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STIMULUS INTENSITY EFFECTS AND SECOND-ORDER RESPONSE ACQUISITION IN PAVLOVIAN FEAR CONDITIONING

by

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The present series of studies was designed to a) determine if, following Pavlovian conditioning of a fear response to a particular conditioned stimulus (CS) intensity, an increase or decrease in the CS intensity would result in changes in the fear response (Experiment 1); b) test Hull's (1943) theory that, in second-order conditioning, the second-order CS becomes associated with the response evoked by the first-order CS (Experiment 2); and c) attempt to replicate Rizely and Rescorla's (1972) finding that, following second-order conditioning, a second-order CS continues to evoke a conditioned response even after the conditioned response to the first-order CS has been extinguished (Experiment 3).

In Experiment 1, 56 rats were randomly assigned to seven equal-sized groups and trained to barpress on an intermittent reinforcement schedule until a steady rate of responding was established. Following this training, a 30-second, 6kHz tone of either 65 db or 90 db intensity was superimposed on barpressing to habituate any suppressive effects of the tone. Four experimental groups then received contingent tone-shock pairings, and three control groups received Rescorla's (1967) completely randomized

control procedure. All experimental groups were conditioned to an equal suppression criterion; control subjects were matched to experimental subjects in terms of total training. Following training, fear to background cues was extinguished and then all subjects were tested for conditioned suppression to the tones. One experimental and one control group, each trained with a 65 db tone, were tested with a 65 db tone. Similarly, an experimental and control group trained with the 90 db tone were tested with a 90 db tone. One experimental and one control group trained with a 65 db tone received a 90 db tone during the test. The remaining experimental group, trained with a 90 db tone, was tested with a 65 db tone. Test trials continued until each subject reached an extinction criterion. The results showed that decreasing CS intensity following conditioning produced a significant decrease in barpress suppression but increasing CS intensity did not produce a significant increase in barpress suppression. CS pre-exposure and the use of a between- rather than a within-subject design were suggested as possible factors contributing to the failure to demonstrate reliable and statistically significant CS intensity effects in Pavlovian fear conditioning.

In Experiment 2, two groups of rats were trained to barpress for sucrose-pellet reinforcement until a steady rate of responding was maintained on an intermittent reinforcement schedule. Following barpress training, presentations of a 90 db tone (S_1) and a 30-second flashing of the houselight (S_2) were superimposed on VI responding to habituate any suppressive effects of S_1 and S_2. Then both groups received contingent pairings of the tone and shock (i.e., first-order conditioning) to establish conditioned suppression to the S_1. After first-order conditioning was completed, one group, Group E, received a series of S_1 extinction trials, while the other group, Group NE, did not. Next, both groups received contingent S_2-S_1 pairings (i.e., second-order conditioning) to establish conditioned suppression to the flashing light. Following second-order training, all subjects were given S_1 extinction trials and both groups were equated on the total number of extinction trials. Finally, all subjects were tested for conditioned suppression to S_2. The results showed that no appreciable degree of conditioned suppression was established to the light S_2 in either group, so no valid conclusions about Hull's S-R theory could be drawn from the data. Group NE showed moderate suppression to the light S_2 during the first and last pairs of second-order conditioning trials, but showed no suppression to S_2 during subsequent test trials. The outcome was interpreted in terms of intermodality stimulus generalization.

In Experiment 3, a single group of rats received the same training and testing procedure as Group NE in Experiment

2, except that subjects received S_2-discrimination training during first-order conditioning. The results showed that discrimination training eliminated intermodality stimulus generalization but that no substantial second-order suppression was established to the light S_2. Furthermore, the slight second-order suppression which was obtained during S_2-S_1 pairings did not persist after S_1 extinction trials. In light of these results, Rizely and Rescorla's (1972) previous findings were interpreted to be partially due to their procedure of presenting a light S_2 to dark-adapted rats. The clinical implications of all three experiments were discussed.

ACKNOWLEDGMENTS

The author gratefully acknowledges the guidance and assistance rendered by Dr. Donald G. Wildemann, adviser, throughout all the phases of this research. Sincere thanks are also extended to Drs. Aaron J. Brownstein, P. Scott Lawrence, Rosemery O. Nelson, William A. Powers, and Kendon Smith, members of the oral examination committee, for their interest and assistance.

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CHAPTER I

INTRODUCTION

In the natural environment, numerous stimuli are paired with aversive events in such a way that these stimuli later evoke a fear response. For example, the flashing lights on a police car being followed by a traffic citation result in flashing lights evoking a fear response. The natural environment also provides numerous examples of a similar but more intricate phenomenon, namely, a stimulus value that has never been directly paired with an aversive event actually evoking more fear than the stimulus value that was paired with the aversive event. Consider the case of a swimmer who is learning to dive. Neither a high dive nor a low dive has ever been paired with an aversive event. If the swimmer takes a "belly flop" off the low diving board, the low diving board will elicit fear. What is more interesting, however, is that the high diving board may actually elicit more fear than the low diving board, even though the high diving board has never been paired with an aversive event. One can readily imagine the swimmer thinking: "If the low diving board can hurt that much, what must a dive off the high diving board feel like?" The diving board example illustrates that the conditioned stimulus intensity originally experienced may evoke a smaller conditioned response (i.e., less fear) than a higher intensity of the same stimulus. Although, in real life, other experiential factors no doubt confound a pure stimulus intensity effect, the diving board does provide a convenient mneumonic for a stimulus intensity effect.

Both Pavlov (1927) and Hull (1949) recognized a phenomenon similar to the fear evoked by the high diving board. For example, Hull's theory of stimulus intensity dynamism posited that a conditioned stimulus (CS) of greater intensity than was experienced during conditioning would result in a conditioned response of greater magnitude than the original conditioned response. This intensity dynamism effect has been obtained both with instrumental conditioning procedures (e.g., Gray, 1965; Grice, 1968), and with classical conditioning procedures. Several different conditioned responses have been employed in classical conditioning studies (e.g., salivation, galvanic skin response, and eyeblinks).

Considering first research from Pavlov's laboratory, Razran (1949) summarized the results of 54 salivary conditioning studies in which stimulus intensity was manipulated. Data were presented for experiments using three types of conditioned stimuli (i.e., a light, a whistle, and a bell). Razran presented the results in a single table showing the mean percentage of conditioned salivation to stimuli of progressively higher and progressively lower intensity than the original conditioned stimulus. The data showed that salivation varied as a direct function of CS intensity. There were no reversals in the data, and all differences in the mean percentages of salivation were statistically significant at the .05 level if repeated treatment effects were ignored.

Hovland (1937) gave two groups of 16 human subjects a total of 16 pairings (i.e., per subject) of a 1,000 Hz tone and shock. For one group, the intensity of the tone during conditioning was 86 db, for the other group the tone was 40 db. Test trials were then conducted in which each subject received three non-reinforced presentations of the 1,000 cycle tone (conditioned stimulus) at intensities of 40 db, 60 db, 74 db, and 86 db (i.e., intensities differing from one another by either 25, 50, or 75 j.n.d. units). Subjects' galvanic skin response (GSR) was measured during each test tone presentation. Hovland found that GSR amplitude either increased or decreased in accordance with variations in CS intensity. Later work by Hall and Prokasy (1961) and Champion (1962), who also used GSR amplitude to index stimulus intensity effects, obtained results consistent with those of Hovland. Studies by Grant and Schneider (1949) and Findlay (1971), however, found that manipulating CS (tone) intensity following tone-shock conditioning had little or no effect on GSR amplitude.

In a series of human studies conducted by Robert Grice and his associates (Beck, 1963; Grice & Hunter, 1964; Grice, Hunter, Kohfeld, & Masters, 1967; Grice, Masters, & Kohfeld, 1966; Walker, 1960), increasing CS intensity has also been shown to increase the number and decrease the latency of conditioned eyeblink responses. Similar results have been reported by other investigators employing both human subjects (Lipkin & Moore, 1966; Mattson & Moore, 1964) and nonhuman subjects (Frey, 1969). Contradictory findings, however, have been reported by Grant and Schneider (1948) and by Carter (1941). Presumably, variations in the procedures employed by the latter authors (e.g., pre-exposure to the training CS prior to conditioning) produced these contradictory results.

Finally, studies by Ison and Leonard (1971), Leonard and Monteau (1971), and Scavio and Gormezano (1974) have shown that the conditioned nictitating membrane response in rabbits is sensitive to differences in CS intensity. Both Ison and Leonard and Leonard and Monteau employed two different intensities of a 1,000 Hz tone as CSs and paired these CSs with shock. Ison and Leonard reported that conditioned response amplitude was greater for the high intensity tone than for the low intensity tone. Monteau and Leonard found that conditioned response latencies were shorter and responses were more frequent to the high intensity CS than to the low intensity CS. Scavio and

Gormezano, in their second experiment, employed several groups. One group had a low intensity tone (65 db) paired with a shock; another group had a higher intensity tone (86 db) paired with the shock. Both groups received 720 tone-shock pairings and then were tested with extinction. During this test, tone intensities of 86, 79, 72, and 65 db were presented to each group. For both groups the 86 db tone evoked more conditioned responses than the 79 db tone, the 79 db tone evoked more conditioned responses than the 72 db tone, and the 72 db tone evoked more conditioned responses than the 65 db tone. The tone of highest intensity also evoked more conditioned responses for subjects trained with this intensity than for subjects trained with the 65 db tone. The latter result, however, may have been due to differences in the strength of conditioning between the two groups at the end of acquisition. At the end of the 720 training trials, the 86 db tone evoked a conditioned response on about 85 percent of the trials while the 65 db tone evoked a conditioned response on only 60 percent of the trials.

Although the bulk of the classical conditioning studies cited above are indeed suggestive that a strong positive relationship exists between CS intensity and the magnitude and frequency of a conditioned response, and an inverse relationship exists between CS intensity and the latency of a conditioned response, only Scavio and

Gormezano's (1974) study can be considered conclusive, since it is the only one employing adequate controls. Rescorla (1967) has pointed out that most classical conditioning studies published to date involve either no control groups or inadequate control groups for distinguishing classical conditioning effects from non-associative effects (e.g., the conditioned stimuli being aversive in and of themselves). In addition, Rescorla has provided experimental evidence that a contingency relationship between the occurrence of two events is the crucial factor determining whether classical conditioning effects do or do not result from repeated pairings of a CS and a US (unconditioned stimulus). To be properly controlled, therefore, a classical conditioning experiment must include a control group which shows that the experimental results are attributable to contingent CS-US pairings and not to non-associative factors.

Rescorla's criticisms of the most commonly used control groups and his proposal for an appropriate alternative can be briefly summarized. The difficulty with the "CS alone" control group is that subjects in this control condition do not receive the same number of US experiences as do experimental subjects; furthermore, there is a possibility that repeated CS presentations without a US may result in a different rate of CS habituation than occurs when both CS and US are presented. The "US alone" and "Novel CS" control groups share the difficulty that control subjects are presented with an unfamiliar CS during testing, whereas experimental subjects are presented with a CS which they have experienced many times in conjunction with a US. Comparing the experimental group with a control group in which the CS is novel may allow one to assess the overall change in reaction to the CS as a function of the conditioning procedure, but it does not permit isolation of changes uniquely due to conditioning as opposed to those due to CS habituation. Backward conditioning (i.e., US-CS) control groups, control groups in which the CS and US are explicitly unpaired, and control conditions associated with a discriminative training procedure utilizing a CS+ and a CS- are all faulty because, at testing, a comparison is not being made between subjects exposed to contingent CS-US pairings and subjects exposed to CS and US where no contingency exists. Instead, a comparison is being made between subjects exposed to two different contingencies, namely, "CS signals US," and "CS signals a period free from the US." Though the information yielded by such a comparison may be valuable, the comparison does not permit one to distinguish associative from non-associative effects in classical conditioning.

In the light of the problems with some of the more widely used control procedures, Rescorla (1967) proposed that the appropriate control procedure is one in which subjects received equal but completely random presentations of the CS and US. In this situation, presentation of the CS provides no reliable information about the occurrence of the US (i.e., no contingent relationship exists). Thus, Rescorla's completely randomized control procedure permits the necessary distinction between effects attributable to contingent CS-US pairings (i.e., conditioning effects) and those attributable to non-associative factors.

While a plethora of studies has provided evidence for the neutrality of the truly random control (e.g., Ayres & Quinsey, 1970; Bull & Overmier, 1968; Holland & Rescorla, 1975a, b; Rashotte & Griffin, 1974; Rashotte & Sisk, 1975; Rescorla, 1968, 1973, 1974; Rizely & Rescorla, 1972), other studies have found that truly random training can produce excitatory conditioning (i.e., Benedict & Ayres, 1972; Kremer, 1971; Kremer & Kamin, 1971; Quinsey, 1971; Witcher & Ayres, 1975). However, Witcher and Ayres (1975) have obtained data confirming that repeated training with a truly random sequence of CS and US presentations produces a "neutral CS." Witcher and Ayres also suggest that a major factor contributing to the conditioning effect reported by other experimenters who have employed the truly random control is the chance occurrence of CS-US pairings early in the randomized control sequence.

