The effects of CS and US intensity on shuttlebox avoidance*

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The effects of CS intensity (70-, 80-, or 90-dB white noise) and US intensity (0.3- or 1.3-mA shock) on acquisition of shuttlebox avoidance were evaluated in a 2 x 3 complete factorial design. Acquisition was inversely related to US intensity. CS intensity was positively related to acquisition at the high US intensity but had no effect at the low US intensity. Intense CS may facilitate acquisition at high US intensities because they disrupt the incompatible response of freezing which occurs with high shock levels.

The shuttlebox task has been used extensively in the analysis of avoidance behavior, and many variables are known to alter acquisition of this task. As would be expected, shuttlebox acquisition is improved with more intense CSs (e.g., Myers, 1962) and prompt CS termination (Bolles, 1970; D'Amato, Fazzaro, & Etkin, 1968; Kamin, 1956). However, unlike some avoidance tasks, shuttlebox acquisition is inversely related to US intensity (Levine, 1966; Theios, Lynch, & Lowe, 1966).

D'Amato and his coworkers (D'Amato & Fazzaro, 1966; D'Amato, Fazzaro, & Etkin, 1968) have suggested that active avoidance acquisition is a function of both anticipatory responding and discriminability of the avoidance contingency. According to this hypothesis, acquisition of shuttlebox avoidance is inversely related to US intensity because more intense shock increases the occurrence of freezing and crouching, which are incompatible with active avoidance. A more intense CS is thought to increase discriminability of the avoidance contingency. Thus, a high level of anticipatory responding puts the S in an advantageous position to discriminate the avoidance contingency and a more discriminable avoidance contingency further facilitates acquisition.

Although many studies have investigated either CS or US intensity effects on shuttlebox avoidance, it is rather surprising that both CS and US intensity have not been investigated in the same study. From results cited above and analysis of the avoidance situation in terms of the D'Amato hypothesis, one might expect that CS

and US intensity effects would be independent, i.e., acquisition would be inversely related to US intensity at all CS intensities and would be positively related to CS intensity at all US intensities. The present study employed three CS intensity levels and two US intensity levels in a complete factorial design to determine if the CS and US intensity function independently in shuttlebox acquisition.

SUBJECTS

The Ss were 64 experimentally naive female Wistar rats, 120-150 days old and ranging in weight from 250 to 350 g. These animals were obtained from a colony maintained by the University of Washington Department of Psychology. The Ss were maintained on ad lib food (Purina Lab Chow) and water throughout the experiment. The colony room had a 17-h on, 7-h off light-dark cycle and a mean temperature of 72° F.

APPARATUS

The apparatus was a completely automated shuttlebox measuring 84 cm long, 12 cm wide, and 22 cm high. The plywood walls were lined with aluminum sheets, and a Plexiglas lid was crisscrossed with 2-cm black tape spaced 4 cm apart. The floor consisted of 0.32-cm stainless steel rods placed 1.5 cm apart (center to center). The floor was separate from the walls and pivoted at the center so that the weight of the animal as it crossed 5.0 cm past the center tilted the floor 3.0 cm at the end. A microswitch was opened or closed whenever the floor tilted. This microswitch led to a series of relays and timers for programming of the apparatus. A 15-W 120-V bulb, mounted 55 cm from the floor, provided general illumination. The shuttlebox was placed inside a 75 x 40 x 110 cm sound-attenuating box constructed of plywood lined with acoustical tile. A three-channel event recorder recorded the occurrence of the CS, US, and responses. All programming equipment was in an adjoining room.

The CS was generated by a Grason-Stadler Model 901B white noise generator and channeled through a relay to an 8-cm speaker centered 48 cm above the grid floor. The CS intensities of 3, 13, or 23 dB over the background noise of 67 dB were used. Thus, the three CS intensity levels were 70, 80, or 90 dB (± 1.5) at the grid floor. All sound level measures were taken with a General Radio Company sound level meter (Type 1551B).

