STIMULUS INTENSITY EFFECTS ON ACUTE EXTINCTION OF THE CER IN RATS

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Abstract. Two groups of 9 rats were trained in the conditioned emotional response (CER) consisting of suppression of food-motivated behavior as a consequence of the pairing of white noise with unavoidable shock. One group was trained and then extinguished with an 80 dB white noise value and the other with the 50 dB white noise intensity as the conditioned stimulus (CS). The CER acquisition was faster with the more intense CS, however, on the last training day, conditioned suppression reached the same asymptotic level in both groups. Then an acute extinction procedure was introduced, wherein the CS was presented only once a day and lasted continuously until the end of the session with no US presentation during this period. This procedure was repeated over several consecutive days. During the first prolonged CS action, CER extinction was more rapid in the 50- than in 80-dB group. However, on the next extinction day the amount of suppression was less with the more intense CS. The results were discussed in terms of CS intensity effects on learning and performance of the conditioned response.

INTRODUCTION

In a number of studies, the positive effect of the conditioned stimulus (CS) intensity on the magnitude of both classical and instrumental conditioned responses (CRs) has been observed (2, 6–9, 14–18). Typically, more pronounced stimulus intensity effect has been observed in within-Ss than in between-Ss comparisons (5).
However, when extinction measures were taken as indices of CR strength, inconclusive results were obtained. Most studies of CS intensity effects on extinction measures have been factorial design experiments, wherein the rate of CR extinction as a function of CS-intensity in acquisition and extinction periods was independently investigated. These experiments involved changes of the stimulus values, and the results reflected mainly stimulus generalization decrement effects (3, 4, 9, 10). Similarly, no effects of stimulus intensity on extinction parameters were obtained with between-Ss design experiment (12). This discrepancy in experimental results, which depend on whether CR acquisition or CR extinction is examined, might mean that CS intensity affects both of these processes in different ways. It is, however, also likely that experimental designs have been inadequate to reveal the effects of the stimulus intensity on CR extinction, or else the data analysis was superficial. Most of the authors took into account either the total number of trials until the extinction criterion was reached, or response strength during selected block of trials, having neglected the possible differences in the course of CR extinction depending on the CS intensity.

We view extinction as an active learning process in which the previously established positive correlation between the CS and the reinforcing event or outcome is transformed into a negative correlation (11). It follows from this hypothesis that the conditioned response (CR) strength measured during a series of extinction trials is confounded by the two opposite effects of CS intensity. The first effect is due to resistance to extinction of the previously established excitatory CR, and the stronger CS the greater such resistance. If CS intensity has an effect on acquisition and stabilization of the excitatory CR, the same parameter ought to have similar effects on acquisition of the inhibitory CR. Thus, the second effect of CS intensity that may be found in a series of extinction trials is related to the positive influence on acquisition and stabilization of the new inhibitory properties of the CS.

On the basis of the above considerations it may be expected that the strength of the excitatory conditioned response will show different relations to CS intensity depending on the stage of extinction. Therefore, the major aim of the present study was to analyse changes of CER strength on consecutive presentations of the CS subjected to extinction.

**MATERIAL AND METHODS**

The Ss were 18 experimentally naive, male hooded rats, approximately 3 mo old at the beginning of the experiments. 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 experiments was located in an adjoining room.

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 pallets on a 1-min variable interval (VI) schedule (magazine training), followed immediately by a period with a continuous reinforcement schedule until 120 food pellets were delivered in a single session. After this training, five daily 2-h sessions of bar-pressing under a 2.5-min VI food reinforcement schedule were introduced. Following stable on-going bar-pressing behavior for food, a sporadic CS was introduced. The CS was a 3-min period of white noise of either 80- or 50-dB intensities, depending on the group. On the Pretest day (P-day), which followed the preliminary training, the CS was presented alone, while on the next five sessions it terminated with 0.5 s of unescapable electric shock of 1-mA intensity. The CS was presented four times during a 2-h session with onsets at 10.5, 49.0, 59.5 and 101.5 min after the beginning of the session. After 5 days of CER acquisition, an acute extinction procedure was introduced, wherein the CS was given at 10.5 min of the session and remained on until the end of the 2-h session with no US presentation during this period. This procedure was given over eight consecutive days.