Of the CS intensity studies previously reviewed, only three (i.e., Moore, 1964; Ison & Leonard, 1971; Scavio & Gormezano, 1974) have included any type of control procedure for non-associative effects, and only Scavio and Gormezano have employed Rescorla's completely randomized control. Moore (1964) included, as his control, a discriminative training procedure in which one tone intensity (CS+) was paired with an air puff delivered to the cornea of the eye while another tone intensity (CS-) was not. Since the CS- was considered to have received the same treatment as the CS+, except that its relationship to the US was an explicitly unpaired one, the differences in the responses to the two CSs were assumed to reflect the effects of conditioning. Unfortunately, as Rescorla (1967) has noted, this CS- control procedure is inadequate. Since the CS- is never paired with the unconditioned stimulus (US), the CS- becomes a conditioned inhibitor (cf. Rescorla & LoLordo, 1965). A further difficulty with Moore's control procedure is that the CS+ and CS- were from the same dimension (i.e., tone intensity); therefore, generalization of CS+ and CS- responding could be expected, making it difficult if not impossible to determine the relative contributions of CS+ conditioning and CS- conditioning during any particular trial. Thus, Moore's design seems clearly inappropriate to test stimulus intensity effects produced by CS+ conditioning.

Ison and Leonard (1971) included a control condition in which the US preceded the CS for a number of trials (backward conditioning), and the data obtained on those trials were compared with data obtained when the CS preceded the US in the normal conditioning sequence. As Rescorla (1967) also noted, however, the backward conditioning control is inappropriate because the occurrence of the CS predicts either shock termination (i.e., in cases where US and CS presentation overlap) or a period free from the US. In the first case, a "CS-US termination" contingency is established which may have effects that are of interest in themselves, but this contingency does not provide a means of discriminating associative from non-associative effects in classical conditioning. In the latter case, the CS signals a period free from the US and could thus function as an inhibitory stimulus (cf. Konorski, 1948). Again, a contingency relationship between CS and US exists, but the contingency is a negative one. Furthermore, Ison and Leonard's alternation of backward and forward conditioning trials within subjects during the experiment would make the data obtained on either type of trial difficult to interpret. Conditioned responses evoked by the CS during forward conditioning trials would be expected to generalize to the backward conditioning trials, and conditioned inhibition from the backward conditioning procedure would be expected to generalize to subsequent forward conditioning trials. Thus, the effects of the experimental and control conditions are almost certainly confounded in Ison and Leonard's data, and it would be difficult to say with confidence what the obtained differences in the "experimental" versus "control" data represent.

Scavio and Gormezano (1974) utilized Rescorla's completely randomized control procedure and provided conclusive evidence that the acquisition, extinction, and generalization of a conditioned nictitating membrane response in rabbits is sensitive to CS intensity effects. Despite the fact that the conditioning procedure involved the presentation of a 1,000 Hz tone followed immediately by the delivery of a 50 msec, 3 ma shock to the paraorbital region of the eye, Scavio and Gormezano were not concerned with conditioned fear and, therefore, did not equate experimental groups for level of conditioning prior to test presentations of the tone. Consequently, Scavio and Gormezano's results cannot be considered a conclusive test of the stimulus intensity effects that might accompany fear conditioning.

A properly controlled Pavlovian fear-conditioning experiment would need to employ Rescorla's completely randomized control so that "true conditioning" could be discriminated from non-associative effects. Furthermore, experimental subjects would need to be equated on the terminal level of conditioning so that possible differences in conditioned response magnitude subsequently evoked by different intensities of the CS could be reasonably interpreted as an "intensity dynamism effect" and not an artifact of differences in the strength of conditioning at the end of acquisition. A conclusive demonstration of CS intensity effects in Pavlovian fear conditioning would be significant both for its possible applied importance and for its theoretical interest.

From an applied standpoint, a demonstration of this stimulus intensity effect in a well-controlled study would offer an interesting insight into the way that aversion therapies should be conducted. Take, for example, the alcoholic who wishes to stop drinking. One procedure which has been employed with only limited success is to pair alcohol consumption with nausea-inducing drugs in an attempt to make alcohol an aversive stimulus (e.g., Lemere & Voegtlin, 1950). If, however, a threshold taste of alcohol could be paired with a relatively mild form of nausea, the conditioning might parallel the conditioning in the diving board example. That is, if a low concentration of alcohol in a drink produced a moderate level of aversion, a higher concentration might produce a very strong aversion. Thus, some aversion therapy procedures may be more effective if relatively low intensity stimuli are used during conditioning. To date, no aversion therapy studies known to the writer have been conducted in such a way that they provide a test of this line of reasoning.

The theoretical value of the stimulus intensity effect is that it provides a means of testing the type of associative bond formed in second-order conditioning. The original intent of Experiment 1 of the following series of studies was to demonstrate a stimulus intensity dynamism effect. Such a demonstration would have permitted a direct manipulation of the magnitude of a conditioned response which was relatively free of confounding by associative factors. Manipulating conditioned response magnitude by systematically varying CS intensity would have provided an elegant procedure for testing the nature of the associations formed in second-order conditioning. Unfortunately, as subsequent results will show, no stimulus intensity dynamism effect was obtained. Thus, stimulus intensity dynamism could not be used to test the nature of the associations formed in second-order conditioning as originally intended. Consequently, a totally different procedure had to be employed. The types of possible second-order conditioning associations and the procedures used to test for particular types of associations will be discussed in greater detail in the introduction to Experiment 2. The first study, Experiment 1, was designed to be an analogue of the diving-board example described earlier and to provide conclusive evidence of stimulus intensity effects in Pavlovian fear conditioning.

CHAPTER II

EXPERIMENT I

Method

Subjects

The subjects were 56 male Sprague-Dawley rats, approximately 100 days old at the beginning of the experiment. Subjects were assigned in a quasi-random[1] fashion to seven groups, eight rats per group. Throughout the experiment subjects were maintained on 23 hour food deprivation and given one hour of free access to food at the end of each experimental session.

Apparatus

Four grey metal chambers, each 10 inches long by 7 inches wide by 8 inches high, were employed. A metal reinforcement-dispensing tube and an aluminum trough were mounted at one end of each chamber 64 cm from the floor and 38 cm from the corner of an endwall. Reinforcement consisted of 45 mg sucrose pellets (P. J. Noyes Co.) delivered

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[1]When rats were received from the supplier they were removed from the shipping crates and placed in cages which were numbered in a continuous series. Thereafter, rats in the first eight cages were assigned to one group, rats in the next eight cages were assigned to another group, and so on. Therefore, the assignment of rats to separate groups in the present series of experiments was "quasi-random" only to the extent that selective factors may have operated when the rats were removed from the shipping crates.

into the aluminum trough. A lever was positioned 38 cm above the floor and to the right of the reinforcement dispensing apparatus. The lever required a .1 N (10 gram) press in order for a response to be recorded. The floor of each chamber was comprised of 3/16 inch stainless steel rods spaced 13 cm apart. A rectified relay sequence scrambler (Hoffman & Fleshler, 1962) connected to a high resistance 1200 V shock source was employed to deliver .5 second, 1.9 mA foot-shocks through the floor grid. A speaker located in the center of the ceiling of each chamber permitted the presentation of a 30-second 6kHz tone of either 65 or 90 db SPL. Tone intensities were measured by a Bruel & Kjaer Precision Sound Level Meter (Type 2203) placed perpendicular to and 11 millimeters below the speaker. The meter reading was taken with the "A" (slow) scale. The chamber doors were open at the time of measurement and ambient room noise was approximately 54 db SPL. The 6kHz frequency lies in about the middle (logarithmically) of rats' auditory range, and the detection threshold at that frequency is approximately 40 db SPL (Gourevitch & Hack, 1966). A 6 watt bulb mounted near the overhead speaker illuminated each experimental chamber. Luminance level was approximately 95 mL in the vicinity of the lever as measured by a MacBeth Illuminometer. Each chamber was enclosed in a wooden, sound- and light-resistant shell lined with 1/2 inch acoustic tile.

White noise from a Lehigh Valley Electronics Noise Generator (Model 1524) was used to mask extraneous sounds in the room housing the experimental chambers. Experimental events were controlled and recorded automatically by programmable solid state equipment located in another room.

Procedure

All sessions were two hours in duration. Subjects received only one session per day. In the first session subjects were magazine trained and shaped to barpress. Each press yielded a sucrose pellet, until a subject had emitted at least 50 barpresses. After 50 reinforced responses, the subject was placed on a VI 1 minute schedule for the remainder of the session. On the second day of barpress training the VI 1 minute schedule was in effect. For all subsequent sessions, reinforcement was delivered on a VI 2 minute schedule. Subjects received a minimum of 5 days of bar press training. Additional training sessions employing both VR and VI reinforcement schedules were given if a subject did not emit at least 700 responses per session on the VI 2 minute schedule.

Following barpress training, two pretest sessions were given to habituate any suppressive effects that the tone may have had on barpressing. During each session, subjects received four presentations of the tone at either

65 db or 90 db SPL, depending on the subjects' respective experimental conditions. The tone was presented once every 30 minutes on the average and the tone intensity was the same as that used in subsequent sessions in which subjects experienced both the tone and shock.

The original experimental design called for three experimental and three control groups; however, considering the preliminary results of the three experimental groups, the inclusion of an additional experimental group seemed appropriate. Consequently, an experimental group trained with a high intensity tone and tested with a low intensity tone was also included in the experiment. This group will be discussed with the other experimental groups in the succeeding sections of this report.

After two days of pretesting, four experimental groups received conditioning sessions in which subjects experienced contingent pairings of the tone (CS) and shock (US), while the remaining three groups received control sessions in which the tone and shock were presented separately in a completely random order. The four experimental groups will hereafter be referred to as groups E 65-65, E 65-90, E 90-90, and E 90-65; the three control groups will be referred to as groups C 65-65, C 65-90, and C 90-90. In these designations, the first number refers to the tone intensity during tone-shock trials, while the second number refers to the intensity of the tone during subsequent test sessions.

During conditioning sessions, experimental groups were given a maximum of four contingent tone-shock pairings per session. A conditioning trial was given once every 30 minutes on the average. A trial consisted of a tone (CS) presentation followed by shock coinciding with CS termination. Groups E 65-65 and E 65-90 received the 65 db tone during CS-US pairings; while groups E 90-90 and E 90-65 received the 90 db tone. Conditioning sessions continued until conditioned suppression to the tone was established. Conditioned suppression was indexed by a barpress suppression ratio having the form A/A+B. In this formula, A represents the number of bar presses emitted during the 30 second CS, and B represents the number of bar presses emitted in the 30 seconds prior to CS onset. Good conditioning is indicated by suppression ratios close to zero. Poor conditioning is indicated by suppression ratios close to .5. Each experimental subject received tone-shock pairings in successive training sessions until a suppression ratio of .2 or lower was obtained on three consecutive conditioning trials. One subject in group E 90-65 never attained the conditioned fear criterion so his data were not included in the subsequent analysis.

During conditioning control sessions, groups C 65-65, C 65-90, and C 90-90 received a maximum of four tone presentations and four shock presentations per session. Within a session, presentations of the tone and shock, respectively, were given at time intervals determined by a table of random numbers. Control groups were matched with their respective experimental groups in terms of the average amount of exposure to the tone and shock. Thus, control sessions continued until C 65-65 subjects had been administered a total of 14 tone presentations and 14 shock presentations, C 65-90 subjects a total of 13 tone presentations and 13 shock presentations, and C 90-90 subjects 12 tone presentations and 12 shock presentations.

Following either conditioning or conditioning control sessions, all subjects received two sessions of barpressing for food on the VI 2 minute schedule. These sessions were given so that fear to background cues could extinguish and so that individual barpress rates could return to approximately the same level as those which existed before subjects experienced shock in the experimental chambers.

Finally, in a series of sessions subjects were tested for conditioned suppression to the tone. During the test the tone was superimposed on barpressing but no shock was delivered. A maximum of eight tone trials was given per session, a test trial being presented every 15 minutes on the average. Two experimental and two control groups (i.e., groups E 65-65, E 90-90, C 65-65, C 90-90) were tested with a tone intensity identical to their training intensity. One experimental and one control group (i.e., groups E 65-90 and C 65-90) were tested with a tone of a higher intensity than was experienced during training. The remaining experimental group (E 90-65) received a tone of lower intensity during the test than had been experienced during training. Test sessions were given until conditioned suppression to the tone had extinguished for each subject. Suppression was considered extinguished when a barpress suppression ratio of .40 or higher was obtained on three consecutive test trials.