A scrambled footshock could be delivered to the grid bars and walls by a Grason-Stadler Model E6070B shock generator. The US was either a 0.3- or a 1.3-mA footshock, as indicated by the dial setting of the shock apparatus.

PROCEDURE

The Ss were assigned randomly to one of the six groups immediately prior to training. All animals were run between 9 a.m. and 4 p.m. Four animals in the low US condition refused to escape and were later replaced so that $N = 10$ per group. Prior to receiving a single session of 100 acquisition trials, the Ss were allowed to explore the shuttlebox for 5 min. The intertrial interval was variable (20-150 sec), with a mean of 90 sec. The CS was presented for 10 sec and was followed by the US if no avoidance response occurred within the CS-US interval. The CS terminated immediately following an avoidance response and both CS and US terminated immediately following an escape response.

RESULTS

Figure 1 presents the mean percent correct avoidance in blocks of 10 trials for groups receiving one of three CS intensities and one of two US intensities. The figure indicates that more rapid acquisition occurs with the weaker US intensity. However, CS intensity appears to be positively related to acquisition at only the higher US intensity. These data were analyzed by a 2 by 3 by 10 complete factorial analysis of variance, with 10 repeated measures. This analysis revealed highly significant trials ($F = 43.70$, $df = 9/486$, $p < .001$), US ($F = 29.92$, $df = 1/54$, $p < .01$), and CS effects ($F = 5.67$, $df = 2/54$, $p < .01$). The US by Trials interaction was also significant ($F = 6.19$, $df = 9/486$, $p < .01$). The CS by US interaction approached statistical significance ($p < .10$).

Although the CS by US interaction was not significant, Fig. 1 suggests that the CS effect was greatest in those Ss receiving the more intense US. Therefore, separate analyses of variance were computed for each US level. These analyses of variance revealed a significant CS effect when the US was 1.3 mA ($F = 5.46$, $df = 2/27$, $p < .03$), but not when the US

*This research was partially supported by U.S. Public Health Service Grant NIMH-13673-03 to the University of Washington (Earl B. Hunt, principal investigator) and partially by a National Science Foundation traineeship to R. H. Bauer.

Fig. 1. Group mean percent avoidance responses in blocks of 10 trials for Ss receiving a 70-, 80-, or 90-dB CS and a 0.3- or 1.3-mA US.

was 0.3 mA ($F = 1.38$). Scheffé's tests between individual groups also revealed significant differences between Ss receiving the 70- vs 80-dB ($p < .01$) and 70- vs 90-dB ($p < .01$) CS with the 1.3-mA US, but there were no significant differences between the corresponding comparisons when the Ss received the weaker US. Therefore, the CS intensity effect is greater in the groups receiving the higher US.

The mean number of shuttlebox crossings during non-CS periods (intertrial responses) per block of 10 avoidance trials for the total 100 avoidance trials was analyzed by a 2 by 3 by 10 complete factorial analysis of variance with 10 repeated measures. There was a small but statistically significant reduction in number of intertrial responses across avoidance trials ($F = 2.28$, $df = 9/486$, $p < .05$). Ss trained with the more intense US also had somewhat fewer intertrial responses, but this effect was not statistically significant ($p < .10$).

DISCUSSION

Results of the present experiment clearly indicate the presence of an inverse relationship between US intensity and shuttlebox acquisition. These results are consistent with earlier reports (e.g., Levine, 1966; Theios et al, 1966) and provide further support for the hypothesis of D'Amato et al (D'Amato & Fazzaro, 1966). The fact that rats trained with the higher US exhibited somewhat fewer intertrial responses also supports this hypothesis. However,

manipulation of the avoidance contingency by varying CS intensity produced an acquisition effect at only the higher US intensity. Therefore, the CS effect appears to depend upon US intensity.

