THE STABILITY AND CONTROL OF CONDITIONED NOISE AVERSION IN THE TILT CAGE¹

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Twenty-six rats were used to study the development of stable conditioned responding to terminate white noise (100 or 105 db) in a tilt cage apparatus. Preliminary work, with one end of the cage consistently associated with silence, demonstrated stability at a high level of cumulative noise-off time per session. Time spent at the noise-off cage end was unaffected by lay-off and showed adaptation to reversal of the cage end functions. Variability in reversal acquisition, insensitivity to stimulus intensity changes and persistence in remaining at one end of the cage in the absence of noise-termination contingencies indicated the need for more precise behavioral control. A schedule programming several reversals of the no-noise end at variable intervals within each session was developed. Performance on the latter schedule was characterized by stability of high noise-off times and also proved more sensitive than the preliminary method to stimulus intensity changes (55, 70, 100 db) as measured by both cumulated noise-off time and cage crossing rates. The ease of training combined with sensitivity to stimulus change and the lack of highly specific motor response requirements make this technique promising for use with animals potentially debilitated by drugs or surgical after-effects.

The termination of intense noise by lever-pressing has been used to strengthen and maintain escape responding in several animal studies (Harrison and Tracy, 1955; Harrison and Abelson, 1959; Lyon, 1964). But the technique presents difficulties. The percentage of animals successfully trained varies from 60 to 100 per cent which may reflect, in part, the relatively weak reinforcing effect of white noise compared, for example, with electric shock (Campbell and Bloom, 1965). Increasing noise intensity to a maximum does not invariably insure improved training. Nor does noise have lasting suppressing effects in an Estes-Skinner paradigm (Tracy, 1956) where its disruptive effects are pitted against a food-reinforced schedule.

One method which may allow improved training and assessment of noise-maintained responding utilizes a spatial localization response as typified by the tilt cage (Campbell, 1955; 1957) or the platform within a cage (Barnes

and Kish, 1957). Such methods apparently result in rapid, consistent training; but these studies were restricted to one to three sessions totalling 45 min or less in the presence of the noise contingency and individual behavioral variations were not reported.

The preliminary study described below studies the stability and strength of tilt cage responding over many sessions and examines the reinforcing effects of noise termination in this situation by testing reversal behavior and extinction. The introduction of a variable interval schedule of reversals within sessions (multiple reversal schedule) and the effect upon behavior of lowering the noise intensity to below previously reported aversive threshold ranges (Campbell, 1955; 1957), are examined in the main experiment.

PRELIMINARY EXPERIMENT

Subjects. Fifteen adult female Long-Evans hooded rats, weighing at least 150 g each, were obtained from Rockland Farms, New City, New York.

Apparatus. A wire cage (11 by 9 by 10 in.) was mounted on central pivots so that each end closed a microswitch when it tilted. This assembly occupied the center of a ventilated, partially sound-proofed wood compartment. The

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compartment was lighted by two bulbs near each end of the cage. White noise was obtained from a General Radio Random Noise Generator, amplified and fed into a University T-202 loudspeaker centered above the pivot line. Frequencies below 2500 cps were highly attenuated but the upper range of the speaker exceeded 20,000 cps. The noise source and all controlling equipment was remotely located. Noise-off time and number of cage crossings were automatically cumulated and a Gerbrands Cumulative Recorder provided a continuous record of each session. Sessions were automatically timed and houselights were on only during the experimental period.

Intensity measurements were made with a General Radio Sound Level Meter Type 1552C using standard microphone extension cable and the "C" weighting scale for frequency distribution. All readings were corrected for ambient temperature and variation within the test cage space was less than 1 db. (re. .0002 dynes/cm²). The ambient noise level in the box (minimum level ca. 52 db) was mainly composed of low frequencies so that the uniform white noise spectrum of even the 55 db signal was grossly different from the background noise.

Procedure. Subjects were given seven 15-min sessions with no noise present to determine which end of the cage was "preferred" (that end on which the animal spent more than half of the session time on at least four of the seven days). Training sessions, also 15 min in length, began on the eighth day. During training sessions, a 105 db (four subjects) or 100 db (11 subjects) noise was presented and remained on as long as the subject stayed at the previously preferred end. As soon as the subject traversed the cage, noise terminated and remained off as long as it stayed there. A subject was considered trained when noise-off time equaled or exceeded 720 sec (80 per cent) of each 900-sec session for seven of the last 10 days of training, with at least two of the last three days above the 80 per cent level.

BB Subgroup. Three subjects reaching the above criterion were allowed to rest in their home cages for two weeks and were then re-tested to assess the effects of lay-off. One failed to meet the training criteria.