Although a barpress suppression ratio was the primary measure of fear used in the study, two other dimensions of bar pressing were also examined as possible indices of fear, namely, the number of test trials to the first bar press during the tone and the number of test trials to reach the extinction criterion.

Results

Subjects conditioned with the 90 db tone required an average of 10.5 tone-shock pairings to attain the conditioned fear criterion, while subjects conditioned with the 65 db tone required more trials (i.e., a mean of 13.8 trials). These differences, however, did not attain statistical significance ($t = 1.48$, $df = 54$, $p \geq .15$).

Visual inspection of the data suggested that successive blocks of four test trials were most representative of group performance. Thus, data analysis was performed on separate blocks of four trials.

Figure 1 shows the mean suppression ratios for all groups of subjects on test trials 1 through 4. The ratio values presented in the figure were obtained by subtracting the actual mean suppression ratios from 1.0. This conversion was employed so that progressively greater amounts of suppression (i.e., conditioned fear) would be indexed by progressively larger suppression ratios. Control subjects showed no fear to the tone on the first four test trials, whereas experimental subjects showed substantial fear. A one-way analysis of variance (ANOVA) performed on the normalized (i.e., via the arcsin transformation) suppression ratios indicated that these differences were significant ($F = 23.3$; $df = 6,48$, $p \leq .0001$). Scheffé post hoc tests revealed that the mean suppression ratios for experimental groups differed significantly ($p \leq .05$) from those of their respective control groups. Among the experimental groups, the suppression ratios for groups E 90-90 and E 90-65 were significantly different ($p \leq .05$) from each other, but no other significant differences were obtained. The mean suppression ratios for the control groups did not differ significantly from each other. The complete ANOVA table for this and all subsequent ANOVAs referred to in this report for which significant F-ratios were obtained appears in the Appendix.

Figure 1. Mean suppression ratios for all groups of subjects on test trials one through four.

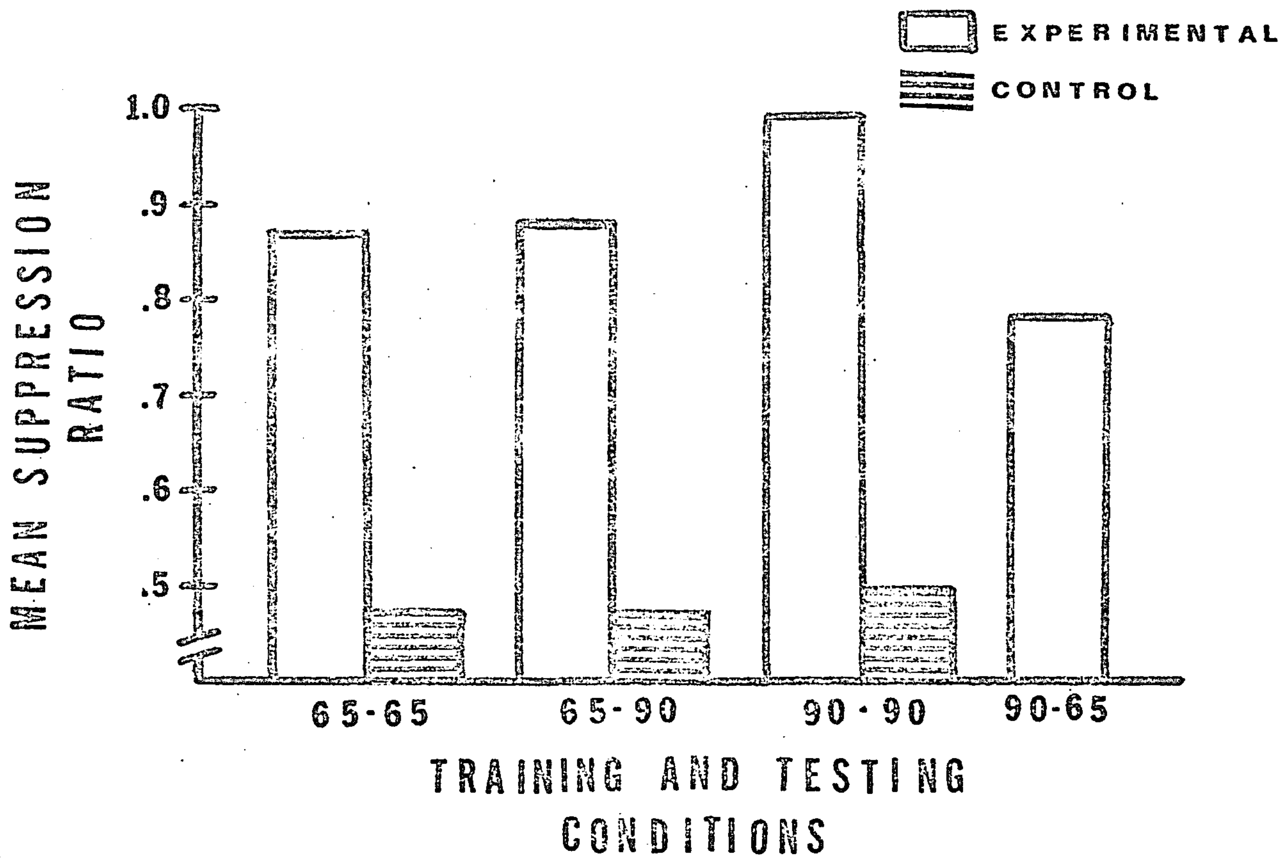
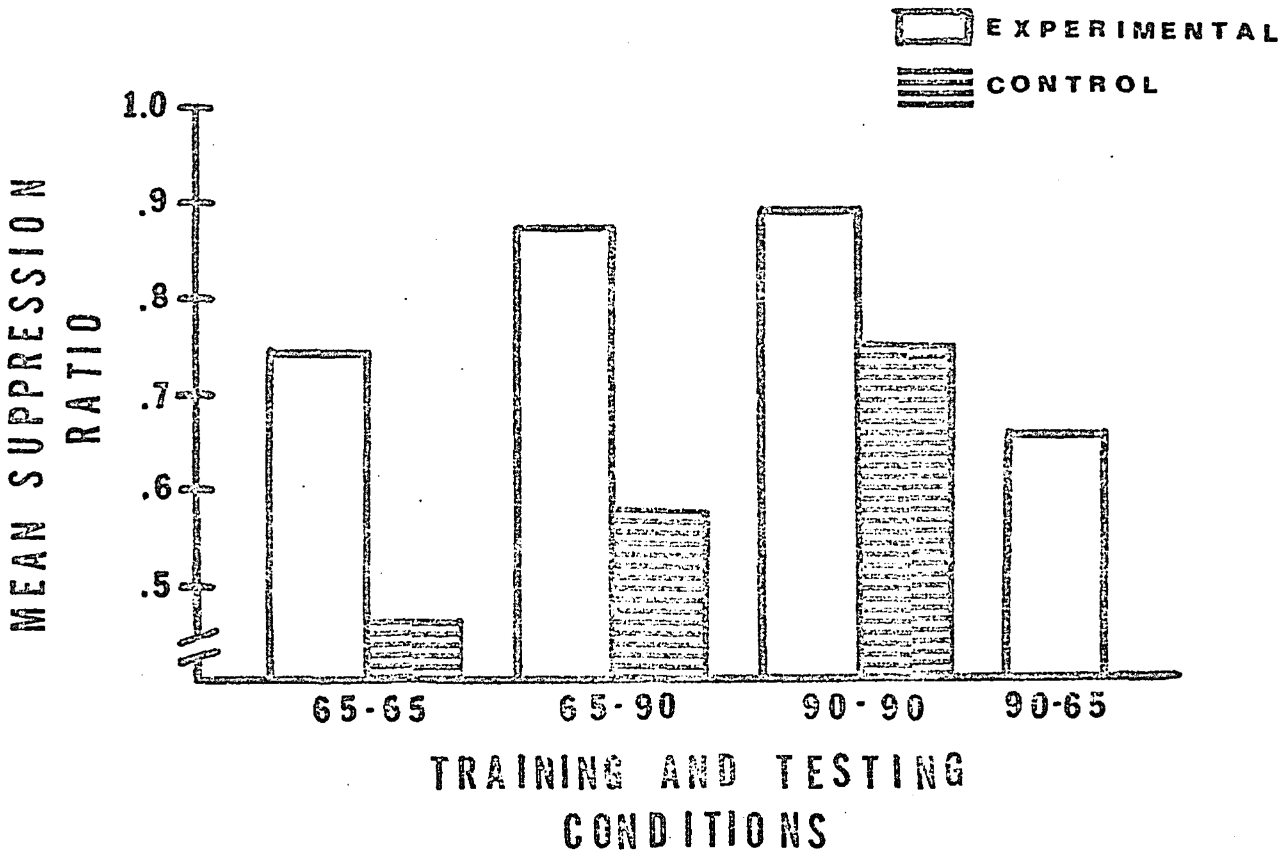

EXPERIMENTAL
CONTROL
1.0
.9
.8
.7
.6
.5
MEAN SUPPRESSION RATIO
65-65
65-90
90-90
90-65
TRAINING AND TESTING CONDITIONS

Figure 2 presents the mean suppression ratios for all groups on test trials 5 through 8. During these test trials, control subjects again showed little or no fear to the tone, but experimental subjects generally exhibited less fear to the tone than they had shown originally. A one-way analysis of variance performed on the mean ratios for the second block of test trials yielded a significant F-ratio ($F = 4.6$, $df = 6,54$; $p \leq .001$). Subsequent Scheffé post hoc tests revealed, however, that experimental groups no longer differed from their respective control groups, nor were there any significant differences among either the experimental groups or the control groups. A significant difference ($p \leq .05$) between the mean suppression ratios for groups E 90-90 and C 65-65 accounted for the significant F-ratio obtained in the analysis of variance.

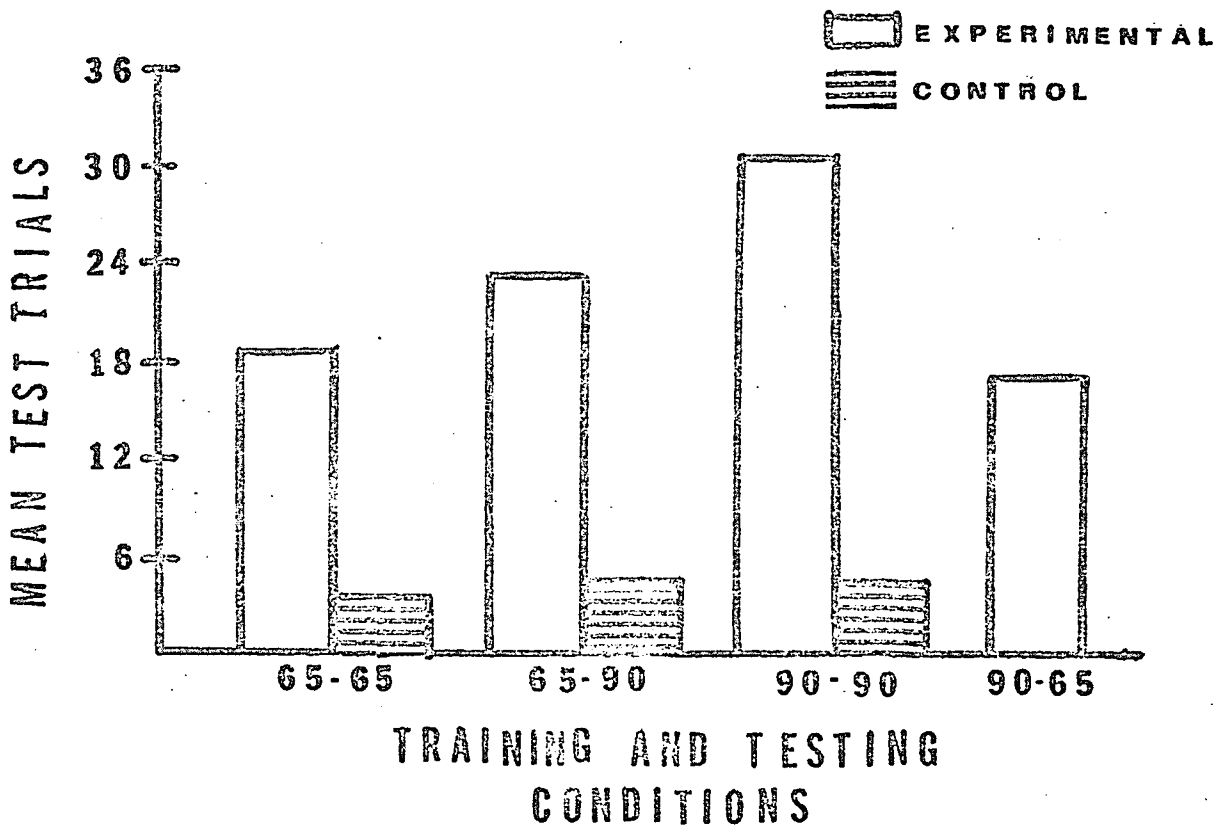
Figure 3 summarizes the mean number of test trials to reach the extinction criterion for each group of subjects. A one-way analysis of variance indicated that there were significant differences among the groups on this measure ($F = 3.7$, $df = 6,48$; $p \leq .005$). Scheffé post hoc tests showed that experimental groups differed significantly from their respective control groups. Experimental subjects tested with the 90 db tone generally took longer to reach the extinction criterion than experimental subjects tested with the 65 db tone; these differences between experimental groups failed to attain statistical significance.

