THE AMOUNT OF DECREASE OF THE BACKGROUND WHITE NOISE INTENSITY AS A CUE FOR DIFFERENTIATION TRAINING

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Abstract. The course of differentiation learning, using the conditioned emotional response (CER) method, was investigated in two groups of 16 rats. The discriminative stimuli consisted of decreases in the 80 dB background white noise to either 70 dB or 60 dB. Differentiation learning was more efficient with the larger decrease of background noise intensity as the CS+ and the smaller decrease as the CS− than vice versa.

INTRODUCTION

After considering the effects of stimulus intensity in his last theoretical book, Hull predicted that differentiation learning is more effective "when reinforcement is given to the more intense rather than to the less intense of the two discriminanda" (12, p. 87). At that time, only an unpublished study by Antoinetti on brightness differentiation in rats provided experimental data supporting Hull's hypothesis.

Since then dozens of papers have been published in which the course of differential learning and final performance levels were compared, depending on which of the two conditioned stimuli (CSI) has been paired with the reinforcing event or outcome. Hull's prediction was not confirmed

1 Following Konorski (1967, p. 93), any procedure, in which discriminative stimuli are utilized for different conditioned responses of the organism, is denoted as differentiation learning. In go, no-go differentiation tasks, the CSI (typically, two CSI) are presented in random succession or in a predetermined order on
in some early experiments performed with rats in which CSi of different brightness (37) or tonal intensity (27, 28) were used. However other studies, in which tonal intensities were employed for rats (2, 29, 33) and humans (24) or different brightness for humans (35, 36), showed that differentiation learning is easier when the more intense stimulus is used as the CS+. Similar results were obtained with rats when a classically conditioned defensive response was established to one white noise intensity using the Estes–Skinner CER technique (6), while the other white noise intensity was not paired with the shock US (13, 39, 43). Stimuli differing in relative duration of sound and silence within a cycle have been used also. Differentiation training was easier, when during periods of the long sound cycles bar presses emitted by rats were reinforced under a 30 s variable interval (VI) schedule while periods of the short sound cycles denoted an extinction contingency, rather than vice versa (22). It was also shown that tones of higher rather than lower frequency were more effective as the CS+ in differentiation training of eyelid responses in human subjects (32).

Not only the intensity but also the relative saliency of the CS+ and the CS− can influence the effectiveness of differentiation learning. Using avoidance bar press latencies as the measure of the response strength, auditory clicks were more salient than tones of similar intensities in cats (42) as well as in dogs (16). Correspondingly, go, no–go differentiation learning was easier when clicks served as CS+ and tones as CS−, rather than vice versa. Further experiments showed that the relative saliency effect on the course of differentiation learning became markedly attenuated when a symmetrical instead of an asymmetrical procedure of reinforcement was employed in go, no–go differentiation of instrumental defensive reflexes (17–19, 40). Nevertheless a marked saliency effect has been observed in avoidance go, no–go differentiation learning with symmetrical reinforcement in rats trained to discriminate between noise (more salient CS) and light (less salient CS) (9, 30, 31). In many of the separate trials. In Pavlovian differentiation one conditioned stimulus, termed "positive" (CS+), is always paired with the unconditioned stimulus (US), and the second, termed "negative" (CS−), is never paired with the US, independent of whether the US is attractive or aversive. In spite of the fact that differentiation learning involving instrumental conditioning is much more complex than in classical conditioning (40), we preserve the notation of CS+ for the conditioned stimulus that requires performance of the specific response to obtain an attractive reinforcing US or to avoid an aversive US. The other conditioned stimulus, to which the lack of the specific response is accepted as correct performance, is termed the CS−. By analogy to the term "go-left, go-right differentiation" we prefer to use "go, no–go differentiation".
experimental groups described in these studies, a conditioned inhibitor compound (38) was used as the CS− in differentiation learning. In all cases differentiation learning was easier with noise as the CS+ and light as the conditioned inhibitor, than when light served as the CS+ and noise as the conditioned inhibitor (7–9, 30, 31).