MS Subgroup. After 20 days of training six subjects were run with the noise-off end reversed. After reversal training these subjects

were "extinguished" with noise continuously on (Harrison and Abelson, 1959). Five of the six subjects were finally tested for reacquisition under the training conditions which had immediately preceded the continuous noise condition. The sixth subject failed to alter its behavior under continuous noise and was continued on that schedule with noise level increased to 110 db.

M Subgroup. Five subjects were trained at 100 db (15 days), tested at 55 db (nine days) returned to 100 db (seven days) and tested with no noise present (seven days).

Results

Fourteen of the 15 subjects reached the 80 per cent noise-off time criterion within 10 sessions. Figure 1 illustrates responding in sample subjects from each subgroup.

The initial seven no-noise sessions labelled "operant" established that the apparent "preference" for one end in the first session did not always represent a lasting choice. Animal 1BB illustrates the typical lack of effect upon responding of a two-week lay-off. After establishing stable responding over 20 days to one end of the cage, the no-noise cage end was reversed for the MS group. Animals 1MS and 3MS illustrate that acquisition of reversal behavior varied widely. In five of the six MS animals subsequent removal of the noise-termination contingency (noise continuously on), reduced the conditioned behaviors which consistently kept the animals at one end of the cage (see 3MS, Fig. 1). The sixth animal (1MS, Fig. 1) continued to remain at one end of the cage and raising the intensity of the continuous noise increased the time spent at that end. For the five animals whose responding was altered, reacquisition illustrated that the change during continuous noise was relevant to the absence of the termination contingency (see 3MS, Fig. 1).

Since continuous noise or continuous silence removes the discriminable properties of noise termination or onset, one group (see 6M, Fig. 1) was tested, after initial acquisition, with a low intensity noise signal of 55 db. Such a signal is easily discriminable (Gourevitch, Hack, and Hawkins, 1960; Lyon, 1964) yet is well below the level of 91 db (re. .0002 dynes/cm²) which Campbell (1955) estimated as the threshold for just noticeable aversion learning with 100 per cent reduction of white noise similar

Fig. 1. Recorded noise-off times for representative subjects in preliminary experiment. Noise-off times during operant sessions represent the time spent at the back (b) or front (f) ends of the cage. During training, one of these ends, as indicated, is associated with noise-off. Abbreviations: 100 db Acq, acquisition; 100 db Rev, reversal; 100 db Ext, 110 db Ext, noise continuously on; 100 db Reacq of Rev, Reacquisition; 55 db Test, test sessions at 55 db; 0 db Test, test sessions with no noise signal.

to that used here. A second, more precise, study of discrimination and aversion thresholds for bands of noise within the lower frequency range of the present stimulus (Campbell, 1957) also demonstrated that 55 db was at least 20 db below the aversion thresholds and well above the discrimination thresholds.

Despite the fact that the 55 db noise is far below these reported aversion thresholds, the noise-off time was reduced only slightly and did not approach closely the region (450 sec) representing equal response to both cage ends which one might expect with a "non-aversive" stimulus. Reacquisition at the 100 db level illustrated that the slight reduction in noise-off time at 55 db was dependent on the change in noise intensity. However, the small reduction in noise-off time at 55 db, plus the fact that all of the M group animals ($N = 5$) during the final no-noise (zero db) conditions continued to remain at the previously reinforced end of the cage for periods equal to and often greater than those obtained at 55 db, raised doubts about the importance of the 55 db noise in maintaining the noise-off times.

No consistent changes occurred in the number of crossings per session. They remained generally low (5 to 20 crossings per session for most subjects) throughout the various experimental conditions.

MAIN EXPERIMENT

The preliminary experiments indicated that acquisition was rapid and behavior generally stable over long periods. However, the considerable variation in time to successful reversal suggested that reversal, rather than response maintenance level, was a critical test of the importance of the noise contingencies in keeping the animal at one end of the cage. Furthermore, one animal which had been exposed to the conditioning persisted in remaining at one end of the cage during continuous noise, even though noise stimulus contingencies did not differ between the two ends (see *LMS*, Fig. 1). In addition, the continuing relatively strong choice of the noise-off end at 55 db, and even at zero db, led us to look for a way to separate the noise-termination from any consistent association with either end of the cage. Such a design would eliminate the possibility that under certain conditions, such as the 55 db stimulus level, the animal's apparently strong tendency

to remain at the no-noise end occurred partially because of odor, temperature, visual appearance or other stimuli which may or may not have been contingent upon the presence of the noise in the past. A simple method for reducing these difficulties was to reverse the no-noise end of the cage several times within each session and at variable intervals to avoid temporal discrimination. The design of the following experiments also included preliminary and final tests with no noise present, which provided an indication of the baseline performance. A "pretraining" period at 70 db was introduced to lessen the possibility of audiogenic seizures when maximum intensity was introduced and also to provide data on responding at an intensity intermediate to 55 and 100 db.