Figure 2. Mean suppression ratios for all groups of subjects on test trials five through eight.



EXPERIMENTAL
CONTROL
MEAN SUPPRESSION RATIO
1.0
.9
.8
.7
.6
.5
65-65
65-90
90-90
90-65
TRAINING AND TESTING CONDITIONS

Figure 3. Mean number of test trials to reach the extinction criterion for all groups of subjects in Experiment 1.


EXPERIMENTAL
CONTROL
36
30
24
18
12
6
MEAN TEST TRIALS
65-65
65-90
90-90
90-65
TRAINING AND TESTING CONDITIONS

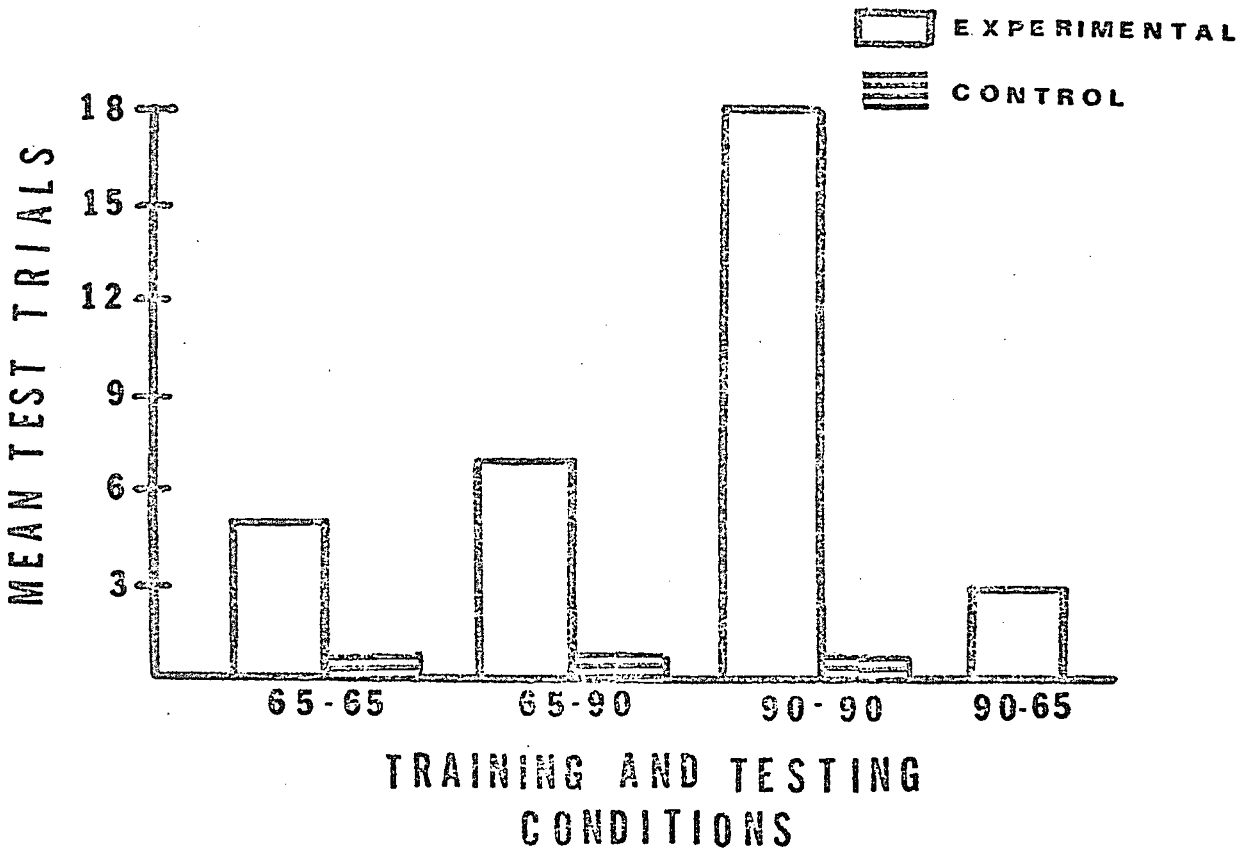
The mean number of test trials presented to each group of subjects prior to the first barpress during the CS is shown in Figure 4. A one-way analysis of variance ($F = 8.4$, $df = 6,48$; $p \leq .0001$), and subsequent Scheffé post hoc tests showed that subjects in the experimental group trained and tested with the 90 db tone took significantly ($p \leq .01$) longer to make the first barpress than any other group. No other experimental or control groups differed significantly from each other on this measure.

Discussion

The critical finding of this experiment was that a statistically significant CS intensity effect was not demonstrated using Pavlovian fear conditioning. Presentation of a low intensity CS following training with a high intensity CS produced a significant decrease in bar press suppression; however, presentation of a high intensity CS following training with a low intensity CS failed to produce a significant increase in barpress suppression. There are several possible explanations for this finding.

From a purely mathematical standpoint, no statistically significant differences could have been obtained between groups E 65-65 and E 65-90 on the first four test trials because both groups showed near asymtotic levels of suppression on these trials. This "ceiling effect," however, does not account for the failure to demonstrate stimulus intensity dynamism on test trials 5 through 8.

Figure 4. Mean number of test trials to the first bar-press during tone presentation for all groups of subjects in Experiment 1.


EXPERIMENTAL
CONTROL
18
15
12
9
6
3
MEAN TEST TRIALS
65-65
65-90
90-90
90-65
TRAINING AND TESTING
CONDITIONS

Secondly, according to Hull's (1949) mathematical formulation, stimulus intensity dynamism does not follow a strictly linear function. It is possible the stimulus values used in this study may not have been at intensity levels which would provide statistically significant differences in response magnitude.

A third explanation focuses on pre-exposure to the CS prior to conditioning. Pre-exposure to the CS prior to contingent pairings of the CS and US may prevent conditioned response magnitude from increasing significantly as a positive function of CS intensity. CS pre-exposure may decrease the novelty of the CS in comparison to background cues and probably decreases the salience of the CS to subjects who have experienced such pre-exposure as compared to those who have not. Thus, a change in CS intensity may produce a smaller change in the behavior of pre-exposed subjects than in non-pre-exposed subjects. Support for this CS pre-exposure explanation is provided in the outcomes of previous CS intensity studies. Investigations which have included CS pre-exposure in the experimental procedure (i.e., Carter, 1941; Grant & Schneider, 1948, 1949) have consistently failed to demonstrate reliable, statistically significant CS intensity effects. On the other hand, CS intensity studies which have omitted CS pre-exposure in the experimental procedure (i.e., all CS intensity studies previously reviewed other than Carter, 1941; Grant &

Schneider, 1948, 1949) have, with one exception (i.e., Findlay, 1971), reported successful demonstrations of a CS intensity effect. Such divergent findings strongly suggest that statistical evidence of stimulus intensity dynamism may be a function of the experimental procedure. Furthermore, if the omission of CS pre-exposure guarantees a significant stimulus intensity effect, then the non-significant results of the present study may be due to CS pre-exposure. A replication of the present study using no pre-exposure would adequately test this assertion.

If the results of such a study should show a statistically significant CS intensity effect, then CS pre-exposure would appear to be a critical factor determining whether stimulus intensity dynamism is or is not demonstrated in classical conditioning studies.

Although CS pre-exposure may yet be shown to be the critical factor determining whether statistically significant CS intensity effects can or cannot be demonstrated in classical conditioning studies, Grice and Hunter (1964) have obtained evidence that the type of experimental design employed may also be important. In a human eyelid conditioning study, Grice and Hunter gave one group of subjects 100 conditioning trials with a loud tone CS, one group of subjects 100 trials with a soft tone CS, and two groups of subjects 50 trials with both loud and soft tones. The groups who received both CS intensities emitted significantly more conditioned responses to the loud tone and fewer conditioned responses to the soft tone during acqusition than the groups who received only the loud or the soft tone. Thus, a within-subject design appears to produce more pronounced CS intensity effects than a between-subject design.

CHAPTER III

EXPERIMENT 2

Recently, Rizely and Rescorla (1972) and Rescorla (1973) have demonstrated in well-controlled experiments a phenomenon which Pavlov (1927) termed second-order conditioning and have suggested that second-order conditioned stimuli may be extremely important in our understanding of a variety of maladaptive behaviors. Suppose that a tone is paired with shock and is subsequently capable of evoking a fear response. As the tone has been directly paired with shock, this procedure is termed first-order conditioning. Now if a flashing light is presented and followed by the tone, even though the shock is omitted, the flashing light will soon evoke the fear response. This phenomenon is called second-order conditioning. One surprising finding which has been obtained in several second-order conditioning experiments by Rescorla and his associates is that, after fear to the tone is extinguished, the flashing light will continue to evoke the fear response. Again considering an applied situation such as the treatment of a phobia, Rescorla's finding seems to imply that the therapist must not only eliminate fear to a first-order conditioned stimulus, but he must also eliminate fear to all of the second-order conditioned stimuli before the phobia can be completely eliminated. Thus, an understanding of the way in which second-order conditioning occurs may be extremely important in applied settings.

To date, three theories have been proposed to account for the types of associations formed in second-order conditioning. One theory, cited by Rizely and Rescorla (1972), is that second-order conditioning results in a direct association between the first-order stimulus (S_1) and the second-order stimulus (S_2). Thus, S_2 evokes a conditioned response because S_1 does so, and S_2 is associated with S_1. A second theory, proposed by Konorski (1948), suggests that S_2 becomes associated with a memory of the unconditioned stimulus (US). According to this view, a memory of the US is encoded during first-order conditioning. During second-order conditioning, presentation of S_1 evokes this memory. Thus, during second-order conditioning, S_2 is followed by the memory of the US and consequently becomes associated with it. According to Konorski's (1948) theory, both S_2 and S_1 become linked to a memory representation of the US but they do not necessarily develop any association with each other. The third interpretation of second-order conditioning was proposed by Hull (1943), who viewed it as stimulus-response learning. This interpretation suggests that an association is formed between S_2 and the conditioned response evoked by S_1 during second-order conditioning.

In a series of recent experiments (i.e., Holland & Rescorla, 1975a, b; Rescorla, 1973, 1974), Rescorla and his associates have systematically tested and disconfirmed Konorski's (1948, 1967) view of second-order conditioning, as well as the theory that second-order conditioning involves the formation of a direct association between S_2 and S_1. Rescorla's experiments have employed both fear conditioning procedures (Rescorla, 1973, 1974; Rizely & Rescorla, 1972) and appetitive conditioning procedures (Holland & Rescorla, 1975a, b) and, thus far, all have yielded remarkably consistent and reliable results. In a typical experiment, rats were given first-order conditioning trials in which a flashing light (S_1) was paired with a US (usually either food or shock), followed by second-order conditioning trials in which a tone or clicker (S_2) was paired with the flashing light. In the fear conditioning studies, suppression of ongoing barpressing was used to index the conditioned response (CR), whereas general activity level (i.e., subjects' gross movements in the test chamber as recorded by a stabilimeter-type device) was the measure of the CR in the appetitive conditioning studies. Rizely and Rescorla (1972) and Holland and Rescorla (1975) showed that no direct connection is formed between S_2 and S_1 in second-order conditioning. They found that S_2 presentations continued to evoke a conditioned response even after extinction of the CR to S_1. If, as the theory suggests,

S_2 evokes a conditioned response only because of its direct associative link with S_1, then the extinction procedure employed by Risely and Rescorla (1972) and Holland and Rescorla (1975) should have eliminated the conditioned response to S_2 as well as S_1.

