METHODS & DESIGNS

Conditioned suppression as a psychophysical technique for the cat*

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A modified conditioned suppression paradigm coupled with a new training apparatus has been applied to gathering sensory data in the cat. The method excels in that training, data collection, and reliability are quickly achieved and it can be used with subtle stimulus changes.

With the possible exception of the frog, the cat has been the organism most intensively studied by sensory physiologists. The wealth of electrophysiological and anatomical data available for the cat's sensory systems make it an exceedingly interesting organism for sensory experiments, but the cat's almost legendary reputation as a difficult behavioral subject has produced a dearth of such experimental data. A fairly recent addition to the methodologies available to investigators interested in animal psychophysics has been the conditioned suppression paradigm using the conditioned emotional response (CER) first described by Estes and Skinner (1941). In brief, the method involves pairing a shock (UCS) with a stimulus (CS) while the animal is performing an operant response. The outcome of this procedure is that the animal reduces the number of responses emitted during the CS, as compared with an equal time period when the CS is absent. As applied in psychophysical studies, some dimension of the stimulus is varied, e.g., intensity, and the degree of response suppression during the stimulus is taken as an indication of whether or not the stimulus was perceived by the S.

As a psychophysical technique, conditioned suppression has been characterized by exceedingly rapid training and psychophysical testing and has been successfully employed with a variety of mammals and birds and in almost every sensory modality (Smith, 1970).

A second recent development has been an improved responding apparatus for the cat (Berkley, 1970)

wherein the animal places his head in a shallow cylinder and presses a nose key to obtain beef baby food. As a two-choice visual discrimination situation, the method has been very successful, allowing as many as 1,000 trials on one cat in 1 day. The following is a description of a testing method combining conditioned suppression and a nose keypress response to achieve psychophysical measurements for the cat.

OPERANT TRAINING

Subjects

The cats were obtained from the local animal shelter, isolated for 2 weeks on ad lib food and water, and then reduced to 80% of their free feeding weight. During all phases of the experiment, the Ss were maintained with rewards (30-50 daily), supplementary dry cat chow (20-40 g daily), restricted water (100-150 g daily), and daily vitamin supplements.

Apparatus

The overall description of the apparatus has been discussed by Berkley (1970). Figure 1 illustrates the major features of the experimental setting. The cat stood in the experimental chamber on a brass grid floor and placed its head into a Plexiglas cylinder (5 x 5 in.). At the back of the cylinder, a nose key (1 in. in diam) was located. The reward, a small bit of beef baby food, was delivered on a flat metal surface (tilt, 45 deg from horizontal) 1.5 in. below the center of the nose key. (Details of the feeder can be found in Berkley, Crawford, & Oliff, 1971.) The stimulus presentation screen was located 1.5 in. above the center of the nose key. This configuration of manipulanda, reinforcement delivery, and stimulus display allowed the cat to respond, eat, and see the stimulus without any major changes in head orientation and had been found earlier to be important determinants in

behavioral training of cats (Berkley, 1970).

In all experiments conducted thus far, the stimulus has been presented on the sand-blasted Plexiglas viewing window via a fiber optic bundle.

Procedure and Results

The S was trained to press the key with his nose by a method of successive approximation. This initial shaping of a nose press response was often complicated by the cats' tendencies to employ their feet in obtaining food. It was necessary to extinguish use of the forepaws before a cat could successfully be trained to press the key with his nose. Initial training was generally achieved within 20 min (range, 5-90 min).

Initial training was followed by approximately 100 continuous reinforcements, after which the S was moved to a dense fixed ratio of reinforcement. Figure 2 presents some of the cumulative records obtained during these early schedules. As can be seen, the fixed-ratio schedules resulted in typical break and run response patterns, while a fixed-interval schedule produced the customary "scallop" response pattern. Trace 2 in Fig. 2 illustrates that the transition from a FR 25 to a FI 25 sec resulted in a rapid change in response pattern. The third trace presents the response pattern seen under a variable-interval 90-sec schedule of reinforcement.

Fig. 1. Schematic representation of operant conditioning chamber employed for psychophysical determinations with the cat.

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Fig. 2. Sample cumulative records obtained during early operant conditioning with different schedules of reinforcement: Record 1, FR 10 and 12; Record 2, FR 25 and FI 25 sec; Record 3, VI 90 sec with a 3-sec limited hold on reinforcement availability.