Subjects. Eleven adult, female Long-Evans hooded rats were used.

Apparatus. The basic apparatus, experimental box, recording and sound producing equipment were similar to those employed in the preliminary experiment.

A 1-min variable interval tape was used to reverse the no-noise end of the cage during sessions. The tape stopped whenever the animal left the noise-off end; the animal thus exercised some control over the actual intervals available. The method prevented noise termination under any condition except crossing the cage from the noise end.

Procedure. All subjects were given one 15-min session on each experimental day using the 1-min variable interval tape to program multiple reversals. The sequence for the GG group ($N = 5$) was: one no-noise "operant" session, five sessions at 70 db, 15 sessions at 100 db, seven sessions at 55 db, seven sessions at 100 db, and four to six sessions with no-noise (zero db). During the early 100 db sessions for this group some distortion was detected in the amplification system. This was temporarily corrected by attenuating high energy peaks in the noise but since this could not be done without affecting the noise quality, the entire system had to be replaced. The HH group ($N = 6$) was run using the new sound system throughout with the following sequence: seven "operant" sessions under no-noise conditions, five sessions at 70 db, 14 or 15 sessions at 100 db and nine sessions at 55 db.

A record was kept of noise-off time and cage crossings for all sessions. During no-noise (operant or zero db) sessions, "noise-off time"

Fig. 2. Recorded noise-off times for GG subjects in main experiment during operant, pretraining (70 db Pre), acquisition (100 db Acq), testing at 55 db (55 db Test), reacquisition (100 db Reacq) and testing with no noise signal (0 db Test) sessions. Arrows indicate first sessions after apparatus modifications as described in text for GG animals.

merely designates the time spent at the end of the cage ordinarily scheduled for noise-off conditions.

Results

During the single operant (no-noise) session (GG group) or extended operant sessions (HH group) noise-off times were recorded from 50 to 550 sec. Noise-off times of 450 sec would represent average expected levels of performance if there were persistent crossing and approximately equal tendency to stay at either end of the cage. As illustrated in Fig. 2-5, the most common operant performance is well below

this level, indicating relatively few crossings and a tendency to remain for longer periods at one end of the cage.

At 70 db, a few subjects decrease noise-off time and some noise-off times are unchanged. But the most common effect is to raise noise-off times to 450 sec or above. At 100 db, noise-off time increases for all subjects. This increase is marked and maintained throughout the training period for most subjects. One subject, 8GG, increased initially but failed to sustain noise-off times above the 450 sec level. This subject also reacted atypically to the initial presentation of noise at 70 db, almost dropping to zero

Fig. 3. Recorded noise-off times for GG subjects in main experiment. Notations as in Fig. 2.

Fig. 4. Recorded noise-off times for HH subjects in main experiment. Notations as in Fig. 2.

Fig. 5. Recorded noise-off times for HH subjects in main experiment. Notations as in Fig. 2.

in both noise-off time and number of cage crossings (see Fig. 3 and Table 1). As indicated in Fig. 2 and 3, the GG group was exposed at a critical period in acquisition to the noise distortion occasionally caused by the faulty apparatus mentioned previously. Comparison with the HH group acquisition at 100 db using the new amplification system throughout suggested that the variability in the GG group performance was probably caused by the apparatus difficulties.

When the noise level was reduced, after training, to 55 db all subjects evidenced reduced noise-off times, most in the HH group registering noise-off times no higher than their operant levels. When the 100 db noise was reintroduced for the GG group, noise-off times increased to meet previous training levels. Finally, noise-off times were reduced sharply when the noise was eliminated for this group. The response level at zero db was equal to or lower than responding at 55 db in all subjects.

The development of this behavior is illustrated by the cumulative records of selected testing sessions from one subject (Fig. 6). During noise sessions, downward displacement of the event pen marks noise termination; as long

as noise-off conditions exist the pen remains down. With noise onset, the pen returns to its baseline position and remains there while noise-on conditions are present. During early training the records are made up mostly of short noise-off periods separated by longer noise-on periods. As acquisition progresses, longer noise-off periods and shorter noise-on periods become most common. When the intensity of the stimulus is reduced to 55 db, the initial response pattern reappears, although there may be some recovery. During the sessions at zero db, after retraining occurred, the total number of crossings decreases markedly.

Table 1 summarizes the cage crossings per session for these animals. Careful examination indicates that as acquisition at 100 db continues, crossings per session increase. Number of crossings per session decreases at 55 db, increases again during retraining, and falls considerably at zero db. These findings are uniform for all but one animal (3HH).

