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Habituation of a "blocked" stimulus during Pavlovian conditioning

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A CER study with rats demonstrated that a series of CS-US pairings, during the compound phase of a "blocking" procedure, may leave the CS with tendencies that are less response suppressive than when the CS is experimentally novel. The results are discussed in the context of prior studies that have reported a loss of CS associability under similar conditions and in relationship to theories of habituation and learned irrelevance.

Studies of Pavlovian conditioning are generally instigated by a concern with the associative processes, whereby a CS may come to act as a signal for the presence (or absence) of a US. In this concern investigators have been less sensitive to the degree to which habituation processes, whereby a CS may come to lose its initial effectiveness, are also importantly involved. The thrust of the present study is that during a so-called blocking procedure (e.g., Kamin, 1969) in which little associative learning is produced by CS-US pairings, CS habituation may be readily apparent.

The investigation follows the related work of Mackintosh and his colleagues (e.g., Dickinson, Hall, & Mackintosh, 1976; Mackintosh, 1971; Mackintosh & Turner, 1971). In the customary blocking design employed in their work, one CS was consistently paired with a US; then, during the blocking phase proper, a compound of that CS and a new CS was paired with the same US. With a variety of comparisons, it was demonstrated that the added CS was rendered less "associable" as a result of the compound trials. The CS, for example, acquired less associative strength on subsequent compound trials with a more intense US (Mackintosh & Turner, 1971) or acquired less inhibitory tendencies as a result of subsequent conditioned inhibition training (Mackintosh, 1971) than did a novel CS. The present study involved a simpler assessment. It evaluated the immediate, postcompound-training response to the added CS in comparison with the response to the same stimulus of subjects that had not experienced the compound training. The data suggest that the loss of associability observed by Mackintosh and his colleagues is but one consequence of a more generally detectable habituation phenomenon.

The study, like the aforementioned investigations, was conducted in a conditioned emotional response (CER) situation. All subjects were trained to barpress for food reward and then received repeated pairings of a noise (N) and electric shock. After the development of consistent suppression of barpressing in the presence of N, half of the subjects received four reinforced trials in which N was accompanied by a visual stimulus (L), whereas the remaining subjects received no similar exposure to L. Finally, all subjects were tested to determine the degree of suppression of barpressing produced by L. Any differences attributable to L-shock association would presumably be in the direction of greater suppression of those subjects receiving the four reinforced compound trials. But, since the unconditioned response to a novel light is also a suppression of instrumental behavior (e.g., Leaton, 1976), the alternative difference of less suppression by those subjects receiving the compound exposures could reasonably be taken as indication of habituation produced by such exposures.

That such a habituation effect, sufficient to be detectable in the face of any counteracting effects of associative learning, has not previously been noted in studies using the blocking paradigm may be due to the common procedure employed (e.g., Mackintosh & Turner, 1971) of preexposing the subjects to the experimental CSs prior to any conditioning. Such preexposure, by itself reducing the unconditioned suppression to the CS that is added during the compound trials, may obscure the fact that the compound trials are also effective in producing such habituation. To evaluate this possibility, half of each of the aforementioned groups were given four nonreinforced presentations of the light and noise prior to any conditioning while the remainder were not.

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METHOD

Subjects

The subjects were 64 experimentally naive male albino rats purchased from the Charles River Breeding Company and approximately 160 days old at the start of training. They were housed individually with water available ad lib and maintained at approximately 75% of their preexperimental weights through limited daily feedings 30 min after each session. Sixteen subjects were assigned to each of four experimental treatments, eight in each of two complete replications.

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Apparatus

Training and testing took place in eight identical 24 x 21 x 19 cm operant chambers, each of which was enclosed in a 48 x 48 x 66 cm isolation box. The operant chambers were constructed of clear Plexiglas sides with adjoining aluminum end walls. The ceiling was frosted Plexiglas, and the floor consisted of 5-mm stainless steel rods spaced 1.9 cm apart. Each chamber had a food magazine recessed in the center of one end wall at floor level and a lever 2 cm to the left and 7 cm above the magazine. A .143-W 120-V houselight covered with a translucent plastic cap was mounted 15 cm above the grid floor over the food magazine; it served to provide a continuous low level of illumination. The ambient sound pressure level inside the chamber was maintained at 56 dB (re $2 \mu N/m^2$; General Radio Sound Pressure Level Meter, Model 1551, A scale) by the masking noise of a continuously operating ventilation fan.