There appear to be two possible interpretations for the presence of a CS effect at the higher US intensity. First, 80- and 90-dB white noise are somewhat aversive to rats, such that they prefer weak shock to these white noise intensities (Campbell & Bloom, 1965). Thus, while intense CSs increase discriminability of the avoidance contingency, they may also increase anticipatory responding. This interpretation is supported by the recent report of Cicala & Ulm (1971) indicating that shuttlebox crossings are greater during presentation of a 10-sec 80-dB white noise that has never been paired with shock than during nonstimulus periods. A count of the avoidances on the first trial as a function of CS intensity in the present experiment showed that 0, 7, and 8 Ss of the 70-, 80-, and 90-dB CS groups, respectively, avoided on the first trial. Therefore, although the D'Amato hypothesis suggests that more intense CSs increase only the discriminability of the avoidance contingency, it appears that more intense white noise may also increase anticipatory shuttlebox responding. However, if more intense CSs simply increase anticipatory responding, then anticipatory responding should be increased at all US intensities, and hence CS intensity should be

positively related to acquisition at all US levels. Therefore, to account for the lack of a CS intensity effect on this basis, one would have to assume a ceiling effect for the low US groups, such that these Ss are learning at a maximum rate and intensity of the CS becomes irrelevant.

A more likely interpretation of the present results is that more intense CSs disrupt freezing and crouching which occur with higher footshock intensities. Blanchard & Blanchard (1969) reported that a single 0.4-mA footshock increases the incidence of crouching over nonshocked controls by 10% and that 1.0 mA increases crouching by 50%. Thus, low-intensity shock produces very little freezing and crouching, whereas intense shock produced marked crouching. In support of these results, Cicala, Ulm, & Drews (1971) reported a negative relationship between number of shuttle crossings and intensity of unavoidable and inescapable footshock. They also reported that crossings during presentation of an 80-dB white noise paired with unavoidable and inescapable footshock were greater than during prestimulus periods. Rats will also shuttle or turn a wheel up to 45% of the time during an 80-dB white noise or buzzer CS paired with approximately 1.0-mA shock in the absence of escape and/or avoidance contingencies (Bolles, 1970; D'Amato et al, 1968; Kamin, 1956). Thus, in spite of the fact that shuttling or wheel turning during a CS are not reinforced by shock termination, rats will respond at a high rate. Myers (1962) has also reported that a 65- or 85-dB buzzer elicits many more pseudoconditioned wheel-turning responses than does either an 80- or a 100-dB pure tone. As would be expected, rats trained with either intensity buzzer as the CS acquired the task more rapidly than rats trained with either tone intensity. Myers suggested that these results were due to the tendency of rats to freeze in response to the tone and to startle to the buzzer. Therefore, it appears that stimuli which suppress the tendency of rats to freeze result in more rapid avoidance acquisition when they are used as CSs. Since the shuttlebox task is thought to produce a maximum amount of freezing (Theios et al, 1966), the present results may be due to disruption of freezing by intense white noise. This interpretation also appears consistent with the recent analysis of avoidance behavior which suggests that rapid acquisition of active avoidance is due to suppression of ineffective species-specific defense reactions (Bolles, 1970). Stimulus events such as intense white noise or buzzers, which suppress the ineffective

defense reaction of freezing, would result in more rapid acquisition than those stimuli which do not suppress freezing. These stimuli, in conjunction with escape and avoidance contingencies, would result in rapid active avoidance acquisition.

McAllister, McAllister, & Douglass (1971) have recently suggested that the inverse relationship between shuttlebox avoidance and US intensity is not due to increased freezing but to an increase in conditioned fear of the apparatus cues. In this experiment, rats were first given 65 shuttlebox avoidance trials with a 1.6- or a 0.3-mA US and then trained to escape from one compartment of the shuttlebox to an adjoining safe compartment in the absence of the CS and US. Animals trained with the 1.6-mA shock were inferior in shuttlebox avoidance and had shorter escape latencies in the second escape task. These workers reasoned that if increased freezing is responsible for interfering with shuttlebox avoidance, then freezing should also interfere

with learning of the second escape task. However, since animals trained with the low shock learned the shuttlebox task to a higher level than those trained with the high shock, these results may indicate that some aspect of shuttlebox avoidance learning transfers negatively to learning of the second escape task.

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