DISCUSSION

The advantages of the multiple-reversal method over the preliminary method are not

Table 1
Median and Range of Crossing Responses per Session
at Selected Stages of Training and Testing

Subject		<i>Oper.</i>	<i>Pre.</i>	<i>First 5</i>	<i>Last 5</i>	<i>Test</i>	<i>Reacq</i>	<i>Test</i>
		<i>Sess.</i>	<i>Sess.</i>	<i>Sess.</i>	<i>Sess.</i>	<i>Sess.</i>	<i>Sess.</i>	<i>Sess.</i>
			70 db	100 db	100 db	55 db	100 db	0 db
7GG	Median	16	14	16	17	15	19	9.5
	Range	—	10-22	9-26	14-21	9-22	14-28	7-14
8GG	Median	20	3	7	12	7	14	9
	Range	—	1-5	3-18	11-13	4-14	6-16	4-9
9GG	Median	12	14	18	20	14	25	8
	Range	—	8-17	17-24	18-22	11-17	20-27	6-8
10GG	Median	29	30	25	29	26	31	25
	Range	—	21-35	20-33	25-37	24-30	24-36	18-31
12GG	Median	14	9	16	19	14	27	10
	Range	—	7-11	9-17	13-23	9-26	18-29	4-15
1HH	Median	30	41	30	36	35	—	—
	Range	22-99	36-49	18-37	31-39	27-37	—	—
3HH	Median	54	25	22	21	28	—	—
	Range	29-97	19-28	17-25	18-41	9-73	—	—
4HH	Median	21	15	19	23	17	—	—
	Range	16-36	12-20	15-47	17-29	9-22	—	—
5HH	Median	13	14	18	24	19	—	—
	Range	4-20	6-17	15-21	22-31	9-23	—	—
6HH	Median	15	10	18	23	18	—	—
	Range	8-26	8-11	15-21	20-26	14-21	—	—
7HH	Median	27	29	30	33	27	—	—
	Range	24-35	23-44	26-31	31-40	18-32	—	—

Fig. 6. Cumulative records of subject 12GG from main experiment, illustrating development of responding to intense noise in the tilt cage with multiple reversals. See text for explanation of recording procedure.

immediately apparent upon cursory examination. The higher noise-off times recorded in the preliminary study should not be equated with greater control of conditioned behavior because of several factors. The multiple-reversal situation was more demanding in terms of repeated cage crossing as the no-noise end changed. Furthermore, in that situation the only consistent coincidence was that noise termination followed crossing of the cage in the presence of the noise; noise onset could follow crossing or occur at the end of a programmed interval and thus was at times contingent upon responding which kept the subject at the no-noise end of the cage. This may explain why the animals never reached the highest noise-off levels possible, since there was probably some tendency not to repeat responses followed by noise onset; in this case these responses were from the class of responses which would maintain the noise-off condition.

The multiple-reversal schedule also set an approximate limit of 450 sec average noise-off time per session with random or highly irregular cage crossing. In the preliminary experiments such crossing behavior, especially if it led to lengthy pauses at one end of the cage, could theoretically have resulted in average noise-off times approaching the total session length. Consequently, when low crossing rates predominated, as in the preliminary study, this measure became quite insensitive to noise intensity variations, as evidenced by the failure to find any consistent change in these low crossing rates throughout a sequence of 100-55-100-0 db testing. However, during the multiple-reversal tests, the number of cage crossings changed with the noise intensity, thus yielding a differential response measure not present in the original tilt method.

A further disadvantage of the original method lay in the relatively high noise-off times recorded at 55 db and zero db (see 6M, Fig. 1), which were highly similar and closer to the 100 db response level than to the initial operant (no-noise) level. Such evidence led us to question the relevance of noise intensity alone in determining the animal's tendency to remain at the no-noise end of the cage. The multiple-reversal method, on the other hand, typically yielded discriminable and intensity-related differences in noise-off time with 100 db

highest, 70 db next and 55 db lowest. The comparison between 55 db and zero db was equivocal since 55-db responses were indistinguishable from initial operant levels in HH animals, but were higher than final zero db sessions in the GG group. The difference between the two sequences of testing makes further study necessary before the 55 db level could be evaluated in terms of an aversion function.

In conclusion, these experiments demonstrated that the tilt cage with multiple-reversal scheduling provides a reliable, easy method of training for use with aversive stimuli (see also Campbell and Bloom, 1965), and that the behavior generated is stable, yet much more sensitive to stimulus change than were earlier methods using the tilt cage. Such a method may be especially valuable for measuring an animal's sensitivity to experimental stimuli where behavioral limitations due to surgery or drug effects undesirably affect motor performance on a lever task or other relatively specific response topographies.

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