

*FLICKER THRESHOLDS AS DETERMINED BY A
MODIFIED CONDITIONED SUPPRESSION PROCEDURE^{1,2}*

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Critical flicker fusion frequencies were determined as a function of stimulus intensity for three White Carneaux pigeons using a modified conditioned suppression paradigm as a threshold procedure. Critical frequencies ranged from 6 cps for the lowest intensity of 0.0014 ml to 77 cps for the maximum intensity of 41.86 ml.

Threshold studies in the infrahuman organism involve three phases: establishment of stimulus control or differential responding of the organism in the presence of the specified stimulus; extension of this control to various values of the stimulus; and determination of the threshold as defined by failure of discrimination.

Certain features of the conditioned suppression paradigm introduced by Estes and Skinner (1941) suggest that this procedure offers unique advantages in establishing and maintaining the differential responding required in threshold investigations. As demonstrated by Estes and Skinner, behavior maintained on a positive schedule of reinforcement may be suppressed in the presence of stimuli such as light or tone which have been terminated previously by a brief, unavoidable electric shock. In addition, broad generalization of the suppression or conditioned emotional response (CER) to other values of the stimulus has been observed in studies of generalization of conditioned suppression (Hoffman and Fleshler, 1961). Further, by modifying the conditioned suppression design as originally introduced by Estes and Skinner so that re-

inforcement never occurs during stimulus presentation, the stimulus-to-be discriminated may thus become a S^A (stimulus in the presence of which no response is reinforced) as well as a signal for the shock.

The present research sought to evaluate the modified conditioned suppression paradigm as a threshold procedure in the determination of critical flicker fusion thresholds in the pigeon.

METHOD

Subjects

Three White Carneaux pigeons were maintained at 80 per cent of their free-feeding body weights throughout the experiment.

Apparatus

The experimental chamber was a standard Lehigh Valley pigeon box, Model 1519C. Electrical switching circuits programmed all procedures.

The aversive stimulus was an electric shock of 45 msec duration provided by an ac shock source, and delivered via internally implanted electrodes (Azrin, 1959). A resistance of 10,000 ohms was placed in series with the bird.

The visual stimulus was produced by a Sylvania R 1131 C glow modulator tube. The intermittent electrical square wave input for the light source was supplied by two independent, variable-frequency pulse generators as described by Roush and Urbanski (1953). The standard stimulus was a fused light of 220 cps frequency. The frequency of the comparison stimulus was varied with a linear helical potentiometer permitting variations in frequency of 1 cps. To avoid brightness differences, duty cycles for both standard and comparison stim-

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uli were held constant at 0.5. Timing calibrations were obtained with a Tektronix oscilloscope. Light from the glow modulator tube was passed through neutral density filters and was focused by an objective lens on the translucent pigeon key. This provided a stimulus spot approximately $\frac{1}{2}$ in. in diameter. It was the only illumination within the experimental chamber except the light which accompanied each presentation of the grain hopper. Stimulus intensity was measured by a Salford Electrical Instruments Exposure Photometer.

A four-pen event recorder provided continuous records of the experimental sessions. Responses made during presentation of the flickering stimulus and during an equivalent time period before onset of the flicker were recorded separately on electrical impulse counters.

Procedure

Throughout preliminary training, the response key was illuminated by the standard or fused (220 cps) stimulus. Key pecking behavior was maintained on a variable interval (VI) 2 min schedule, that is, response contingent reinforcement was available on the average of once every 2 min. Preliminary training included the following phases: shaping of the pecking response by successive approximations, 500 continuous reinforcements, VI 30 sec for four sessions, and VI 1 min for 12 sessions. All training sessions lasted 1 hr.

After a minimum of 25 sessions on VI 2 min, conditioned suppression training was initiated using a modified Estes-Skinner procedure in which no reinforcements were delivered in the presence of the stimulus-to-be discriminated. For the conditioned suppression training, the standard or fused illumination of the key was interrupted by a 20-sec presentation of a flickering stimulus of 10 cps followed by an electric shock of 45 msec duration. Shock was omitted after 40 per cent of the stimulus presentations according to predetermined schedule permitting no more than four successive shock or no-shock presentations. Each subject was given a minimum of 12 sessions of conditioned suppression training. An average of 30 trials was given within each 1-hr session. To measure the degree of suppression, the suppression ratio introduced by Hoffman, Fleshler, and Jensen (1963) was used. Ratios were computed as follows:

Pre-flicker responses — Flicker responses Pre-flicker responses

The number of responses made during the 20 sec preceding onset of flicker was designated as pre-flicker while the number made during the 20-sec stimulus was designated as flicker. According to this procedure, for complete suppression of responding during flicker, the result would be a ratio of 1.00 whereas for an equal number of pre-flicker and flicker responses, the ratio would be 0.00. A negative ratio would be possible in instances where flicker responses exceeded pre-flicker responses.

