sec non-shock interval between successive shock presentations. In each session, the first 1000-Hz tone was presented after 10 min of pecking on the VI 2-min schedule. The tone was presented again approximately 10 min later. Ten minutes after the final tone, the lights in the chamber were extinguished and the session ended. In all, each subject received a total of 100 tone-shock pairings. The subject could receive food by pecking at any time during tone, during shock, or during the interval between tones.

Recording Technique

The ninety-fifth and one-hundredth tone-shock pairings were designated as probe trials. During these two trials, the birds' collateral movements were recorded. The measurement technique involved continuous recordings of the birds' behavior during 60-sec periods immediately before, during, and after the tone-shock presentations. The experimental chamber was divided into eight areas by means of

markings on the walls of the chamber (Fig. 1). Recording the rapid movements that accompanied key pecks was accomplished by having two trained observers, located in separate rooms, watch the subject via closed-circuit television and provide a running verbal account of the bird's movements. The observers were trained to call out the number of the area into which the bird's beak moved, and they sought to do so at the moment the beak crossed a given boundary. Thus, two independent records were simultaneously obtained from identical pictures on the television screens. A series of lights connected to the scheduling equipment were located beside the television sets and were used to indicate the onset of the Pre-tone, Tone, and Post-tone periods for the observers. Moreover, a relay activated by each key peck was placed next to the observers' microphones. The relay clicks provided acoustic markers on the audio tapes and served to enhance the accuracy of the recording procedure.

RESULTS

During adaptation procedures, the 1000-Hz tone produced some suppression during its initial presentations, but with repeated presentations adaptation occurred and, by the end of this phase, the tone did not disrupt the baseline rate of key pecking. Inspection of the cumulative records indicated that the base rate of key pecking remained fairly stable during the experiment. The average rate of key peck-

ing during the 60-sec interval that preceded tone presentations fluctuated between approximately 30 and 60 responses, with a mean of 48 responses per minute. To measure suppression, response frequencies were recorded for each 60-sec interval before, during, and after tone presentations and an index of conditioned suppression was obtained from the formula: $\text{Pre-tone responses} - \text{Tone responses} / \text{Pre-tone responses}$. Pre-tone responses were the number of key pecks in the 60-sec period immediately preceding tone onset, and tone responses were the number of key pecks during the first 60 sec of Tone presentation.

Conditioned suppression of key pecking during the 1000-Hz tone proceeded gradually and was complete (*i.e.*, the index of suppression approached 1.0) after approximately 80 tone-shock trials. The development of suppression is not shown because the function describing it was quite similar to functions that have been reported previously (Hoffman and Fleshler, 1961; Hoffman, Fleshler, and Jensen, 1963; Hoffman and Selekman, 1967).

Throughout the eighty-first to the ninety-fourth tone-shock pairings, subjects were observed via television, the procedures for recording ongoing behavior were refined, and the observers were trained. Recordings were made of the head position and key pecks for each subject during the Pre-tone, Tone, and Post-tone periods of the ninety-fifth and the one-hundredth tone-shock pairings (probe trials). Figures 2 and 3 show the individual records of Birds 4-C and 10-C, which are representative of the records obtained from other subjects. The figures were derived from the transcriptions of the tape recordings made by the two observers. Originally, the recordings were taped at a speed of 3.75 in. per sec (ips) but, for purposes of analysis, were played back at $1\frac{7}{8}$ ips. Using this procedure it was possible to transcribe carefully each observation and the intervals between observations as well as individual clicks from the relays, which was activated by each key peck.

The various positions of the bird's head are represented by the numbers one through eight on the vertical axis. The numbers correspond to the sections of the experimental chamber shown in Fig. 1. The letter "P" signifies key pecks, the occurrence of which are indicated by dots. Horizontal lines located on Line P indicate intervals in which the bird's head

Fig. 1. A scale drawing showing the salient features of the experimental chamber and the areas used for categorizing the bird's movements. Each area was approximately 6 by 6 by 6 in. (14 by 14 by 14 cm).