The auditory CS (N) was a broad-spectrum noise that raised the sound pressure level to 72 dB. It was produced by a Foringer 1291 noise generator and was delivered through a 4-in. (10.16-cm) speaker mounted beneath the grid floor directly below the food magazine. The visual CS (L) was a general increase in chamber illumination. It was produced by one or two 3-W bulbs mounted above the frosted ceiling and powered by a 116-V or 140-V source (see Procedure). The US was a .5-sec 1.0-mA electric shock delivered through the grid floor via a Grason-Stadler E1066S shock scrambler.

Experimental events were controlled and recorded automatically via electromechanical equipment located in an adjoining room.

Procedure

Pretraining. All subjects were trained to barpress over 12 daily 1-h sessions. On Day 1 they were placed in individual chambers with eight .045-g Noyes pellets in the food tray and then reinforced with a similar pellet for each barpress. On Day 2, following 10 min of such continuous reinforcement, subjects were shifted to a variable interval (VI) 90-sec schedule of reinforcement that remained in effect throughout the remainder of the experimental sessions.

Conditioning and testing. The sequences of Pavlovian conditioning and testing for the four experimental groups are depicted in Table 1. All subjects eventually received 24 presentations of the noise CS paired with the shock US, and they were tested over four presentations of the light CS. The four groups were distinguished by whether they received four nonreinforced exposures to the light and noise CSs alone prior to noise conditioning (Groups L,N/NL+ and L,N/O) or not (Groups O/NL+ and O/O) and, orthogonally, by whether they received four reinforced exposures to the light in compound with the noise following noise conditioning (Groups L,N/NL+ and O/NL+) or not (Groups L,N/O and O/O). All trials, as designated in Table 1, were administered in daily blocks of four within 65-min barpressing sessions. The first trial uniformly began in Minute 10 of each session, with the remainder following at mean intervals of 15 min. Each CS presentation was 1 min in duration and when reinforced terminated with shock onset.

Table 1
Sequences of Conditioning and Test Trials for the Four Experimental Groups

Group	Pretest	Conditioning: Element	Conditioning: Compound	Posttest
L,N/NL+	4L,4N	24N+	4NL+	4L
L,N/O	4L,4N	24N+		4L
O/NL+		24N+	4NL+	4L
O/O		24N+		4L

Note–"+" indicates reinforced trials.

Among other procedural details, it may be noted that the two pretested groups were administered two nonreinforced exposures to L and N in balanced orders in each of two preconditioning sessions; during this time the nonpretested groups received equivalent 65-min sessions of barpress training only. The final light tests were administered to all groups on the day immediately following their last scheduled conditioning trials, that is, either after the last day of N+ training or after the single day of NL+ training. The two replications differed in two ways. First, in Replication 1 the noise CS was continuous, whereas in Replication 2 it was interrupted once per second. Second, in Replication 1 the light CS was of constant intensity throughout, involving a single overhead bulb at 140 V, whereas in Replication 2 it was of constant intensity prior to testing, using two bulbs at 116 V (judged to be of the same apparent brightness as the source in Replication 1), but was then increased in intensity in half of the test trials (in balanced orders) by illuminating the two bulbs at 140 V. Since there was no detectable effect within subjects of the two test lights used in Replication 2 and no notable difference between the two replications employing the different noise CSs, these variables were ignored in subsequent analyses.

Scoring and analysis. Percentage suppression scores were based on the number of barpress responses per minute during the 1-min CS (B) and during the 3-min period preceding the CS (A), according to the formula $(A - B)/A \times 100$. According to this measure, a score of 0 indicates no change in barpressing rate in the presence vs. absence of the CS, whereas 100% indicates complete suppression of responding during the CS.

Due to the skewness of the distributions of the percentage suppression scores, the central tendencies of the data are reported in terms of group medians and reliability assessed by nonparametric statistics. Wilcoxon's matched-pairs signed-rank test has been used throughout, with subject matching on the basis of experimental-chamber assignment within each replication.

RESULTS

All groups adopted sustained barpressing behavior on the VI schedule and, with the eventual introduction of noise-shock pairings, rapidly displayed near 100% suppression during noise presentations. Figure 1 presents the median daily percentages of suppression for each of the four groups over the course of the N+ trials. As may be seen, the only notable difference among the several groups during this common phase of training occurred on Day 1 of conditioning, when Groups O/O and O/NL+, which had received no prior exposure to the experimental CSs, suppressed substantially more than did Groups L,N/O and L,N/NL+, which had received four prior nonreinforced presentations of the noise CS as well as four nonreinforced presentations of the light. This overall difference between the pretested and nonpretested subjects on Conditioning Day 1 was highly reliable [$z(32) = 4.2$, $p < .001$], whereas there was no reliable difference between Groups O/O and O/NL [$T(16) = 40.5$, $p > .05$] or between Groups L,N/O and L,N/NL+ [$T(16) = 53$, $p > .05$] prior to their differential treatment.