This review indicates that nearly all relevant experimental data showed easier differentiation learning when the more salient stimulus from a pair was used as the CS+, intensity being one of the factor determining the saliency of discriminative stimuli. The aim of the present study was to test the relative saliency of CSI consisting of either larger or smaller decreases in the background white noise intensity level. The comparison of the difficulty of go, no–go differentiation training in which either one or the other conditioned stimulus from a pair was the CS+ seemed an appropriate method to examine the issue of relative saliency.

Two opposite predictions concerning the saliency of CSI consisting of changes in the background noise or illumination levels have been proposed. According to the classical Pavlovian (25) and Hullian (11) statements, the higher the absolute intensity of the CS the greater strength of the evoked conditioned response. On the other hand, the “discrimination” interpretation of stimulus intensity effects by Perkins (26) and Logan (21), as well as Champion’s (4) “modified Hullian theory”, postulated that the effectiveness of the CS varies with the degree of physical energy change regardless of its direction. Experimental data are equivocal (see 3, 41). In most experiments, increases of background intensity level evoked conditioned responses of greater strength than the equivalent decrease in intensity. On the other hand, the larger the decrease of the background noise or illumination level used as the conditioned stimulus, the greater the strength of the elicited response (4, 14, 23, 34, 41). On the basis of these data, easier differentiation learning with the greater decrease of the background white noise intensity level as the CS+ and the smaller decrease as the CS− was expected than in the arrangement where the same decreases of the white noise possess opposite signalling properties.

MATERIAL AND METHODS

The subjects were 32 experimentally naive, male hooded rats, approximately 3 mo old at the beginning of the experiment. The experiment was conducted in four identical operant chambers, each having an electrifiable grid floor, a single bar on one of the walls and a food-tray under it. Additional equipment providing for automatic programming and recording of the experiment was located in an adjoining room.
Before the experiment, the rats were randomly distributed into two experimental groups, 16 subjects in each. The experiment was conducted in four replications, two squads each. In each squad two rats were assignet to Group I and two to Group II. The operant chambers were counter-balanced between groups. One rat from Group I was lost due to a middle-ear infection, and data from the earlier stages of its training were not used in the statistical evaluation of the results.

Prior to any training, the rats were reduced to 75% of their ad lib. body weight and maintained at that weight on a 24 h feeding rhythm during the entire experiment. Daily portions of food were given immediately after each experimental session. Preliminary training consisted of initial presentation of 40 “free” 45 mg food pellets on a 1-min VI schedule (magazine training), followed immediately by a period with a continuous reinforcement schedule until 120 food pellets were delivered in a single session. Starting from the second day of the experiment until the end of training, a white noise of 80 dB (0.0002 dyne/cm²) was present at all times in the experimental space. After the preliminary training, seven daily 2-h sessions of bar-pressing under a 2.5-min VI food reinforcement schedule were introduced.

**Table I**

Design of the experiment.

<table>
<thead>
<tr>
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<th>P-day</th>
<th>CER training (8 sessions)</th>
<th>Differentiation training (30 sessions)</th>
</tr>
</thead>
</table>
| Group I | 4×80–70 CS  
4×80–60 CS | 4×80–70 CS and US        | 4×80–70 CS and US  
4×80–60 CS no US |
| Group II | 4×80–60 CS  
4×80–70 CS | 4×80–60 CS and US        | 4×80–60 CS and US  
4×80–70 CS no US |

The outline of the experiment is shown in Table I. Following acquisition of stable on-going bar-pressing behavior for food, sporadic CS were introduced. The CS was a 3-min period of decreases of the 80 dB level of white noise intensity to either 70 dB or 60 dB. On the Pretest day (P-day), which followed the preliminary training, both CS were presented, four times each, in a predetermined order and without the shock US. Then the classically conditioned defensive response was established during 8 days of CER training. For Group I the CS was a decrease of the 80 dB background white noise to 70 dB (80–70 CS⁺), for Group II the CS was a decrease of the 80 dB background noise to 60 dB (80–60 CS⁺). The CS⁺ of both groups were presented four times during the 2-h session, with onsets at 18.5, 53.5, 74.5 and 92.0 min after
the beginning of the session. During the CER and further differentiation training each CS+ action was terminated with 0.5 s of inescapable scrambled electric shock of 1-mA intensity.