One important requirement for employing conditioned suppression as a psychophysical technique is that the S exhibits a steady response rate. For this reason, relatively sparse variable-interval schedules of reinforcement have been employed. It has also been useful to encourage rapid response rates, since the number of responses emitted during the non-CS periods affects the variability of the suppression measure; the more rapid the response rate, the less variable the suppression measure. Response rates have naturally varied from one S to another, but a VI 90-sec schedule with a limited hold on reinforcement availability of 3 sec has generally produced cats which will respond steadily, emitting between 1,500 and 2,000 responses per hour. We have not encountered a cat that could not be brought to this acceptable level of operant performance.

CONDITIONED SUPPRESSION

A variety of ratios have been developed for quantifying suppression of an operant response during a stimulus which has been paired with unavoidable shock. All of the ratios developed serve to compare the number of responses emitted while the CS is present (during period) to the number of responses emitted during an equal time when the CS is absent, generally the period immediately

preceding the CS (preperiod). We have employed the formula developed by Dinc (1965): $[(\# \text{ pre-CS responses}) - (\# \text{ during-CS responses})] / [(\# \text{ pre-CS responses}) + (\# \text{ during-CS responses})]$. This suppression ratio yields 0.00 if the number of pre-CS responses equals the number of during-CS responses, 1.00 if no responses are made during the CS, and 0.33 if during-CS responses are 50% the number of pre-CS responses. This formula has the advantage of yielding symmetrical ratios if the number of during-CS responses exceeds the number of pre-CS responses.

Training

Initial suppression training involved the presentation of a white stimulus light on the viewing window for a period of 30 sec. The termination of the stimulus (CS) was coincident with the presentation of a 0.5-sec shock (UCS) to the S's feet. The shock intensity on the first trial was very low but was adjusted upward in small increments until an intensity was reached at which the S ceased responding for a short time following shock presentation. This intensity varied between 1.5 and 6 mA, depending upon the S.

During all suppression training and testing, daily baseline trials were taken. A baseline trial involves comparing the number of responses emitted during two consecutive 30-sec periods employing the suppression formula. Since these trials did not involve CS presentation or shock, the two periods contained approximately equal numbers of responses and therefore yielded ratios of approximately 0.00 (± 0.10). Reinforcements were withheld for preperiods and during periods on both suppression and baseline trials. Trials were programmed independently of reinforcement on a variable-interval 5-min schedule. Figure 3 presents the first 50 consecutive days of suppression training for the first two Ss tested.¹

Each S received five to seven suppression trials and three to five baseline trials daily. The mean suppression ratios for both Ss were above 0.33 by the second day of training. Suppression ratios of 1.0 were achieved by both Ss by the fourth day of training. During the initial 9 days, neither S had been receiving shock at CS offset with 100% reliability. This unreliability of the shock was evidenced by the erratic

Fig. 3. First 50 consecutive days during initial conditioned suppression training for two cats. Days upon which a S was not tested are represented by the absence of a corresponding data point. Ordinate represents suppression ratio calculated $[(\# \text{ pre-CS responses}) - (\# \text{ during-CS responses})] / [(\# \text{ pre-CS responses}) + (\# \text{ during-CS responses})]$. Baseline trials compare the number of responses during two consecutive 30-sec periods in which no stimuli occurred and are a measure of response stability.

Fig. 4. A sample cumulative record obtained during five conditioned suppression trials employing four different intensities of monochromatic light.

suppression of Momma throughout the first 9 days and by No. 18 on the ninth day. During the following 13 days, the cats were not tested and appropriate adjustments were made in the shock delivery system. As can be seen in Fig. 3, these adjustments resulted in immediate criterion suppression, +0.90, in both Ss. The following 28 days included 14 days of testing, with a 10-day vacation for all concerned. The points to be derived from Fig. 3 are (1) training was exceedingly rapid, and (2) once suppression was established, it remained constant, despite periods of inactivity. Subsequent experience with other cats who received reliable shock from the onset of training has generally shown that +0.90 mean suppression is established within 4-6 days (40-60 trials). Following the establishment of criterion suppression, monochromatic light was employed as the CS. This training was continued for 3 months, with the wavelength of the CS changed daily. The wavelengths employed varied from 403 to 700 nm. These various wavelengths were not initially equated for equal quanta emission and thus established light onset per se as the relevant cue, with wavelength and apparent brightness irrelevant. Late in monochromatic training, two sham trials per day were presented. During a sham trial, the shutter was operated and shock delivered but the CS light was not present. These trials had the dual effect of establishing the presence of the CS as the controlling stimulus and preparing the Ss to receive a percentage of unsigned shocks during the course of threshold determinations.