The frequency of the flicker stimulus remained at 10 cps until the mean of the suppression ratios for 10 consecutive trials reached 0.90. The following procedure was then employed. Initial stimulus presentations for each session were frequencies in the presence of which pecking behavior was completely suppressed. The frequencies of the stimuli were then increased in increments of 1 to 2 cps throughout the session. When the suppression ratios fell below the 0.50 value, frequencies were again lowered to values in the presence of which complete suppression occurred, and the increments gradually continued. This procedure was repeated daily until the terminal frequencies at which the pigeons suppressed did not exceed a range of 6 cps for at least four consecutive sessions. Upon reaching this criterion, threshold trials were begun.

To determine thresholds, the same procedure was followed with one exception. When suppression ratios began to fall below 0.75, three trials with a suppression ratio above 0.50 out of a block of five trials were required before increasing the flicker rate to a higher frequency. The threshold for fusion was defined as the first frequency of the stimulus which yielded a suppression ratio of 0.50 or below on a minimum of three trials in a block of five presentations. Throughout threshold training and determination, the shock schedule employed during conditioned suppression training was maintained. At frequencies with no clear evidence of suppression, shock was omitted. Sham trials were introduced periodically to determine whether the birds were responding to extraneous cues. A sham trial consisted of presenting a frequency of 220 cps as the comparison stimulus. Critical fusion frequencies were established for 10 intensities of the

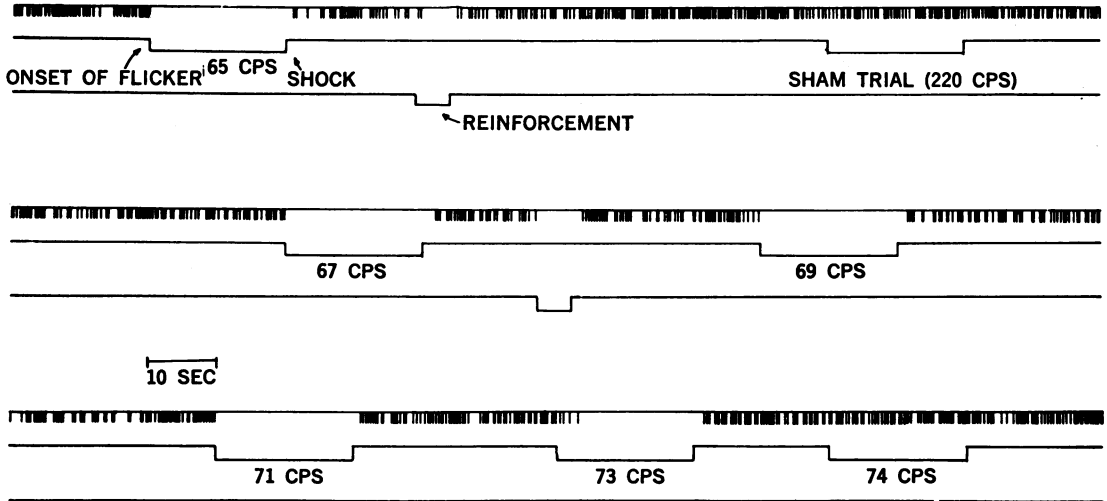


Fig. 1. Tracing of continuous polygraph recording of suppression trials on Day 11 of threshold training for Bird 98. Responses are recorded on line 1; trials on line 2; and reinforcements on line 3. Shock followed presentation of frequencies of 65, 71, and 73 cps. Intensity of the stimulus = 41.86 ml.

stimulus ranging from 0.0014 ml to 41.86 ml. For four of the intensity levels, the thresholds were determined on each of three successive days to evaluate intrasubject reliability.

RESULTS

The typical procedure for threshold training before determining final thresholds and the

suppression behavior of Bird 98 at the maximum intensity level of 41.86 ml are shown in Fig. 1. Pecking was completely suppressed at frequencies of 71 cps and below. A suppression ratio of 0.88 was recorded at 73 cps. At 74 cps, suppression was not evident. The sham trial of 220 cps shows no change in performance, indicating that the bird was responding to the flicker rather than to some