After completing CER training, differentiation learning was conducted for 30 days. For Group I the CS− was a decrease of the 80 dB background white noise to 60 dB (80–60 CS−), for Group II the CS− was a decrease of the 80 dB background noise to 70 dB (80–70 dB CS−), and the respective CSi− were presented four times during the 2-h session with onsets at 29.0, 43.0, 61.0, and 106.0 min after the beginning of the session. The presentations of the CS− were not accompanied by the nociceptive US stimulus, whereas the presentations the CS+ were given with shock US and in the same time intervals as during the CER training.

The magnitude of the CER was measured by computing “suppression ratio” described by Annau and Kamin (1). The ratio is $B/(A + B)$, where $B$ represents number of bar-presses emitted during the 3-min action of CS, and $A$ was number of responses during the 3-min immediately before the CS onset. Suppression ratios were computed for each presentation of the CS independently. Additionally, daily suppression ratios were computed for each rat by summat ing responses emitted during the appropriate intervals for each of the four positive and the four negative trials.

Different statistical methods were used to evaluate changes in bar-pressing rate evoked by presentations of the CSi. The overall information on the course of learning was provided by the median daily suppression ratios estimated for the type of trials (CS+ or CS−) and the group of subjects independently. For a given group of subjects and the type of trials, the numbers of bar presses before and during presentations of the CS during the session (daily $A$ and daily $B$ scores) were compared and differences estimated by the Wilcoxon two-tailed test (5). The results of these analyses provided information on the suppressive properties of the CS+ or CS− on each consecutive training session. Further, for each individual rat in a given session, the amount of overlapping in suppression ratios between positive and negative trials was estimated using the Mann–Whitney $U$ statistic. Assuming that suppression ratios for four positive and four negative trials are independent “samples”, in the case of no overlap between these samples, the Mann–Whitney $U$ statistic has a value of 0 and the probability of occurrence of such behavior in a single session by chance is as small as $P < 0.028$ (two-tailed test). This measure is especially useful, when both CS+ and CS− change the response rate in the same direction but to different degrees. Estimation of the between groups differences was done by routine methods.
RESULTS

Pretest day. The general pattern observed during the P-day involved the decrease of the response rate when the background white noise intensity level decreased (Fig. 1). However, as seen from Table II, comparisons of bar presses emitted before and during each presentation of the to-be-CS showed that only in one case (out of 16) this decrease was statistically significant. Similar comparisons based on daily A and B scores showed that in the Group I the decreasing effect of the 80–60 CS was significant at the $P \leq 0.05$ level and the 80–70 CS did not significantly change the response rate. In the Group II the decreasing effect of the 80–70 CS was significant at the $P \leq 0.01$ level. Comparisons of the numbers of responses for corresponding time intervals on the day preceding introduction of the changes in the 80 dB background white noise intensity (the Dummy-day) did not showed any significant changes in response rats.

CER acquisition. The median daily suppression ratios presented in Fig. 1 indicate that CER acquisition was more rapid and the resulting suppression of the on-going bar-pressing behavior more pronounced in Group II (80–60 CS) than in Group I (80–70 CS). This observation was confirmed by analysis of variance (mixed design, Type I, 20). The main effect of groups was significant ($F(1/29) = 11.45, P < 0.005$) as was the effect of days of training ($F(7/203) = 27.65, P < 0.001$), whereas their interaction did not reached significance ($F(7/203) = 1.88, P < 0.1$). Duncan tests showed that the two experimental groups differed on the 4th ($P < 0.05$), 5th and 6th ($P < 0.01$) as well as on the 7th ($P < 0.05$) days of CER training, while differences on other days were not significant. The Mann–Whitney test revealed between group differences in daily suppression ratios on the 2nd, 5th, and 7th CER training days, each at the $P < 0.02$ level.