On the single day of reinforced compound training that followed the noise conditioning for Groups L,N/NL+ and O/NL+, suppression was generally high, in accordance with that previously exhibited to the noise alone. It is potentially interesting that more suppression was

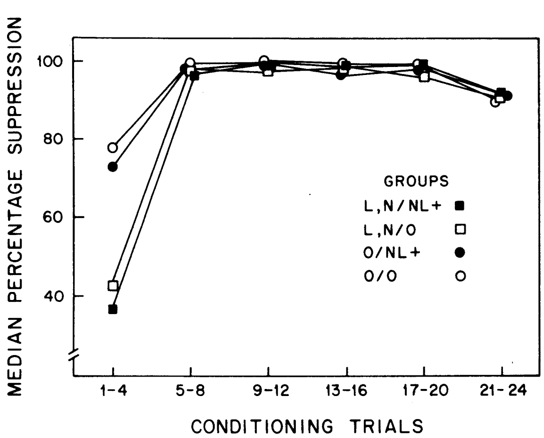

Figure 1. Median percentage suppression of each of the four experimental groups over the common phase of N+ conditioning.

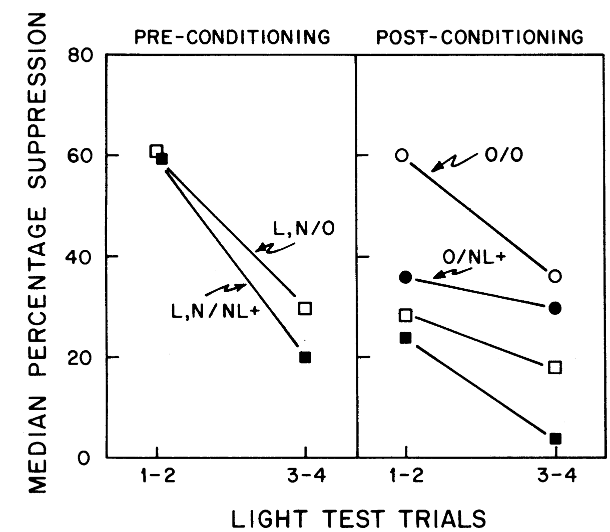

Figure 2. Median percentage suppression to the L stimulus preceding (left panel) and following (right panel) conditioning. Group labels designate the presence (L,N) or absence (O) of preconditioning stimulus exposure and the presence (LN+) or absence (O) of final compound training in conditioning (see Table 1).

observed in Group O/NL+ (median = 96.5%), for which the light was a novel stimulus, than in Group L,N/NL+ (median = 84.0%), which had previously been exposed to the light, but the difference did not approach statistical reliability.

The data of primary concern are the percentages suppression during the final light tests. Figure 2 presents the median such percentages for all four groups over successive blocks of two trials (right panel) and, for comparison, the similar median percentages for Groups L,N/O and L,N/NL+ during their preconditioning exposures to the light (left panel). The major finding was that in the postconditioning tests, Group O/NL+, which had received four reinforced compound trials with the light, suppressed less to this stimulus than did Group O/O, which had had no prior exposure to the light. This difference between the two groups was statistically reliable on the first trial block [$T(16) = 24.5$, $p < .05$], but no longer by the second trial block [$T(16) = 39$, $p > .05$].

As expected, the preconditioning exposures to the experimental CSs in Groups L,N/O and L,N/NL+ reduced the suppression observed on the postconditioning light tests in comparison with that seen in Groups O/O and O/NL+. The overall difference in suppression between the preexposed and nonpreexposed subjects during the final test session was highly reliable [$z(32) = 3.1$, $p < .002$]. With this reduction in overall suppression there was also less apparent effect of the compound trials: Although Group L,N/O suppressed more than did Group L,N/NL+, the difference on neither trial block was statistically reliable [$Ts(16) \geqslant 55$, $ps > .05$].

DISCUSSION

Exposure to a CS in pairings with electric shock during the compound phase of a blocking procedure appears to produce a CS-habituation effect that may be detected in various ways. In the present experiment such exposure produced a decrement in the suppression occasioned by an otherwise novel CS (the comparison of Group O/NL+ vs. Group O/O). In the studies of Mackintosh (1971) and Mackintosh and Turner (1971), such exposure diminished the ease with which the CS could subsequently be trained to signal the presence or absence of a US, that is, diminished the apparent "associability" of the CS.