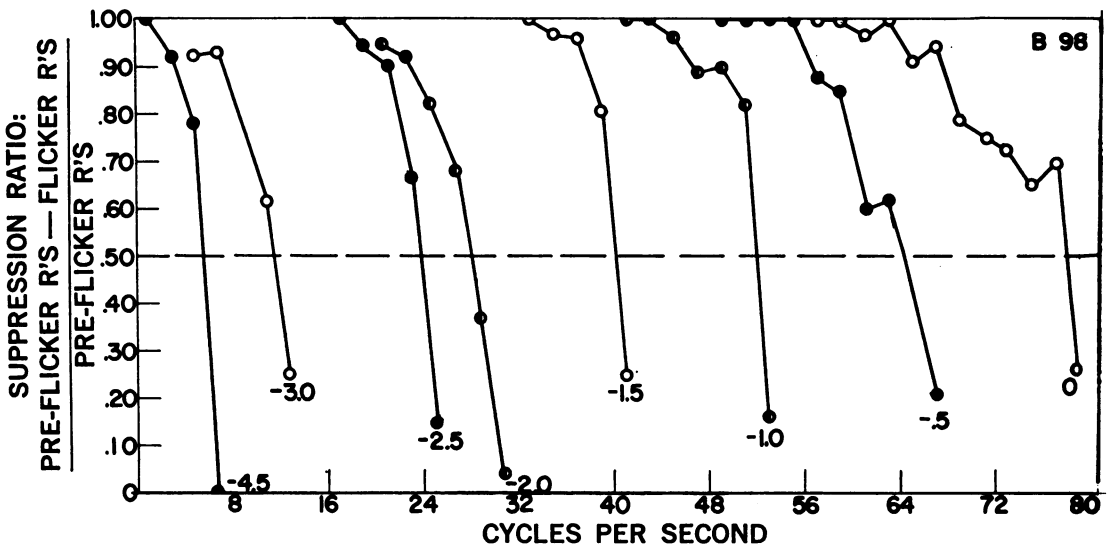


Fig. 2. Mean suppression ratios obtained for eight intensities of the stimulus during threshold sessions. Each point represents the mean suppression ratio for all trials at the frequency and intensity indicated. Intensity = 0 (41.86 ml) represents Day 1 of threshold investigation while Intensity = -4.5 log units represents Day 17. Suppression ratios of 0.50 or above indicate pre-fusion flicker frequencies. Ratios immediately below the 0.50 line indicate the determined value of the critical fusion frequency.

extraneous cues. Typically, the pattern of a slight decrease in the suppression ratio was observed throughout threshold training and determination as the frequency of the flickering stimulus neared the fusion value. At the critical frequency, the degree of suppression changed abruptly.

The strength of discriminative control achieved and maintained by the modified conditioned suppression threshold technique is shown in Fig. 2. The fusion threshold was clearly marked by a sharp decrease in the suppression ratio from that of the pre-fusion frequency. As indicated by the graph, this characteristic pattern was observed for the various values of stimulus intensity. In addition, no disruption of control was observed as a function of repeated sessions of threshold determinations. Suppression ratios for pre-fusion and fusion frequencies on Day 1 and Day 17 are comparable.

The range of intrasubject variability together with mean threshold frequencies for the four intensities of the stimulus presented on three successive days are presented in Fig. 3. Variability within subjects across sessions and intensities averaged less than 4 cps for all subjects.

Critical flicker fusion thresholds for the three subjects are plotted as a function of stimulus intensity in Fig. 4. As indicated, inter-subject variability was minimal, not exceeding 5 cps at any intensity level.

A slight lateral displacement may be observed for all subjects at an intensity level of approximately 0.1388 ml (-2.5 log units). This displacement, which occurs at a critical fre-

quency of about 27 cps, suggests that the function consists of two phases. The first is associated with lower levels of illumination and the second with higher intensities.

DISCUSSION

Critical Flicker Fusion Thresholds In the Pigeon

Critical frequencies were found to increase as a function of stimulus intensity. Except in the very low intensities, the linear relationship suggested by the Ferry-Porter law was found to hold over the range of intensities studied.

Limited research in the area and absence of comparable behavioral data prohibit adequate evaluation of rod and cone activity as related to the visual processes in the pigeon. The small lateral displacement in the current data appearing at an intensity of approximately 0.1388 ml suggests the possibility of both rod and cone activity and agrees with the low intensity or rod phase of the double sigmoid curve described by Hecht and Verrijp (1933).

Methodological Considerations

Any attempt to evaluate the modified conditioned suppression paradigm as a threshold procedure must consider factors related to stimulus control of behavior of the organism.

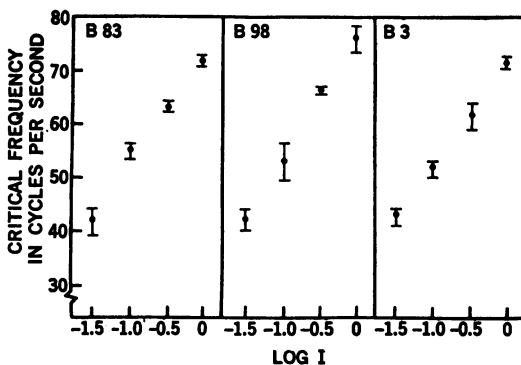


Fig. 3. Mean critical flicker fusion frequencies for each subject for three successive days at each of four intensity levels. Ranges of threshold frequencies for each intensity level are indicated by horizontal lines.