In three subsequent studies, Rescorla (1973, 1974) and Holland and Rescorla (1975) tested Konorski's theory that both first- and second-order CSs become associated with a memory representation of the US. In the 1973 study, subjects were given a series of US (loud noise) habituation trials after first- and second-order conditioning. If an association was formed between the second-order CS and a memory representation of the US, then habituation trials would be expected to degrade the US representation and thereby reduce the conditioned response evoked by S_2. When S_1 and S_2 were superimposed on bar pressing after US habituation trials, however, the conditioned fear response to the S_1 was degraded while the conditioned response to the S_2 was not. In a later study, Rescorla (1974) gave subjects both first- and second-order conditioning and then presented them with an additional series of first-order conditioning trials in which the US was of a higher intensity than the US originally employed. These trials were designed to inflate the memory image of the US. Thus, if in second-order conditioning the S_2 becomes associated with a US representation, inflating this representation should result in a larger conditioned response to S_2. The results paralleled those of the habituation study in that the conditioned response to S_1 was modified by US inflation but the conditioned response to S_2 remained unaffected. In an even more recent study involving an appetitive conditioning procedure, Rescorla (1975) gave all subjects contingent light-food pairings to establish a first-order conditioned response (i.e., heightened gross motor activity to a flashing light). He then gave half of the subjects contingent pairings of a 1,200 Hz tone and food and half of the subjects contingent pairings of the tone and the flashing light. Thus, for one group of subjects, the tone was a first-order conditioned stimulus, and for the other group the tone was a second-order conditioned stimulus. Next, the positive reinforcing properties of food were altered by means of either satiation or by following food presentation with high speed rotation. In subsequent test trials, it was found that the conditioned response to the tone as a first-order CS decreased after US devaluation, whereas the conditioned response to the tone as second-order CS remained basically unchanged. Finally, food was restored as a positive US by either depriving previously satiated subjects or by presenting food without high speed rotation for a number of days. Further test trials showed that conditioned responses to the tone as a first-order CS had been reinstated while the conditioned responses to the tone as a second-order CS remained unchanged. The outcome of these studies disconfirmed Konorski's interpretation of second-order conditioning: altering the representation of the US by either degrading it or inflating it had no effect on the conditioned response evoked by the second-order CS. These findings led Rescorla (1974) to endorse Hull's (1943) interpretation of second-order conditioning (i.e., the S_2 becomes associated with the conditioned response evoked by S_1), inasmuch as it was the only theory which his experiments had not disconfirmed.

Data inconsistent with Rescorla's findings have, however, been reported by Rashotte and his co-workers. The latter experimenters investigated second-order appetitative conditioning in pigeons using an autoshaping procedure. Autoshaping is formally identical to Pavlovian conditioning procedures and, when employed, produces pecking movements toward a localized visual signal which reliably precedes food or water. In one study, Rashotte and Griffin (1974) gave pigeons first-order conditioning sessions in which a 6 second, white key light (S_1) preceded each of 30 (US) presentations. When the S_1 reliably elicited key pecking, second-order sessions were given in which a 6 second, blue light (S_2) immediately preceded S_1 presentations for ten trials. Food was never presented during second-order sessions, and second-order conditioning sessions alternated with first-order conditioning sessions. Following first and second-order conditioning, subjects were given a series of S_1 extinction sessions in which the white key light was presented without food. Then test sessions were given in which the S_1 and S_2 were presented randomly. The data showed that responding to both S_1 and S_2 had declined about equally. Such an outcome was inconsistent with Rescorla's data, for he found no decrement in S_2 responding after S_1 extinction trials. To test the possibility that the reduction in S_2 responding was merely a generalization effect, Rashotte and Griffin replicated the experiment and extinguished S_2 responding instead of S_1 responding before administering test trials. Testing revealed no decrease in S_1 responding, suggesting that the earlier finding could not be attributed to a simple generalization effect.

In a follow-up study, Rashotte and Sisk (1975) investigated the possibility that the discrepancy between the results obtained by Rashotte and Griffin (1974) and those previously obtained by Rescorla could be related to the fact that Rescorla employed both visual and auditory stimuli as CSs, whereas Rashotte and Griffin (1974) had used only visual stimuli. In Rashotte and Sisk's (1975) study, a modified autoshaping procedure ("first-order conditioning") was used to bring pigeons' keypecking under the control of a 15 second tone (S_1). Then subjects received second-order training in which a blue key light (S_2) preceded nonreinforced presentations of the S_1. After alternating first- and second-order training sessions over a total of eight sessions, the experimenters gave one group of subjects S_1 extinction trials and another group of subjects further S_1-US training. Subsequent test sessions revealed that S_2 responding declined for those subjects who received S_1 extinction trials but stayed about the same for subjects who received further S_1-US training. The authors concluded that the change in S_2 responding was attributable to the intervening S_1 extinction trials and that their results challenged Rescorla's contention that second-order conditioning establishes associations of an S-R variety.

Close examination of the procedures employed by Rescorla to establish second-order conditioning and those employed by Rashotte reveals some important differences which may explain the discrepancies in their data. Rescorla typically gives his subjects a series of first-order conditioning trials followed by two conditioning sessions in which an overall total of six to eight S_2-S_1 pairings are given. Rashotte, on the other hand, alternates first- and second-order conditioning sessions and gives his subjects a total of 40 S_2-S_1 pairings. In Rescorla's experiments, S_1 extinction trials are given after the early stages of S_2 response acquisition; in Rashotte's S_1 extinction trials are given after near-asymtotic levels of S_2 responding.

Rescorla (1975) has also pointed out and demonstrated that the procedures used to establish second-order conditioning are functionally equivalent to those used to establish a first-order conditioned inhibitor. Although in second-order conditioning procedures two discriminable stimuli are presented in a series rather than simultaneously (i.e., as is the general case when a compound stimulus is being trained as a conditioned inhibitor), extended S_2-S_1 pairings do result in a gradual decrease in responding to the S_2. Extended second-order conditioning may enable a subject to learn that the S_1 will not be followed by the US when it is preceded by the S_2. Once the subject has begun to learn that the S_2 predicts the absence of the US, it would be expected that he would decrease and eventually discontinue responding to the S_2. Furthermore, the decrease in S_2 responding would be expected to occur regardless of any subsequent manipulations of the US or of the response strength to S_1. This line of analysis provides at least one logical framework within which the discrepant results obtained by Rescorla and Rashotte can be evaluated. Admittedly, such an analysis does not account for the fact that in the Rashotte and Sisk (1975) study subjects receiving S_1 extinction trials after second-order conditioning showed a decrease in S_2 responding, whereas those who received further first-order conditioning trials did not; however, it is possible that, in this case, there is some generalization of inhibition from the S_1 extinction trials which enhances the partially inhibitory properties of the "well trained" S_2 and subsequently affects responding to the S_2.

Regardless of the way the aforementioned issues are resolved experimentally, previous research still indicates that after relatively few contingent pairings of a first-order conditioned stimulus (S_1) and a previously neutral event (S_2), S_2 elicits the conditioned response (CR). Furthermore, this CR appears to be independent of a "mental representation" of the US and independent of any direct association between the S_1 and S_2. Hull (1943) and Rescorla (1974) have proposed that the CR produced by the S_2 in second-order conditioning is attributable to an association which is formed between the S_2 and the response evoked by the S_1. To date, no experiments have directly tested this theory.

The crucial element in any experiment purporting to test the S-R theory of second-order conditioning would be the systematic variation of the conditioned response evoked by S_1 (i.e., the first-order CS) during second-order conditioning in at least two groups of subjects. If Hull and Rescorla are correct, the result of such a manipulation should be a noticeable difference in the conditioned response established to S_2 (i.e., the second-order

CS) in the separate groups during S_2-S_1 pairings, and a noticeable difference in the conditioned response subsequently evoked by S_2 in those subjects after the conditioned response to S_1 has been extinguished.

If CS intensity manipulations in Experiment 1 had produced statistically significant differences in conditioned response magnitude, a manipulation of S_1 intensity in two groups of subjects during second-order conditioning would have been a feasible means of testing Hull's S-R theory; however, the failure of Experiment 1 to convincingly demonstrate a CS intensity effect precluded the use of such a procedure. Consequently, an alternative test of the S-R theory was devised which employed extinction trials as the means of systematically varying the conditioned response to S_1.

The test experiment included two experimental and three control groups. All subjects were initially pretested to insure that the to-be-conditioned stimuli (i.e., S_1 and S_2) were neutral events. The two experimental groups were then given contingent pairings of the S_1 and shock to establish conditioned suppression to the S_1. Following this first-order conditioning, one experimental group, the extinction group, received a series of non-reinforced presentations of the S_1 to reduce the strength of the conditioned response to the S_1, whereas the other experimental group (NE) did not receive extinction trials. Next, both experimental groups were given contingent pairings of the S_2 and the nonreinforced S_1 to establish a second-order conditioned response to S_2. Inasmuch as the conditioned response to the S_1 should have been smaller for group E than group NE during S_2-S_1 pairings, group E was expected to acquire a smaller conditioned response to S_2 than group NE. After all second-order conditioning trials were completed, both groups were given S_1 extinction trials. Both experimental groups had an equal total number of S_1 extinction trials. Finally, all subjects were given presentations of the S_2 alone.

An additional three control groups were necessary to show that the conditioned response evoked by the S_1 and S_2 during first- and second-order conditioning were due to contingent pairings of a stimulus and a neutral event and not to non-associative factors. A group receiving separate and completely random presentations of the S_1 and US would be the appropriate control for first-order conditioning. Two groups would be necessary to provide the appropriate controls for second-order conditioning. One group should receive contingent pairings of the S_1 and US during first-order training, followed by completely random presentations of the S_2 and S_1 during second-order training. The other group should receive completely random presentations of the S_1 and US during first-order training, and contingent pairings of the S_2 and S_1 during second-order training. However, due to the results obtained from the two experimental groups, it was not necessary to run the three control groups.

Experiment 2 consisted of the experimental conditions previously described to see if the extinction procedure would produce the hypothesized effect on second-order conditioning.

Method

Subjects

The subjects were 16 Sprague-Dawley male rats, approximately 100 days old at the beginning of the experiment. Subjects were quasi-randomly assigned to two groups, eight rats per group. As in Experiment 1, subjects were maintained on 23 hour food deprivation and given one hour free access to food at the end of each experimental session.

Apparatus

The apparatus was the same as that used for Experiment 1. Shock intensity was increased to 2.4 milliamperes and only the 90 db tone was employed. All other stimulus parameters were identical to those described in the previous experiment.

Procedure

All experimental sessions were two hours in duration. Subjects were taught to barpress for sucrose pellets delivered on a VI 2 minute schedule as described in Experiment 1. After at least five days of barpress training, subjects received a series of pretest sessions. During each session, four presentations of a 30-second 6kHz tone (S_1) and four 30-second flashings of the houselight (S_2) (2/second; 250 milliseconds ON, 250 milliseconds OFF) were superimposed on barpressing to habituate any suppressive effects that the tone or flashing light may have had on VI responding. Pretest trials were administered every 15 minutes on the average. On the first day of pretesting, subjects received four consecutive presentations of the tone during the first hour of the session and four consecutive presentations of the flashing light during the second hour. On the second day of pretesting the tone and light were presented in the reverse order. If, for any subject, there was evidence of barpress suppression to either the tone or the flashing houselight after two days of pretesting, that subject received further pretest sessions in which the suppressive stimulus/stimuli were presented in blocks of four trials. Habituation trials to each stimulus continued until a barpress suppression ratio of .40 or higher (i.e., calculated according to the formula A/A+B which was described in Experiment 1) was obtained over a single block of four trials. When pretesting was completed, some of the rats in the two groups were interchanged so that subjects in both groups were roughly matched on the amount of pre-exposure to the tone and flashing light.

Next, Phase 1 conditioning began. Both groups of subjects were given two sessions of contingent tone-shock pairings designed to establish first-order conditioned suppression to the tone (S_1). During each session, subjects received four presentations of the tone followed immediately by a shock coinciding with S_1 termination. Conditioning trials were given every 30 minutes on the average.

In the three sessions following Phase 1 conditioning, one group of subjects received a series of non-reinforced presentations of the S_1, while the other group merely bar pressed for food. The former group will hereafter be referred to as Group E (extinction); the latter group will be referred to as Group NE (no extinction). Group E received eight S_1 presentations per session during the first two sessions of extinction trials, and two S_1 presentations during the third session. The S_1 was presented every 15 minutes on the average for a total of 18 extinction trials over the three sessions.

Then the two groups entered Phase 2 conditioning. In each of two sessions, all subjects received contingent pairings of the flashing houselight (S_2) and the tone

(S_1) in an effort to establish second-order conditioned suppression to the S_2. In the first session, four S_2-S_1 pairings were administered. In the following session, only two second-order conditioning trials were given. Subjects received S_2-S_1 pairing every 30 minutes, on the average, and a total of six trials was administered.

Next, all subjects received sessions designed to completely extinguish conditioned suppression to the S_1. Eight non-reinforced presentations were given per session, and extinction trials were administered every 15 minutes on the average. Group E received five days of extinction trials. Group NE received eight days of extinction trials but only two S_1 presentations were given on the eighth day. When all S_1 extinction sessions were completed, groups E and NE had each received a total of 58 extinction trials.