Fig. 2. Record of Bird No. 4-C, showing head positions before, during, and after tone-shock presentation on the two probe trials. The dots indicate key pecks (P), horizontal lines correspond to presence of head in a given section of the chamber, rectangle on line P shows reinforcement, and arrows represent wing flapping. Cross-hatchings show observer disagreements. The insets are the cumulative records of the probe trials, with brackets indicating Pre-tone, Tone, and Post-Tone periods. Above the insets are the corresponding suppression ratios.

Fig. 3. Record of Bird No. 10-C, showing head positions before, during, and after tone-shock presentation on the two probe trials. The dots indicate key pecks (P), horizontal lines correspond to presence of head in a given section of the chamber, rectangle on line P shows reinforcements, and arrows represent wing flapping. The insets are the cumulative records of the probe trials, with brackets indicating Pre-tone, Tone, and Post-tone periods. Above the insets are the corresponding suppression ratios.

remained directly in front of the response key. In the present schema for representing the sequential order of behavior, it was assumed that changes from one category to another occurred instantaneously as, for example, when the bird's head crossed a boundary or the key-peck response caused a relay closure. Accordingly, the vertical lines of the bars correspond to a change in head position; the horizontal lines indicate no change in position. Reinforcements are represented by the rectangles immediately preceded by a dot and are located on Line P. The angular markings that are located in the "Tone and Shock" intervals on each individual record denote the flapping of wings during shock presentations. While this behavior was consistently evoked by the shock in all subjects, it was observed that two subjects (e.g., see Fig. 2) also exhibited wing flapping during the tone before delivery of shock. It is probable that wing flapping during tone in these subjects was directly related to the method of shock delivery employed.

When the observers disagreed in their judgments of head position, both observations were included in the record. The disagreements are emphasized in the records by filling the space between them with cross-hatching. The insets to the left of the main bodies in Fig. 2 and Fig. 3 show the cumulative records obtained during the corresponding probe trial. The bracketed areas designate the Pre-tone, Tone, and Post-tone periods, with the suppression ratios presented above the insets.

The measurement of head positions served as a means of documenting the collateral behavior before, during, and after tone-shock trials. Only one subject (Bird No. 2-C) failed to engage in any form of collateral movement as measured in the present situation. This bird's behavior during the Pre-tone periods was characterized by the head remaining directly in front of the response key between successive pecks. Presentations of the tone produced immediate cessation of key pecking and a motionless stance before the key. Following electric shock presentations, the bird's key pecking gradually recovered but collateral movements remained absent.

To obtain a clearer indication of the effects of tone-shock pairings on behavior, the number of times subjects either entered a given section of the chamber or pecked the key was tabulated (Fig. 4). During the Pre-tone periods,

the relative frequency of key pecking was quite high and collateral movements were generally restricted to the area of the chamber located on the subject's right side. Entrances into Section 2 exceeded other movements. As seen in Fig. 4, the conditioned suppression procedure reliably reduced the frequency of the birds' collateral movements. The suppression of collateral movement, however, was not uniform across the categories. The most frequent movements during the Pre-tone (key pecking and entrances into Section 2) were suppressed disproportionately more than movements with a lower frequency of occurrence. Movements into sections of the experimental chamber that occurred infrequently during the absence of tone remained virtually unaffected, in terms of their rate of occurrence, during presentations of the tone. Also during a period ending 60 sec after shock termination, there was only a partial recovery of key pecking and movement into Section 2 relative to the Pre-tone rate of responding.

Figure 5 shows the relative distribution of intervals between movements for the Pre-tone, Tone, and Post-tone periods. In deriving Fig. 5, the intervals between successive movements were classified according to their lengths and these durations were summed to provide an accumulative time. This was accomplished by measuring the interval between any of the following movements: from peck to peck, from a peck to the entry into a given portion of the chamber or *vice versa*, and a shift from one portion of the chamber into another. The cumulation or sum of these intervals for a particular subject equalled 60 sec (assuming that the onset of a movement was instantaneous), which was the duration of a given period. Thus, for example, the first bar in the Pre-tone period of Probe Trial No. 1 was derived by summing all intervals between successive movements with durations not exceeding 2 sec and computing the mean accumulated (total) time across subjects occupied by intervals ranging from 0 to 2 sec between movements. All intervals greater than 10 sec were pooled to form a separate category.