TABLE II

<table>
<thead>
<tr>
<th>White noise intensity (dB)</th>
<th>Consecutive presentations</th>
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<tr>
<td></td>
<td>1</td>
</tr>
<tr>
<td><strong>Group I</strong></td>
<td></td>
</tr>
<tr>
<td>80-70</td>
<td>+4.0</td>
</tr>
<tr>
<td>80-60</td>
<td>+1.5</td>
</tr>
<tr>
<td><strong>Group II</strong></td>
<td></td>
</tr>
<tr>
<td>80-60</td>
<td>+1.0</td>
</tr>
<tr>
<td>80-70</td>
<td>0</td>
</tr>
</tbody>
</table>

* $P < 0.05$, Wilcoxon two-tailed test.
Fig. 1. Median daily suppression ratios during the Dummy day (D), the Pretest day (P), CER training and differentiation learning in Group I (upper part) and in Group II (lower part). Circles indicate the 80–70 stimuli and the triangles show the 80–60 stimuli. Closed figures denote stimuli presented with US and open figures represent stimuli presented without US.

The numbers of bar presses emitted in 3 min periods before and during each consecutive presentation of the CS (the A-B index) were compared by the Wilcoxon test. The 80–70 CS+ significantly suppressed the on-going behavior initially on the 1st trial of the 3rd CER training day, after eight pairings with the US. The 80–60 CS+ elicited significant suppression one day earlier, after four pairings with the US. This test showed that during the 32 trials of the CER training the 80–70 CS+ significantly suppressed the bar-pressing on 16 trials, whereas the 80–60 CS+ did so on 27 trials.

All of these analyses indicated greater response strength in Group II than in Group I. However, neither Duncan tests, based on daily suppression ratios, nor the comparisons of the suppression ratios calculated for each trials with the Mann–Whitney test showed any differences between the two groups on the 8th CER training day.

Acquisition of the CER was related to the overall decrease of the on-going behavior (Fig. 2). Analysis of variance based on daily A scores indicated a significant day effect \( F(8/261) = 14.93, P < 0.001 \), whereas the group effect and the interaction were not significant. Duncan tests revealed that daily A scores on the 2nd–8th CER training days were lower then on the D-day, P-day and the 1st CER day (in each case
The lowest level of the on-going behavior was observed in Group I on the 6th CER day and in Group II on the 3rd CER day. Then small and insignificant recovery of the bar-pressing behavior was noted in both groups.

Fig. 2. Median number of bar-press responses per minute emitted in pre-CS periods during Dummy day (D), Pretest day (P), CER training and differentiation learning in Group I, (upper part) and Group II (lower part).

*Differentiation training.* Changes in the bar-pressing rate before, during, and after the first presentations of the CS+ and the CS− at the very beginning of differentiation training are depicted in Fig. 3. As seen, the first presentation of the CS− evoked significant suppression in both groups (A-B index, \( P < 0.01 \) in each group, Wilcoxon test). The statistical analyses indicated that in Group I the first presentation of the 80–60 CS− evoked similar suppression as observed during the preceding presentation of the 80–70 CS+, whereas in Group II the 80–70 CS− evoked smaller suppression that the 80–60 CS+ (\( P < 0.05 \), Wilcoxon test). Inspection of Fig. 1 showed that the suppressing effects of the CSi− were maintained throughout the entire duration of differentiation training. Comparisons of the daily A and B scores indicated that the CSi+ suppressed the on-going behavior on each day of differentiation training in both groups. Similarly, the 80–60 CS− suppressed bar pressing during all sessions except for one day, and the 80–70 CS− evoked the same effect on each day of differentiation training. Further, between group
comparisons of the daily suppression ratios observed during CSi+ presentations showed no difference in any day of differentiation training. Similar comparisons for CSi- presentations revealed that the 80–60 CS- suppressed the on-going behavior more than the 80–70 CS- on the 4th ($P < 0.02$) and the 28th ($P < 0.05$) days of differentiation training only (Mann–Whitney $U$ test).