Both of these decremental products of CS exposure are well known to follow from isolated preconditioning stimulus presentations. The decrease in suppression with simple stimulus exposure, as depicted in the left panel of Figure 2, has frequently been exploited in studies of habituation (e.g., Leaton, 1976). The decrease in associability that follows simple stimulus exposure is the so-called latent inhibition effect that has been demonstrated in a wide variety of aversive and appetitive conditioning situations (see Lubow, 1973, for review). The present study supports the notion that these two effects are also correlated products of at least certain instances of reinforced stimulus exposures.

That CS habituation during reinforced stimulus exposures is not unique to the blocking paradigm is indicated by the recent studies of Hall and Pearce (1979). In these studies (also in the context of CER conditioning), a CS initially paired with a weak but demonstrably effective US was subsequently retarded, in comparison with a novel stimulus, in developing association with a more intense US. Furthermore, analogous to the results of the present study, there was clear evidence of less suppression to a CS immediately following exposure in pairings with the weak shock than when the CS was experimentally novel.

A possibility that must be considered is that CS habituation, whether indexed in the waning of an initial response tendency or in a decrease in associability, occurs equally on all occasions of stimulus presentation, whether reinforced or nonreinforced and whether preceding or following some course of Pavlovian conditioning. Given the available data, such a possibility might be entertained with the further supposition that the habituation process is simply more or less obscured by specific excitatory or inhibitory response tendencies that can accrue with different CS-US relationships. Stimulus exposures to the CS alone preceding CS-US pairings (e.g., Lubow, 1973; the present experiment), to the CS in pairing with a weak US (Hall & Pearce, 1979), or to the CS in reinforced compound during a blocking procedure (e.g., Mackintosh & Turner, 1971; the present experiment) may all allow detection of habituation, because in these instances little or no associative learning with a US occurs to mask it.

However, current theoretical treatments of the loss of associability and the decrease in unconditioned response tendencies seen in the aforementioned cases, in apparent relationship to those in other Pavlovian contexts, have suggested a more active influence of the reinforcement contingencies upon the decremental processes involved. Wagner (1976), for example, has proposed that habituation may, in fact, occur to some degree in all instances of stimulus exposure but be more or less interfered with by different conditions of contemporaneous stimulation. According to Wagner's account, long-term habituation is the result of an association developing between the contextual cues and the habituating stimulus so that the latter comes to be "expected" in the experimental circumstance. Since it is known that posttrial distractors following conventional CS-US pairings can interfere with associative consolidation (e.g., Wagner, Rudy, & Whitlow, 1973), it is reasonable to assume that poststimulus events will similarly interfere with the context-CS association that is the presumed basis of habituation. Indeed, such interference effects have been demonstrated using relatively neutral poststimulus distractors in studies of response decrement (Wagner, 1976) and latent inhibition (Lubow, Schnur, & Rifkin, 1976). On this theoretical and empirical basis it might be anticipated that CS-alone presentations would maximize habituation, whereas following the CS by a Pavlovian US would produce lesser degrees of habituation, depending upon the effectiveness of the US as a distractor. Following the CS by a weak US, as was done by Hall and Pearce (1979), could reasonably be expected to interfere with CS habituation in comparison with isolated CS presentations (which the authors confirmed) but be less interfering than following the CS by a stronger US, as is more conventionally employed in CER studies. Similarly, following a CS by a US that is explicitly arranged to be well predicted, as was the case in the present investigation and the related blocking studies of Mackintosh (e.g., Mackintosh & Turner, 1971), may allow substantial CS habituation since "expected" USs are known (Wagner et al., 1973) to be less effective posttrial distractors than are more "surprising" USs.

Mackintosh (1975) has alternatively approached the data on loss of CS associability in terms of a theory of "learned irrelevance." On this account the loss of associability of the added CS in a blocking procedure (e.g., Mackintosh, 1971; Mackintosh & Turner, 1971) is due to its being experienced as redundant to a better trained predictor of the reinforcement that follows. However, as Hall and Pearce (1979) point out, this interpretation would not explain why a similar loss of associability occurred in their study when a CS was made uniquely predictive of a weak US. And, Mackintosh (1975, p. 290) has allowed that latent inhibition may also lie outside the scope of this theory, "to be explained perhaps, in terms of some simpler mechanism of habituation." The present data add force to the larger question of whether some "simpler" theory of habituation may not, in fact, accommodate the overall pattern of decreases in unconditioned responding, as well as associability, that have been observed in these instances of Pavlovian conditioning.

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