Inspection of Fig. 5 reveals that during the Pre-tone period, successive movements were seldom separated by more than 2 sec. The presentation of tone produced a profound shift in the shape of the distribution, with successive movements separated by intervals

Fig. 4. The mean frequency of movement of all subjects in the eight sections of the experimental chamber during the Pre-tone, Tone, and Post-tone periods of the two probe trials. The dark bar indicates the mean number of key pecks during the respective periods. The frequency of collateral movement for each subject was determined by the number of entrances of the subject's beak into a given section, irrespective of duration.

Fig. 5. The mean accumulated time, calculated across subjects, of the interval between successive movements. Each bar in the distribution represents the mean time between successive pecks, between a peck and entry into a section of the chamber or *vice versa*, and between a shift from one section of the chamber into another.

usually longer than 10 sec. Thus, exposures to the tone reduced the rate of key pecking and high-frequency collateral movements, and increased the time between movements. Moreover, a period of 60 sec after shock was insufficient to produce a complete recovery to the trends evidenced during a 60-sec period before tone onset.

Descriptive Data

To supplement the quantitative relationships, descriptive accounts of the birds' behavior were made throughout the Pre-tone, Tone, and Post-tone periods of the probe trials. This was accomplished by having the observers record, after each probe trial, the qualitative characteristics of the ongoing behavior. By including this information it was possible to describe the characteristic topographical features of the behavior that occurred while the subject remained within a particular section of the experimental chamber. Since each section of the chamber was considerably larger than the area occupied by the pigeon's head, it was possible for the subject to engage in overt movements while remaining within a particular section. The present analysis serves to account for this possibility.

Table 1 summarizes the typical form of behavior exhibited by each subject during the periods of the two probe trials. Examination of Table 1 reveals that during tone presentations, the subject's head remained within a given section of the chamber, and the body and head tended to remain in a fixed and immobile position. These observations complement those regarding the decreased frequency of movement across the categories. Moreover, it suggests that the increase in the temporal interval between successive movements, as shown in Fig. 5, is a valid reflection of the behavioral effects produced by conditioned suppression procedures during tone presentations.

Finally, comparisons between the characteristics of the behavior exhibited during the Pre-tone and Post-tone periods indicate that the Post-tone periods were characterized by qualitatively different forms of collateral behavior relative to the baseline behavior.

DISCUSSION

In previous investigations of conditioned suppression (Hoffman and Fleshler, 1961,

1964; Hoffman, Fleshler, and Jensen, 1963), it was found that by the end of a comparable number of tone-shock presentations, subjects typically exhibited an abrupt return to the baseline rate of key pecking within 1 sec or so of the termination of tone-shock. That the key-pecking rates of the present subjects failed to recover completely during the first 60 sec following the termination of tone-shock may be related to several procedural differences between the present study and these earlier experiments (*e.g.*, differences in tone duration, differences in the number of tone-shock pairings per session, differences in shock intensity, *etc.*). It is also possible that the differences observed in collateral behavior during the Pre-tone and Post-tone periods may be related to the incomplete recovery. However, the suppression of key pecks during the tone in the present experiment is directly comparable to earlier results under this general procedure. This finding, coupled with the decline in collateral behavior during the tone, points to the general conclusion that during a pre-shock stimulus the subject's overt behavior is disrupted and slowed, a phenomenon that is perhaps best described by the use of the term "freezing".