Finally, both groups were tested for conditioned suppression to S_2. Subjects received a single session in which the S_2 was superimposed on bar pressing a total of eight times. Test trials were given every 15 minutes on the average.

Results

At the end of the second day of pretesting, all subjects showed little or no suppression to the tone (S_1), but 7 of the 16 subjects required additional flash

(S_2) habituation trials. Four of these subjects were assigned to Group E, the other three were assigned to Group NE. The mean number of S_1 pretest trials administered to both groups of subjects was 8.0. The mean number of S_2 pretest trials administered to Group E was 16.5, and the mean number of S_2 pretest trials administered to Group NE was 15.0. The difference in the average amount of pre-exposure to S_2 for the two groups was not statistically significant.[2]

The acquisition of conditioned suppression to the tone proceeded rapidly in all subjects during first-order conditioning. Figure 5 presents the mean suppression ratios to S_1 for Groups E and NE during the eight first-order conditioning trials. The data are presented in blocks of two trials and the suppression ratios are not transformed as they were in Experiment 1. Thus, suppression ratios near zero indicate strong conditioning and suppression ratios near .5 indicate little or no conditioning. The data of the present experiment were analyzed in two-trial blocks so that direct comparisons could be drawn between the results obtained in this experiment and those obtained by Rizely and Rescorla (1972).

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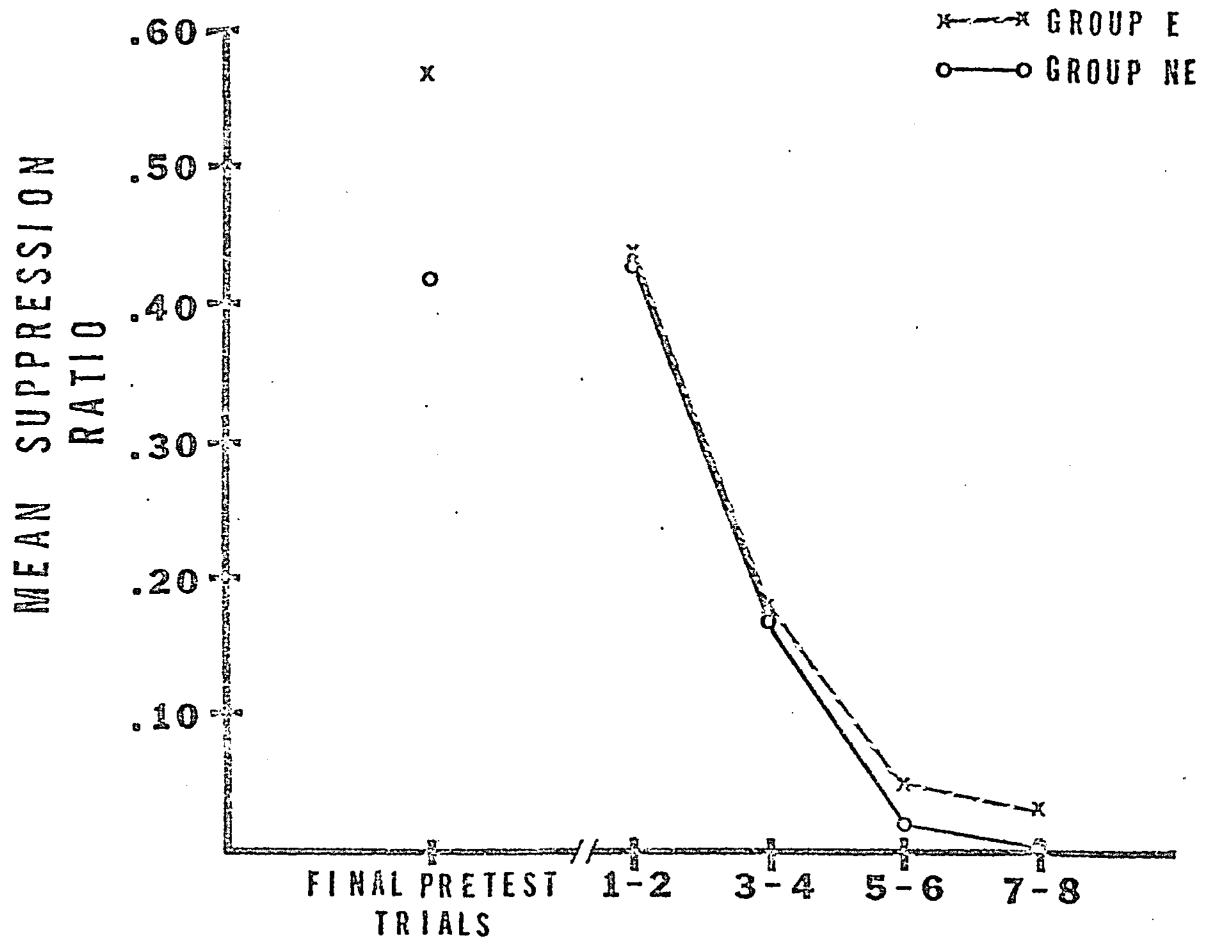
[2] A one-way analysis of variance was performed on the number of flash pretest trials administered to subjects in Groups E and NE of the present experiment, and subjects in Group D of the succeeding experiment (i.e., Experiment 3). The analysis indicated that there were no significant differences among the groups in the average amount of pre-exposure to the flash ($F = .02$, $df = 2,23$; $p \geq .97$).

Figure 5. Mean suppression ratios to the tone during final pretesting and first-order conditioning in Experiment 2.

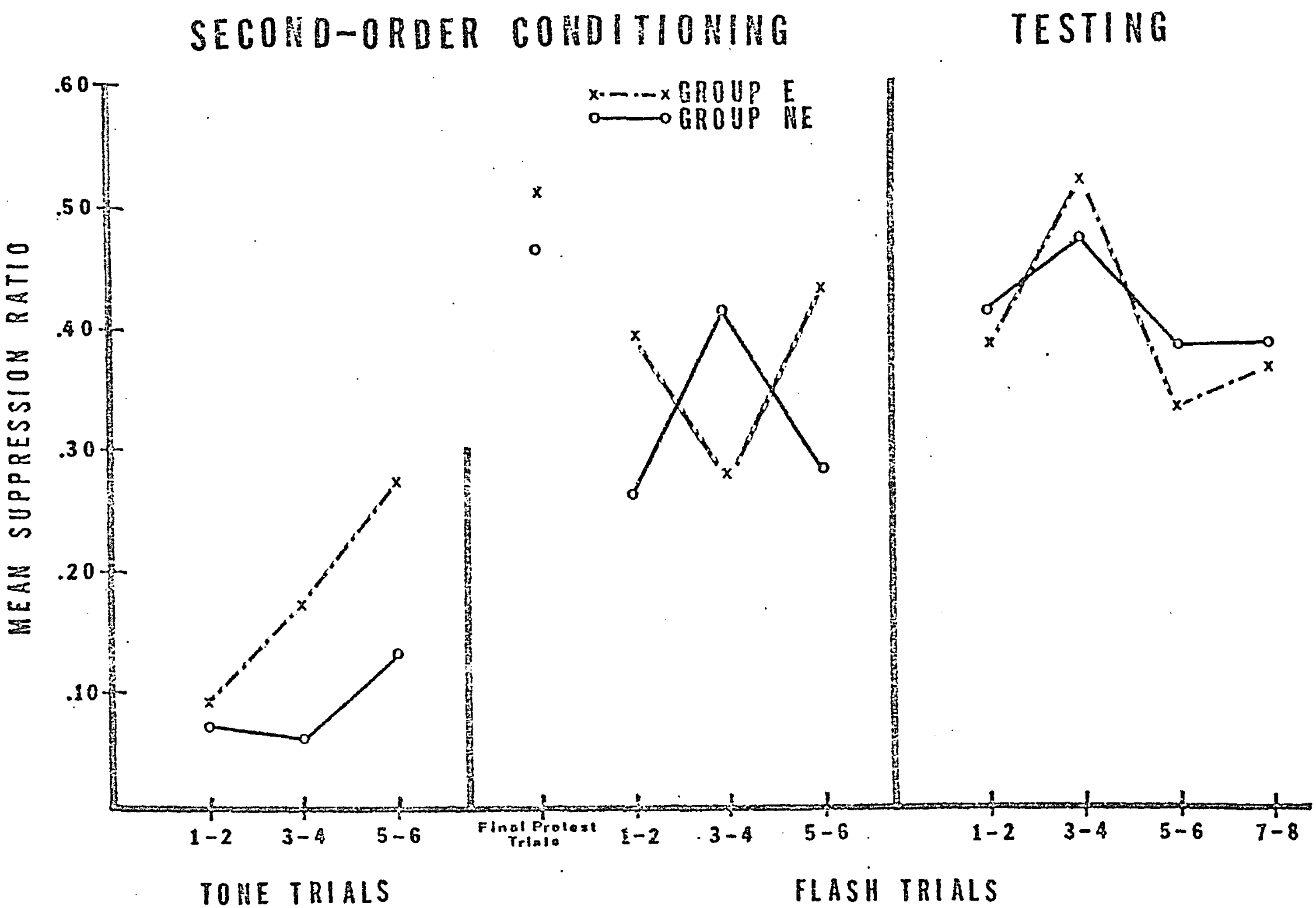
FIRST-ORDER CONDITIONING



Neither group showed any appreciable amount of suppression to S_1 during the first two S_1-US pairings. During the last two first-order conditioning trials, however, Group NE showed complete suppression to S_1 (i.e., a mean suppression ratio of .00 was obtained) and Group E showed nearly complete suppression (i.e., the mean suppression ratio was .03). A two-way repeated measures analysis of variance (Groups x Trials) was performed on the normalized (i.e., via the arcsin transformation) suppression ratios for both groups of subjects during consecutive pairs of first-order conditioning trials. The results showed that there were no significant differences in bar press suppression between groups ($F = .069$, df 4,44) during S_1-US pairings, but there was a significant conditioning effect ($F = 22.05$; df=2,4; $p < .001$) for both groups of subjects. Scheffé post hoc tests revealed that the mean suppression ratios obtained on the last block of first-order conditioning trials for groups E and NE differed significantly ($p \leq .05$) from those obtained on the first block of trials, but no other between-trial differences were significant.

Figure 6 shows the mean suppression ratios to S_1 and S_2 for both groups of subjects during second-order conditioning. Figure 6 also shows the mean suppression ratios to S_2 during test trials. Inspection of the mean

Figure 6. Mean suppression ratios during three phases of Experiment 2. (The first panel shows the mean ratios to the first-order CS during second-order conditioning. The second panel shows the mean ratios to the flashing light during final pretesting and second-order conditioning. The third panel shows the mean ratios to the light during final testing. Extinction of the first-order tone followed second-order training to the light.)


SECOND-ORDER CONDITIONING
TESTING
GROUP E
GROUP NE
MEAN SUPPRESSION RATIO
.60
.50
.40
.30
.20
.10
1-2
3-4
5-6
Final Protest Trials
1-2
3-4
5-6
1-2
3-4
5-6
7-8
TONE TRIALS
FLASH TRIALS

suppression ratios to S_1 during S_2-S_1 pairings reveals that the tone remained an effective first-order CS. Both groups showed less suppression to the tone during the last two second-order conditioning trials than they had during the first two trials, and this decrement in suppression was most pronounced in Group E. The mean suppression ratio to S_1 for Group E during the last pair of second-order conditioning trials was .27, and the mean suppression ratio for Group NE on the same two trials was .13.

A two-way repeated measures analysis (Groups x Trials) of variance was performed on the normalized suppression ratios to S_1 for all subjects during second-order conditioning trials. The analysis revealed that there were no significant differences in the mean suppression ratios to S_1 either between groups or across trials during S_2-S_1 pairings.

Examination of the mean suppression ratios to the flashing light (S_2) during second-order conditioning shows that S_2-S_1 pairing had no consistent effects. Group E showed little or no suppression (mean ratio = .39) to S_2 during the first two S_2-S_1 pairings, moderate suppression (mean ratio = .27) to S_2 during the second two S_2-S_1 pairings, and essentially no suppression (mean ratio = .43) to S_2 during the last two S_2-S_1 pairings. In contrast, even though Group NE showed no suppression to S_2 at the end of pretesting, they showed a moderate suppression (mean ratio = .26) to S_2 during the first two second-order conditioning trials. In the next two trials, Group NE showed little or no suppression (mean ratio = .41) to S_2, and in the last two trials they showed moderate suppression (mean ratio = .28).