The magnitude of the CER was measured by computing the “suppression ratio” described by Annau and Kamin (1). The ratio is $B/(A + B)$, where $B$ represents the number of bar-presses emitted during the 3-min period of the CS and $A$ represents the number of responses during the 3-min period immediately before the CS onset. For each subject and presentation of the CS on the P-day or on the CER acquisition sessions, suppression ratios were computed independently. Additionally, daily suppression ratios were calculated by suming numbers of responses emitted during all 3-min actions of the CS and in the 3-min periods immediately prior to consecutive CS onsets of a given CER acquisition session. During extinction sessions suppression ratios were computed for each consecutive 3-min period of the prolonged CS presentation and, in each case, the number of responses emitted immediately before CS onset was used as the $A$ value in the formula.

**RESULTS**

The first presentation of the 50 dB white noise value on P-day did not have any significant effect on the on-going bar-pressing behavior. On the other hand, the 80 dB stimulus produced a statistically significant
reduction of response rate when compared with the 3-min period preceding the first pretest trial ($P < 0.05$, Wilcoxon matched pairs two-tailed test). During the following presentations of the 50- or 80-dB white noise intensities, a tendency to increase bar-pressing rate was observed, although this effect was not significant (Table I).

**Table I**

<table>
<thead>
<tr>
<th>White noise intensity (dB)</th>
<th>Consecutive presentations</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
</tr>
</thead>
<tbody>
<tr>
<td>80</td>
<td>+2.0*</td>
<td>-2.0</td>
<td>0</td>
<td>-7.0</td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>-0.5</td>
<td>+0.5</td>
<td>-0.5</td>
<td>-1.5</td>
<td></td>
</tr>
</tbody>
</table>

* $P < 0.05$, Wilcoxon two-tailed test.

The CER acquisition was more rapid with the more intense CS (Fig. 1). Comparisons of the rate of response before and during each CS presentation using the Wilcoxon test showed that the first significant suppression of the on-going bar-pressing behavior during the 80 dB CS occurred on the third CER acquisition trial, and on the fifth trial with the 50 dB CS. On all of the following trials during the acquisition

![Fig. 1. Suppression ratios computed for consecutive CS presentations on P-day, the five acquisition days, and during the first 3-min periods of CS action on the eight extinction days. Squares represent the group trained with the 80 dB CS, and triangles indicate the group trained with the 50 dB CS. Filled in symbols denote the CS followed by shock, while open signs show when the CS was not associated with shock.](image-url)
period, the CSi produced a significant reduction in the response rate. The greatest conditioned suppression was observed on the third day of CER training in the group having the 80 dB white noise as the CS and on the fourth day in the group trained with 50 dB CS. The lowest mean daily suppression ratios in both of these groups were 0.054 (md — 0) and 0.108 (md — 0.120), respectively. The largest differences in the amount of conditioned suppression appeared between groups on the second and third days of CER acquisition ($P < 0.02$ and $P < 0.05$, respectively, Mann–Whitney two-tailed test). On the fifth and last day of the CER acquisition training, daily suppression ratios were nearly at the same level in both groups.

Despite of the finding that on the last acquisition day there was no significant between-groups difference in the amount of conditioned suppression, in the first extinction session, CER extinction was more rapid with the 50- than with the 80-dB CS (Fig. 2). The significant

![Fig. 2. The course of CER extinction on the first two extinction sessions. Suppression ratios are presented for 10 consecutive 3-min periods of the prolonged CS action. Squares represent the 80 dB group, triangles indicate the 50 dB group; solid lines for the first extinction trial and dashed lines, the second extinction session.](image)

between-groups differences were observed in the 3rd, 4th and 5th 3-min periods of the first prolonged CS action ($P < 0.02$, $P < 0.05$ and $P < 0.025$, respectively, Mann–Whitney two-tailed test).