The conclusion that subjects are "freezing" is consistent with the results of a number of other investigators who have examined the behavioral effects that are produced by aversive procedures other than conditioned suppression. In the area of discriminated avoidance learning, Myers (1959), Meyer, Cho, and Wesemann (1960), and Feldman and Bremner (1963) have reported the tendency of rats to "freeze" during presentations of a warning signal, and have also reported that procedures designed to disrupt "freezing" and increase the animal's activity served to enhance avoidance learning. The tendency of rats (Hall, 1936; Hayes, 1960; Welker, 1959; Windor and Stone, 1946), mice (Willingham, 1956), and chickens (Candland, Nagy, and Conklyn, 1963) to "freeze" during presentations of an aversive stimulus during an open field test has been thoroughly documented. Moreover, in previous studies on conditioned suppression, certain investigators have noted that the rat tends to crouch and assume some stylized position during a pre-shock stimulus (Brady and Hunt, 1955). Thus, the phenomenon of "freezing" during a stimulus which is

Table 1
 Descriptions of the Typical Collateral Behavior Exhibited by Each Bird during the Pre-tone, Tone, and Post-tone Periods of the Two Probe Trials

Subject	Collateral Behavior		
	Pre-tone	Tone	Post-tone
2-C	Body in center of chamber, with head and beak directly in front of key	Initially, head and body remained 1.5-in. from front of key. After approximately 15 sec, head and body gradually lowered until subject was sitting motionless on floor.	Body in center of chamber, with top of head on the same plane as bottom of key. Pecks preceded by moving beak on a 45° angle from standing position to response key
4-C	Body in center of chamber, moving head in an extended arc	Head and body remained motionless, except during complete body turns and wing flapping. During wing flapping, body perpendicular to Plexiglas wall.	Body in center of chamber, with head arcing back and forth
5-C	Body in center of chamber, moving head about 2-in. to the immediate right followed by 90° turn downwards. The pattern was reversed before key pecks	Body and head remained motionless	Same as Pre-tone behavior, except for absence of rapid 90° downward motions
9-C	Body in center of chamber, head extending approximately 1-in. to the immediate right, followed by head turns of either 90° or 180°	Body and head motionless except when wing flapping. During wing flapping body was perpendicular to Plexiglas wall	Body at approximately 45° angle to Plexiglas side wall, with neck and head extending upwards
10-C	Body in center of chamber, with head movements extending approximately 2.5-in. to the immediate right of the response key	Body perpendicular to side walls and motionless	Body in center of chamber and parallel to side walls, head extending about 2.5-in. to immediate right of key. Tended to engage in abortive key pecks which were of insufficient force to be recorded as key pecks

directly associated with an aversive event has wide generality across species, responses, and situations.

Under certain conditions, however, unavoidable electric shock does not necessarily produce "freezing" or a reduction in the rate of ongoing behavior. Whether it does or not depends, in part, on the relative duration of the pre-shock stimulus, the baseline schedule of reinforcement, and the history of the organism. For example, Kelleher, Riddle, and Cook (1963) trained monkeys on a three-component multiple schedule, in which a VI schedule of food reinforcement was in effect during a white stimulus and a continuous avoidance schedule was in effect during a yellow stimulus. During the middle portion of the VI schedule, a blue pre-shock stimulus was superimposed. Results indicated that the highest response rates consistently occurred during the pre-shock (blue) stimulus, even when food reinforcements were absent during the pre-shock stimulus or when avoidance responses and VI performance were extinguished. Thus, the use of a pre-shock stimulus may increase rather than suppress food reinforced responding in organisms that have an extensive history of avoidance training. Results similar to this were obtained by Herrnstein and Sidman (1958) and Waller and Waller (1963). Moreover, Sidman, Herrnstein, and Conrad (1957) showed that a pre-shock stimulus superimposed on a continuous shock avoidance schedule results in an elevated rate of responding during the stimulus.

The present results indicate that a stimulus that precedes unavoidable shock produces a reduction in the rate of large classes of behavior maintained by positive reinforcement (*i.e.*, baseline responding and collateral movement). Thus, the effect of conditioned suppression procedures on baseline responses maintained exclusively by positive reinforcement does not result simply from an increase in the frequency of incompatible responses (movements) during the pre-shock stimulus, as suggested by Dinsmoor (1954, 1955) and Weiskrantz (1968). Rather, findings in the present experiment are consistent with the interpretation forwarded by Brady and Hunt (1955), in which the conditioned suppression phenomenon was characterized as the result of a general state that reduced the rate of all ongoing behavioral movements.

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