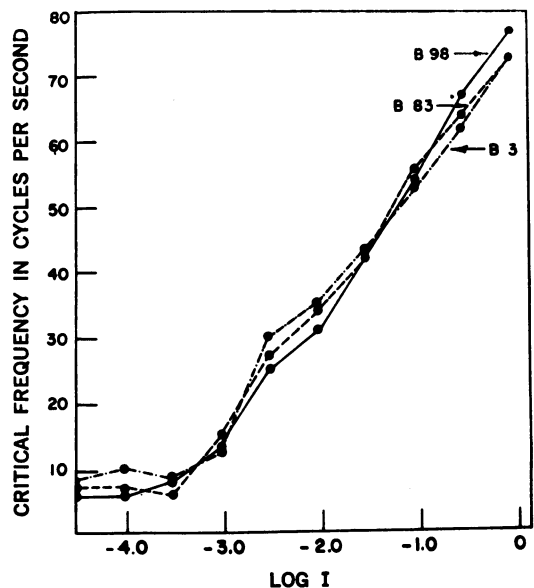


Fig. 4. Critical flicker fusion frequencies for each subject plotted as a function of stimulus intensity. 0 intensity = 41.86 ml.

The first consideration involves the speed and efficiency with which differential responding in the presence of the specified stimulus may be established. In contrast to the extensive training sessions required with certain other procedures (Symmes, 1962; Elliott, Frazier, and Riach, 1962), the present data indicate that stable conditioned suppression baselines were established by Day 11.

The data further indicate a second and even more important factor concerning maintenance of stimulus control at near-threshold values of the stimulus. Loss of stimulus control to the extent of requiring lengthy periods of retraining as well as various manipulations within the session to reestablish stimulus control has been reported by Dworkin, Katzman, Hutchison, and McCabe (1940) and Heise (1953). Similar problems have been reported in an investigation utilizing the tracking procedure of threshold study in which control procedures resulted in the rejection of from 20 to 40 per cent of the threshold data collected in an investigation of critical flicker frequencies in the monkey (Symmes, 1962). With the modified conditioned suppression paradigm, stimulus control was maintained during repeated threshold measurements throughout the investigation. At no period during threshold sessions was retraining necessary. A possible contributing factor may have been the withholding of reinforcement during the stimulus associated with shock, thus strengthening the control of the stimulus.

Perhaps of even greater significance in maintaining discriminative control was the use of a schedule in which only 60 per cent of the suppression trials were followed by shock. Such a schedule suggests the possibility of increased resistance to extinction which typically accrues from intermittent reinforcement or punishment (Ray and Stein, 1959).

Furthermore, the fact that every presentation of the flickering stimulus had not been terminated by shock during training eliminated the need to administer shock in situations where responding occurred to a considerable extent throughout the conditioned stimulus. For example, as shown in Fig. 1, shock followed presentation of the 73 cps stimulus; however, when there was no evidence of suppression during the 74 cps stimulus, shock was omitted. Consequently, the probability of shocking subjects at frequencies above fusion

level was greatly decreased, thereby reducing the disruption of behavior which frequently occurs at near-threshold values of the stimulus.

An additional advantage of the modified conditioned suppression procedure involves rigor in data analysis. The technique permits interruption of ongoing behavior with discrete stimulus presentations, allowing accurate comparisons of response rates for pre-stimulus periods with changes occurring as a function of flicker.

Although applicable to the study of other types of stimulation, this procedure was particularly efficient in the study of flicker thresholds in the pigeon. Since flicker threshold determination involves instantaneous stimulus changes from a fused or high frequency light to a flickering light, continuous monitoring of the stimulus spot by the organism is required. With the steady rate of responding generated by a variable interval schedule of reinforcement, the animal was largely restricted to the key area. Consequently, the head of the pigeon was constantly oriented toward the key onto which the stimulus light was focused via the optical system.

The absence of comparable data for critical flicker fusion in the pigeon prohibits comparison of the sensitivity of the conditioned suppression procedure with other threshold techniques, such as the tracking procedure introduced by Blough (1958). However, the overall efficiency of the conditioned suppression technique is indicated by the stability of baselines and the maintenance of stimulus control in the presence of sub-threshold frequencies, the reliability of intrasubject thresholds, and intersubject replication.

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