As seen, none of these analyses showed any clear-cut difference in the course of differentiation training between the groups compared. Since all conditioned stimuli exerted similar effects on bar pressing behavior, the magnitudes of suppression ratios on positive and on negative trials were compared for each session and rat independently, using the Mann–Whitney $U$ test. Thus, out of 480 values of the $U$ statistic estimated for Group I only 38, i.e. 7.9%, showed that CS+ presentations suppressed bar pressing significantly more than the CS- presentations. The same estimations for Group II showed: 450 $U$-tests, 65 cases i.e. 14.4% with $U = 0$ scores. The individual variability in the number of sessions having no overlap in suppression ratios on positive and on
negative trials was similar in both groups. However, as seen in Fig. 4 most subjects from Group I were characterized by small numbers of such sessions, whereas more sessions with $U = 0$ values were typical for subjects from Group II. The two curves presented in Fig. 4 differed statistically ($P < 0.05$, Smirnov two-tailed test). Accordingly, the method based on the estimation of the amount of overlapping suppression ratios between positive and negative trials for each individual rat and session showed that go, no–go differentiation with 80–70 CS$^+$ and 80–60 CS$^-$ was less efficient than this with 80–60 CS$^+$ and 80–70 CS$^-$. 

![Fig. 4. Cumulative percentage of subjects from Group I (solid line) and Group II (broken line) which perfectly discriminated between CS$^+$ and CS$^-$ in indicated number of sessions.](image)

In the course of differentiation training, on–going bar pressing recovered to values observed during the D-day session. The daily $A$ scores were summed in blocks of 5 consecutive sessions (Block I: D-day, P-day, 1–3 CER days; Block II: 4–8 CER days; Block III: 1–5 Differentiation days; and so on) and compared. Analysis of variance showed a block effect ($F(7/203) = 5.83$, $P < 0.001$) with the group effect and the interaction not significant. Duncan tests showed that during the second half of differentiation training the on–going bar pressing rate was greater ($P < 0.001$) than during the end of CER training and the beginning of differentiation (Blocks II and III).

**DISCUSSION**

The results of the present experiment supported the notion that in the case of stimuli less intense than the background level the amount of change and not the absolute intensity is the main parameter determining the strength of conditioned responses. This effect was evident already during the CER training, which was more rapid with the 80–60 CS$^+$ (Group II) than with the 80–70 CS$^+$ (Group I). Similar results
were obtained in a previous study in which effectiveness of 70-50 and 70-60 conditioned stimuli for acquisition and performance of the bar pressing avoidance in cats were compared (41).

After introduction of negative trials, substantial generalization from CS+ to CS− was observed in both groups. However, during the first presentation of the CS− differences between groups emerged. In Group I the 80-60 CS− suppressed the on-going behavior with the same strength as the 80-70 CS+, whereas in Group II the 80-70 CS− evoked smaller suppression than the 80-70 CS+. These differences were maintained during further differentiation training as indicated by the numbers of sessions in which suppression ratios to the CS+ presentations were significantly lower than to the CS− presentations.

In CER experiments with stimuli consisting of the onset of white noise it has been shown that generalization was greater from a less intense CS+ to a more intense CS−, than from the more intense CS+ to the less intense CS− (13, 39). Similarly, the introduction of a new CS+ after training of the CER with one CS+ resulted in more pronounced suppression when the new CS+ was more intense in comparison with the previous one, than vice versa (44). These data are in full agreement with the classic Hovland experiment showing more generalization from weaker to stronger stimuli than vice versa (10). However, this statement is valid for stimuli consisting of onset (or increase) of the physical energy impinging on subject’s perceptive surface. In the case of stimuli consisting of a decrease in physical energy, more generalization from smaller to greater change in the background intensity level was observed in the present study. Thus, not the absolute intensity, but the relative saliency of the stimuli is the main factor influencing the amount of generalization. Both for stimuli more or less intense than the background, the generalization is greater from the less salient conditioned stimulus to the more salient stimulus than generalization from the more to the less salient stimulus.

The generalization between CS+ and CS− must be overcome in the course of differentiation training. In the introductory section to this paper, numerous experiments were mentioned showing that with the same pair of conditioned stimuli, the differentiation training is easier when CS+ is more salient than CS− and more difficult with the opposite relation of CS+ and CS− saliency. The present experiment indicates that differentiation training with 80–60 CS+ and 80–70 CS− is more efficient than that with 80–70 CS+ and 80–60 CS−. This finding shows once again that a greater decrease in background noise level is a more salient stimulus than a smaller decrease.

Collectively, the present paper is in agreement with the notion that
the concept of stimulus saliency is more general than the Pavlovian and Hullian notions, or their contemporary modifications, concerning stimulus intensity effects on the strength of the conditioned response.

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