Finally, during test trials neither group showed any substantial amount of suppression to S_2. The lowest mean suppression ratio obtained for both groups of subjects during the first four test trials was .38. A two-way repeated measures analysis of variance (Groups x Trials) was used to compare performance on the last two pretest trials with performance on the first two test trials. Again, the results indicated no significant differences in the mean suppression ratios to the flashing light either between groups or across trials.

Discussion

Due to the unanticipated failure to establish second-order conditioning in either group of subjects, no conclusions about the accuracy of the S-R theory can be drawn from the results of Experiment 2. Despite the fact that the tone was an effective first-order CS during second-order conditioning, neither group of subjects showed significantly greater suppression to S_2 during the first two test trials than they had shown during the final trials of pretesting. While Group NE showed a moderate degree of suppression to S_2 during the last two second-order conditioning trials, they showed even greater suppression during the first two second-order conditioning trials. Thus suppression to S_2 was not the result of contingent pairings of S_1 and S_2.

The experimental results appear to offer very little evidence for a second-order conditioning effect. Since Rescorla has consistently demonstrated a strong second-order conditioning effect, these unanticipated results prompted a personal communication with Rescorla. Rescorla suggested that intermodality stimulus generalization may have occurred. Such a finding is at variance with Rescorla's findings. Rescorla routinely employs a tone and a flashing light as the S_1 and S_2 in his second-order conditioning experiments and reports (e.g., Rescorla, 1974) that he obtains little or no generalization of suppression from S_1 to S_2 following first-order conditioning. The discrepancies between the present results and Rescorla's results prompted Experiment 3.

CHAPTER IV

EXPERIMENT 3

The unexpected results of Experiment 2 prompted a modification in the experimental procedure away from the control conditions of Experiment 2. It was Rescorla (personal communication) who suggested that generalization of conditioned suppression had occurred in Experiment 2. Rescorla also pointed out two procedural differences between his second-order conditioning studies and Experiment 2. Although the fact is not mentioned in his published reports, Rescorla usually gives his subjects discrimination training to S_2 during first-order conditioning to prevent generalization. Rescorla also indicated that subjects in his second-order conditioning studies are routinely run in the dark. Thus, the "flashing houselight" specified as the CS in his studies is actually the introduction of a flashing light into a darkened experimental chamber. Consequently, the present Experiment 3 was conducted to see whether S_2 discrimination training during first-order conditioning would eliminate generalization between S_1 and S_2, and to see whether the second-order conditioning reported by Rescorla could be replicated using the normally illuminated chambers previously employed in Experiments 1 and 2.

Method

Subjects

The subjects were eight Sprague-Dawley male rats approximately 100 days old at the beginning of the experiment. Subjects were maintained on 23 hour food deprivation throughout the experiment and given one hour free access to food at the end of each experimental session.

Apparatus

The apparatus and all stimulus parameters were the same as those employed in Experiment 2.

Procedure

With one exception, the training and testing procedure administered to subjects in the present experiment were identical to those used with Group NE in Experiment 2. The only difference in procedure was the inclusion of discrimination training in the two first-order conditioning sessions. During each session subjects received four presentations of the tone (S_1) and four presentations of the flashing houselight (S_2). S_1 presentations were followed immediately by a shock whose onset coincided with tone termination, whereas S_2 presentations were followed by no shock. The S_1 and S_2 were presented separately on alternate trials, and stimulus presentations occurred every 15 minutes on the average. In the initial session of first-order conditioning, S_1 was presented first in the series of alternating stimulus presentations. During the second session, the order of presentation was reversed. Hereafter, subjects in the present experiment will be referred to as Group D (discrimination).

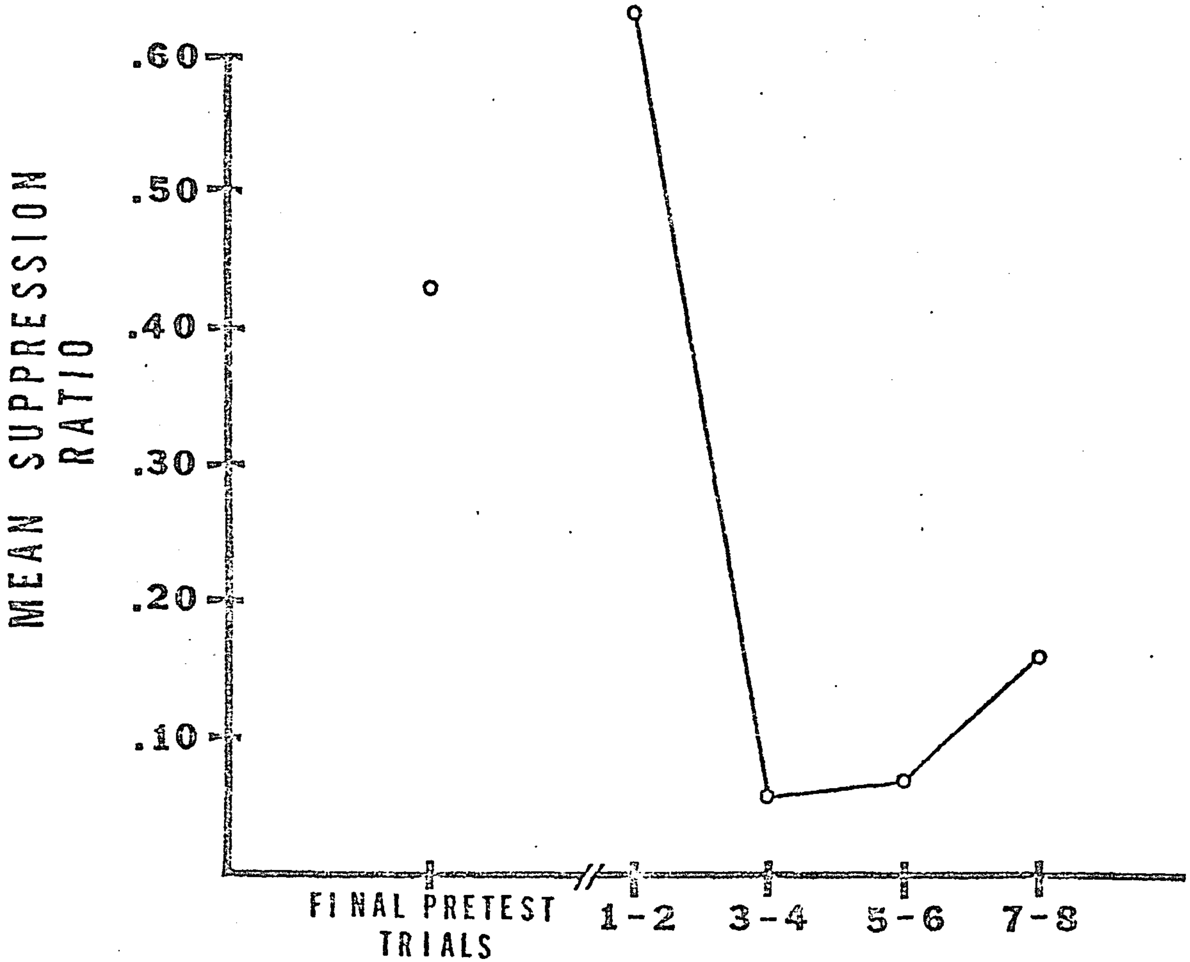
Results

Prior to first-order conditioning, each subject received 8 pretest trials to S_1. Prior to second-order conditioning the amount of pre-exposure to S_2 for each subject totaled 16 trials (i.e., 8 pretest trials and 8 discrimination trials). The average amount of pre-exposure to S_1 and S_2 prior to first- and second-order conditioning for Group D is not significantly different from the average amount of pre-exposure to S_1 and S_2 given to Groups E and NE in the previous experiment.

Figure 7 shows the mean suppression ratios to the tone during successive pairs of first-order conditioning trials. The S_1 had a slightly excitatory effect on bar pressing during the first two S_1-US pairings (i.e., as indexed by a mean suppression ratio greater than .5), but it quickly acquired suppressive properties during the next three pairs of first-order conditioning trials. The mean suppression ratio obtained on each of the four successive pairs of first-order conditioning trials was .62, .06, .07, and .17, respectively. A one-way repeated measures analysis of variance and subsequent Scheffé

Figure 7. Mean suppression ratios to the tone during final pretesting and first-order conditioning in Experiment 3.

FIRST-ORDER CONDITIONING

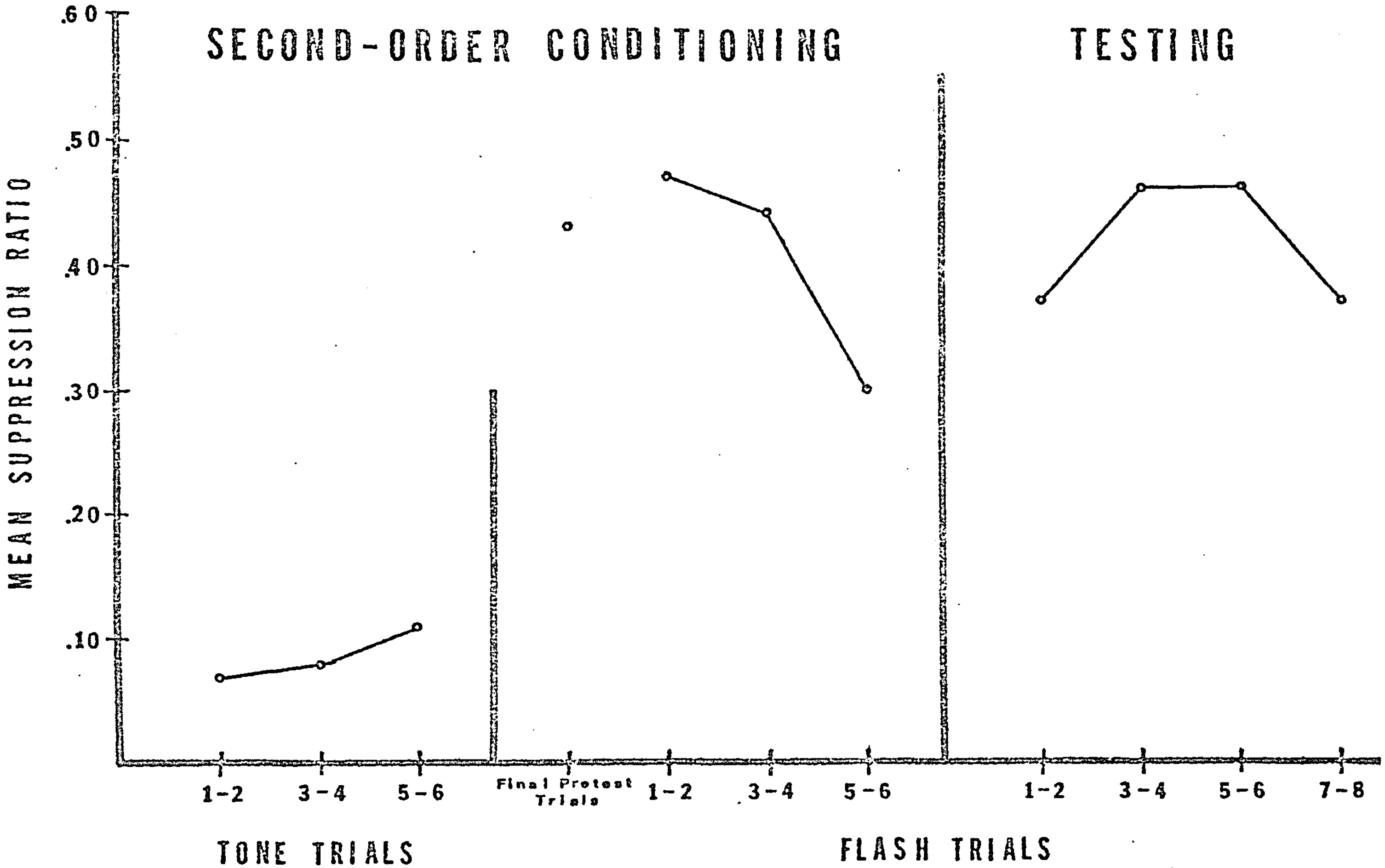


post hoc tests were used to confirm that subjects showed significantly greater suppression ($p \leq .05$) during the last two S_1-US pairings than they had shown during the first two pairings.

Figure 8 shows the mean suppression ratios obtained to S_1 and S_2 during second-order conditioning. In addition, Figure 8 shows the mean suppression ratios obtained to S_2 during test trials. Inspection of the mean suppression ratios to S_1 during S_2-S_1 pairings reveals that the tone was an effective first-order CS throughout second-order conditioning. The mean suppression ratio to S_1 for Group D during the last pair of second-order conditioning trials was .11.