Psychophysical Testing

Once reliable suppression had been

established, psychophysical measurements were made by varying some dimension of the CS—e.g., intensity. The Ss were given eight suppression trials and five baseline trials per day. CS intensities were chosen so that during any given session, the S did not receive more than three trials on which a suppression ratio of less than 0.33 was elicited. While subthreshold trials were kept to a minimum, shock intensity and probability (100%) were kept constant. Figure 4 illustrates the effect of four different CS intensities on baseline responding for part of one daily session. Relative light intensities of 1.0 and 0.1 resulted in perfect suppression; intensity .001 elicited discernible suppression on one of two occasions, while intensity .0001 produced no response suppression.

The suppression-ratio/CS-intensity relationships presented in Function 1 (Fig. 5) are the results obtained on the first day of testing while determining the scotopic luminosity function for the cat. Each data point represents the suppression ratio obtained on one trial at a particular intensity. Momma was tested with a stimulus light of 440 nm, No. 18 was tested with a stimulus light of 498 nm. The log attenuation threshold for the particular wavelength employed was the estimated intensity which corresponded to a suppression ratio of 0.33 and represented a 50% reduction in response probability during the CS. As can be seen, a stimulus light of 440 nm yielded a threshold estimate of 3.7 log attenuation, while a light of 498 nm

yielded a threshold estimate of 4.6 log attenuation. During the course of determining the entire scotopic luminosity function, three cats were tested on 10 wavelengths, each wavelength employed on 3 separate days. The average error across days, wavelengths, and Ss was $\pm .29$ log units. The overall scotopic luminosity function determined by this method agreed very well with the behavioral determinations of other investigators (Gunter, 1952; LaMotte & Brown, 1970) and will be discussed elsewhere (Loop & Berkley, in preparation). The major advantage of the present method was that only nine threshold determinations (720 trials) were required at each point. Gunter (1952) employed over 3,500 trials at each point, and LaMotte and Brown (1970) required 24-42 threshold determinations per point for their scotopic luminosity function.

Other stimulus dimensions have also been used. Figure 5 also presents some data achieved while determining the temporal contrast modulation function for the cat. During these experiments, the CS was a flickering light, while the "safe" signal was a steady light. Transition of suppression behavior from a steady light (the CS employed in the first function) to a flickering light required one trial in two of the Ss and approximately 50 trials in the third S. Function 2 (Fig. 5) presents the CFF as determined for Igor and No. 18. Employing the same threshold criterion of a suppression ratio of 0.33, the CFF for the two cats was

Fig. 5. Three suppression ratio functions employing three different stimulus dimensions for the same three Ss: Function 1—suppression-ratio/CS-attenuation relationship for two wavelengths of light, each data point corresponding to one trial; Function 2—mean suppression-ratio/CS-frequency (herz) relationship at 100% modulation depth; Function 3—mean suppression-ratio/CS-modulation depth relationship for two frequencies (25 and 30 Hz) of flicker. In all cases, a suppression ratio of 0.33 is taken as "threshold."

53 Hz for No. 18 and 33 Hz for Igor. The modulation depth was held constant at 100%. Function 3 (Fig. 5) presents the suppression ratio as a function of modulation depth for two frequencies of flicker—30 Hz for Momma and 25 Hz for No. 18. Again, thresholds may be estimated for a 50% reduction in response probability by employing a suppression criterion of 0.33.

DISCUSSION

There are a number of factors which recommend conditioned suppression as a psychophysical technique for the cat. First, once adequate operant responding was established, training of the desired discrimination proved to be a task requiring very little time (less than a week in all cases). Second, once the response was established, periods of inactivity resulted in no decrement in performance. Third, transfer of stimulus control from one dimension

to another, light onset to light flicker, was instantaneous in two of the three Ss and rapid in the third. Fourth, where comparison with other data on the cat was possible, the scotopic luminosity function, the method at hand, yielded virtually identical results in considerably less time.

In conclusion, we would like to put to rest the myth that the cat is a difficult behavioral S and offer this technique as a solution.

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NOTE

1. Our primary reason for presenting these data was that it represented our first attempt with the procedure. The rationale was that anyone else considering adopting the technique would be most interested in our initial degree of success. We also felt that these data rather dramatically demonstrated the importance of a dependable UCS in obtaining a dependable CR. We have acquisition data uncomplicated by shock difficulties, but, for the most part, it simply reflects the rapid establishment of control already discussed by Smith (1970).