The variability in the length of the period of bar-press suppression during the first and the second extinction sessions are illustrated by Fig. 3 and 4. The graphs show a number of responses emitted by each rat in 1-min intervals during 6 min before and during the 30 min after
the CS onset on the first and the second extinction days independently. The extinction criterion was defined as the first minute of CS action on which a number of responses was equal to or greater than the mean number of bar-press emitted during 3 min before the CS onset. During the first extinction session, the CER was extinguished after 20 min of the CS action in the 80 dB group, and after 3 min in the

![Graph showing the course of CER extinction in individual subjects trained with the 80 dB CS during the first (left side) and during the second (right side) extinction sessions.](image-url)

Fig. 3. The course of CER extinction in individual subjects trained with the 80 dB CS during the first (left side) and during the second (right side) extinction sessions.
50 dB grup (in both cases group median values). In the course of this extinction session bar-press suppression completely disappeared and both groups converged to an asymptotic suppression ratios close to 0.50. As seen from Fig. 3 and 4, the return to normal response rate typically had character of a switching phenomenon. At the beginning of the second extinction session in both groups partial restoration of the CER occurred, but this time the conditioned suppression of the on-going bar-pressing behavior was greater and lasted longer with the less intense CS (see Fig. 2–4). On this trial, however, the significant difference in the amount of the conditioned suppression was observed between groups only during

Fig. 4. The course of CER extinction in individual subjects trained with the 50 dB CS during the first (left side) and during the second (right side) extinction sessions.
the first 3-min period of CS action \( (P < 0.05, \text{ Mann-Whitney test}) \). On the second extinction session the return to the normal response rate occurred much faster in both groups than during the first extinction session, namely after 2 min of CS action in the group with more intense CS and after 5 min in the group with less intense CS. In none of the subsequent extinction sessions was the on-going bar-pressing behavior suppressed by the CS so that significant between-groups differences observed in conditioned suppression did not emerge.

**DISCUSSION**

In the present experiment, as in other studies (6–9, 14, 18), a significant effect of the CS intensity on CER magnitude during training of the suppressing properties of the CS was observed. The between-groups differences related to CS intensity disappeared when suppression ratios reached asymptotic values. Similarly, CS intensity exerted different effects on suppression ratios depending on the stage of extinction of the previously established CER. Thus, only with the appropriate experimental desing may CS effects on the CR strength measured during a series of extinction trials be discovered. In the present experiment the method of acute extinction was employed, which consists in presentation of the same CS as used in previous training many times in succession, each without the reinforcing event or outcome. Additionally, the CS duration was drastically prolonged enabling the measure of suppressing properties of the CS during consecutive periods of its action.

On the basis of the results obtained by Stein, Sidman and Brady (13) it was expected that restoration of the on-going bar-pressing would be observed during the prolonged action of the CS due to competition between food-motivated behavior and fear-evoking properties of the CS. These expectations were confirmed, however, on the first extinction session suppressing properties of the 80 dB CS disappeared more slowly than those of the 50 dB CS. On the other hand, changes in the strength of the conditioned fear response, which occurred during the first extinction session were more persistent in the 80- than in the 50-dB group and restoration of the CER observed at the beginning of the second extinction session was much smaller with the 80- than with the 50-dB CS intensity.

Many experiments which investigated the CS intensity effect on response strength measured in extinction were dealing with the question of whether CS intensity affects learning, performance or both. The attempts to separate the CS intensity effect on learning from this on performance yielded negative results (3, 4, 9, 10). The results obtained in our
Experiment seemed to confirm CS intensity effects both on learning and performance. That is, because of the lack of significant between-groups differences in the magnitude of conditioned suppression on the two last days of the CER acquisition, the differences in the rate of the CER extinction, which appeared between groups on the first extinction session, seem to reflect the effects of the CS intensity on performance of the previously established CR. However, if one assumes that CS intensity affects only performance we should have obtained stronger suppression of the on-going behavior in the 80 dB group on the second extinction session as well. The weaker conditioned suppression observed after onset of the stronger CS on the second extinction session indicates the positive effect of the CS intensity on the learning of the new inhibitory properties of the CS, which in the case of the Estes–Skinner CER technique are manifested by undisturbed bar-pressing for food.

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REFERENCES


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