Examination of the mean suppression ratios to S_2 during S_2-S_1 pairings shows that subjects exhibited little or no suppression to S_2 during the first two second-order conditioning trials, and progressively greater suppression during the next two pairs of trials. The mean suppression ratio obtained for Group D during the initial pair of second-order conditioning trials was .47 while the mean suppression ratio obtained during the last two S_2-S_1 pairings was .30. A one way repeated measures analysis of variance performed on the normalized suppression ratios to S_2 for all subjects during second-order conditioning revealed, nevertheless, that this difference in suppression was not statistically significant.

Figure 8. Mean suppression ratios during three phases of Experiment 3. (The first panel shows the mean ratios to the first-order CS during second-order conditioning. The second panel shows the mean ratios to the flashing light during final pretesting and second-order conditioning. The third panel shows the mean ratios to the light during final testing. Extinction of the first-order tone followed second-order conditioning to the light.)


SECOND-ORDER CONDITIONING
TESTING
MEAN SUPPRESSION RATIO
.60
.50
.40
.30
.20
.10
1-2
3-4
5-6
Final Protest Trials
1-2
3-4
5-6
1-2
3-4
5-6
7-8
TONE TRIALS
FLASH TRIALS

Finally, subjects showed little or no suppression to S_2 during test trials. The lowest mean suppression ratio obtained during testing was .37, and that ratio was obtained during the first two test trials.

Discussion

Group D having shown no suppression to S_2 at the beginning of second-order conditioning, discrimination training during first-order conditioning appears to have been successful in preventing intermodality stimulus generalization. Even though the discrimination procedure prevented intermodality generalization, however, second-order conditioning was not demonstrated. Subjects showed progressively greater suppression to S_2 during S_2-S_1 pairings, but there were no statistical differences in the mean suppression ratios obtained for the first and last pairs of second-order conditioning trials.

During the last two S_2-S_1 pairings the mean suppression ratio was .30. Rizely and Rescorla (1972) have reported suppression ratios of .10 or less after an equal number of second-order conditioning trials. The failure of Experiments 2 and 3 to establish any appreciable amount of second-order conditioning is especially surprising in view of the fact that S_1 remained an effective suppression-producing stimulus during S_2-S_1 pairings. Indeed, all subjects showed substantial suppression to the first-order CS during second-order conditioning.

The slight S_2 suppression exhibited by Group D at the end of second-order conditioning did not persist following extinction of conditioned suppression to S_1. Subjects showed little or no suppression to S_2 during final testing. This finding is contrary to the findings of Rescorla and consistent with those of Rashotte and his associates. It will be recalled that Rashotte and Griffin (1974) employed pigeons and autoshaped to a white key light (S_2). They then established second-order responding to a blue light (S_2) by immediately following S_2 presentations with the S_1. After second-order conditioning, keypecking to S_1 was extinguished. In subsequent test sessions responding to both S_2 and S_1 had declined. The experimenters then replicated their training procedure with new subjects and extinguished keypecking to S_2 but not to S_1 prior to testing. Test trials showed no decrease in keypecking to S_1, indicating that their initial results could not be attributed to generalization. In a later study, Rashotte and Sisk (1975) used a modified autoshaping procedure to bring pigeons' keypecking under the control of a 15 second tone (S_1) and then preceded the S_1 with a white key light (S_1) until keypecking was established to the S_2 (i.e., second-order conditioning). Next, half of the subjects received extinction trials to the S_1, whereas the other half received further tone-food pairings (i.e., first-order conditioning). Subsequent testing revealed that S_2 keypecking declined for those subjects who had received S_1 extinction trials but stayed about the same for subjects who had received further first-order training. The results of both experiments demonstrated that the S_2 maintained high rates of keypecking only as long as the S_1 also maintained keypecking. The present experiment yielded similar results, in that subjects showed a small amount of S_2 suppression (mean ratio = .30) as long as S_1 evoked suppression but very little S_2 suppression (mean ratio = .37) after S_1 suppression was extinguished.

Rashotte concluded that the decrement in S_2 responding in his experiments was attributable to intervening S_1 extinction trials. In addition, he argued that his findings challenged Hull's (1943) and Rescorla's (1972) S-R theory of second-order conditioning. The present experiment appears to provide further evidence against the S-R theory and, along with Rashotte's, seems to support the theory that an association is formed between S_2 and S_1 in second-order conditioning.

Apparently, the difference in the outcome of the present experiment and the outcomes of Rescorla's studies are due to procedural differences. The only identifiable procedural difference between the present experiment and Rescorla's second-order conditioning experiments is that the present study employed normally illuminated experimental chambers, whereas Rescorla employs darkened chambers.

Experiment 3 failed to demonstrate second-order conditioning and failed to replicate Rescorla's finding that the S_2 continues to evoke a conditioned response even after the conditioned response to S_1 has been extinguished. One possible reason for these discrepancies in experimental outcomes is that presentation of a flashing light to dark-adapted rats may produce a much more salient and non-neutral stimulus than the presentation of intermittent darkness to light-adapted rats.

The fact that rats have primarily scotopic visual systems (Walls, 1963) and prefer environments having low luminance levels (e.g., Allison et al., 1967) would seem to support such a hypothesis. Skinner (1938) has shown, for example, that light depresses the rate of lever-pressing in food-deprived rats. Pretesting would not in itself eliminate rats' natural aversion to light, nor would habituation to a "light on" stimulus in dark adapted subjects during one experimental session necessarily transfer to all subsequent sessions. Thus, it is probable that part of the "conditioned suppression" Rescorla obtains to a light CS in his experiments can be attributed to the fact that the light itself has aversive properties, and part of the "conditioned suppression" Rescorla obtains to the light S_2 after S_1 extinction may be due to an inherent aversiveness of a light stimulus to dark adapted subjects. Rescorla (1973) mentions that, in his studies using bar press suppression as the conditioned response, stronger conditioning is obtained when a light rather than a tone is used as either the first-order or second-order CS. In a later study in which general activity level was used as an index of appetitive conditioning, Rescorla (1975) states that ". . . experiments from this laboratory indicate that although the observation of conditioning is difficult when the light CS is used, substantial levels of first- or second-order conditioning may be observed to auditory stimuli."

Examination of Rescorla's (1973) study provides additional affirmation that his second-order "conditioned suppression" to a light CS is partially (if not primarily) due to the use of normally darkened experimental chambers. In this study, Rescorla gave one group of subjects first-order conditioning to a flashing light (S_1) followed by second-order conditioning to a tone (S_2); another group received identical training except that the tone was the S_1 and the light the S_2. After second-order conditioning, half of the subjects in each group were given US habituation trials while the other half were not. All subjects were then given test trials with both the tone and the light. Of primary interest to the present discussion is the magnitude of the conditioned suppression evoked by the tone and light S_2. If, to dark adapted subjects, the presentation of a flashing light were more aversive than presentation of a tone, then a light S_2 should evoke more suppression than a $tone_2$. This was the result obtained. For subjects who did not receive US habituation and who had a flashing light S_2, the mean suppression ratio at the end of second-order conditioning was approximately .13 and the mean suppression ratio during the first two test trials was approximately .20. For tone S_2 subjects, however, the respective ratios were much higher, .31 and .40, respectively. Thus, the tone S_2 produced suppression ratios similar to the light S_2 in Experiment 3. To light-adapted rats, therefore, a flashing light and a tone may be equally nonaversive stimuli that result in little suppression when they are not paired with aversive unconditioned stimuli. Thus, some of Rescorla's second-order results do seem to be due to his use of dark-adapted subjects and a flashing-light second-order CS.

A certain amount of interpretive caution is still indicated, however. It should be noted that Holland and Rescorla (1975) have shown convincing evidence of second-order, food elicited motor activity to a tone CS. Furthermore, the second-order response was shown to remain unaffected by extensive extinction training to the first-order CS (a flashing light). This outcome is not easily explainable in terms of a procedural artifact and appears to provide strong evidence that, in at least some situations, a second-order CS can continue to evoke a conditioned response even after the conditioned response to the first-order CS has been extinguished. An equally significant finding of Holland and Rescorla's experiment, however, was that very little first- or second-order motor activity could be established to a flashing light CS. There are two possible explanations for this finding. The first follows from the notion that light is an aversive stimulus to rats which may evoke a central emotional state which is incompatible with appetitive behavior (cf. Schwartz, 1976). The second explanation, similar to the first, is based on Bolles's (1970) concept of the "species' specific defense reaction (SSDR)." The general notion behind the SSDR is that, for some species of animals, a given environmental event may evoke a reflexive response which either interferes with or is incompatible with the learning of a specific behavior, whereas the same event will not have this effect on other species. Thus, to rats, light onset may be a stimulus to which the innate response is a temporary cessation of motor behavior and which, therefore, cannot be used as an effective CS for increased motor activity.

CHAPTER V

GENERAL DISCUSSION

Experiment 1 was designed as an analog of human fear conditioning and consistent trends in the experimental results suggest that a CS intensity effect can be demonstrated in a Pavlovian fear conditioning paradigm. For example, experimental subjects trained with the high intensity tone generally showed higher rates of conditioning than subjects trained with the low intensity tone. In addition, subjects tested with the high intensity tone showed lower suppression ratios, greater resistance to extinction, and longer latencies to bar press during test presentations of the CS than subjects tested with the low intensity tone. Until statistically significant CS intensity effects are convincingly demonstrated in a Pavlovian fear conditioning experiment, however, the utility of applying the "stimulus intensity dynamism" concept to clinical aversion therapy procedures remains questionable.

Experiment 1 provided some interesting data suggesting that after a fear response has been acquired to a high intensity of some environmental event, a subsequent encounter with a lower intensity of that same stimulus may evoke less fear than if the low intensity stimulus had been involved in the original learning experience. Recalling the diving board example, if the swimmer originally did a "belly flop" off the high dive and was thereafter afraid to dive from that diving board, he might nevertheless be less fearful of diving from the low diving board and may even underestimate the aversiveness of taking a "belly flop" off the low diving board.

Although Experiments 2 and 3 were designed to test the S-R theory of second-order conditioning, no appreciable degree of second-order conditioning was obtained in either of the two experiments. Consequently, a test of the theory was impossible. It is true that the slight evidence of second-order conditional suppression which was obtained in Experiment 3 did not persist after conditioned suppression to the first-order CS was extinguished, and this outcome does not support Hull's S-R theory. From a clinical viewpoint, the results of Experiments 2 and 3 suggest that, in treating phobias, the extinction of fear to a primary (i.e., first-order) fear stimulus reduces and probably eliminates fear to any second-order fear stimuli. It would be difficult and probably impossible to identify positively a "second-order" fear stimulus in a clinical situation, however.

Rescorla (1975) and Rashotte and his associates (Rashotte & Griffin, 1974; Rashotte & Sisk, 1975) appear to have demonstrated second-order appetitive conditioning in rats and pigeons, respectively; but only Rescorla has obtained evidence that the second-order conditioned response remains unaffected by extinction of the conditioned response to the first-order CS. Procedural differences such as the number of S_2-S_1 pairings during second-order conditioning, the number of S_1 extinction trials, and other factors such as species differences, etc. may account for the discrepancies in the results. However, even if Rescorla's findings are replicated in future appetitive conditioning research so that the S-R theory of second-order conditioning is given considerable empirical support, it would be difficult to assess the applied (i.e., clinical) significance of these findings. As mentioned previously it would be extremely difficult, if not impossible, to discriminate a second-order CS from a first-order CS in human experience. In treating a clinical disorder which may be related to appetitive conditioning such as functional obesity, therefore, a therapist would attempt to extinguish appetitive behavior to a specified set of conditioned stimuli whether they could be identified as first- or as second-order CSs.

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APPENDIX

SUPPLEMENTARY TABLES

Table 1A

Analysis of Variance for the Normalized Suppression Ratios Obtained on Test Trials One Through Four for All Groups of Subjects in Experiment 1

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Between Groups	6	1869.9448	311.6575	8.438
Within Groups	48	1772.9644	36.9368	
Total	54	3642.9092		

Table 2A

Analysis of Variance for the Normalized Suppression Ratios Obtained on Test Trials Five Through Eight for All Groups of Subjects in Experiment 1

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Between Groups	6	3.4160	0.5693	4.568
Within Groups	48	5.9820	0.1246	
Total	54	9.3980		

Table 3A

Analysis of Variance for the Number of Test Trials to Reach the Extinction Criterion for All Groups of Subjects in Experiment 1

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Between Groups	6	1242.7578	207.1263	3.668
Within Groups	48	2710.6250	56.4713	
Total	54	3953.3828		

Table 4A

Analysis of Variance for the Number of Test Trials to the First Barpress During Tone Presentation for All Groups of Subjects in Experiment 1

Source	Degrees of Freedom	Sum of Squares	Mean Squares	F Ratio
Between Groups	6	1869.9448	311.6575	8.438
Within Groups	48	1772.9644	36.9368	
Total	54	3642.9092		