Classical conditioning in the cat as a function of the CS-US interval¹

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Abstract

Classical leg flexion conditioning was studied in 24 cats using CS-US intervals of 250, 500, 1000 and 2000 msec., and 100 CS-US pairings. Learning, as evidenced by a significant positive slope of the function relating anticipatory flexion to trials, could be demonstrated only with the 250 and 500 msec. intervals. The 500 msec. CS-US appeared optimal, yielding 99% CRs at the end of 100 trials. Final response levels of 58%, 42% and 33% were recorded for the 250, 1000 and 2000 msec. groups, respectively. Comparison of these results with those of other studies of conditioning of overt responses in mammals (including man) indicates that, in the case of discrete adaptive responses, the functions relating CS-US interval to levels of conditioning are essentially similar. However, when diffuse preparatory responses are studied, other relationships may apply.

Introduction

Parametric studies of classical aversive conditioning of skeletal muscle responses in man suggest that the optimal CS-US interval is from 250 to 500 msec. (finger-withdrawal: Wolffe, 1930, 1932; eyelid: Bernstein, 1934; Reynolds, 1945; Kimble, 1947; Spooner & Kellogg, 1947; McAllister, 1953; Hanche & Grant, 1960; Jones, 1961).

Studies based upon infra-human mammals show less clear-cut agreement. Kappauf & Schlosberg (1937) reported 667 msec. as the optimal interval for conditioning "sharp inspirations" in the rat. McAdam (1962) reported 93% conditioned leg flexion in the cat, in from 45 to 150 trials using a 500 msec. CS-US interval and delayed conditioning, but no conditioned responses could be demonstrated within 150 trials when a 4-5 sec. CS-US interval was used in a trace conditioning paradigm.

Noble & Adams (1963) reported that a CS-US delay of from 4-8 sec. was optimal for conditioned gross body movements (primarily "bracing") in the pig, and Noble & Harding (1963) reported 2 sec. as the optimal interval for the development of conditioned body movements in the monkey. Both of these latter studies lacked an objective, instrumentally recorded measure of a discrete skeletal muscle response. Training was limited to a relatively small number of trials (30-60), and the level of CRs was low (ca. 50%).

The present study utilized objectively recorded anticipatory leg flexion, a discrete skeletal muscle response, as an index of conditioning. This provided data comparable to those obtained in man based upon the

development of comparable CRs, e. g., eyelid closure and finger withdrawal.

Method

The Ss were 24 experimentally naive adult cats, divided into four equal treatment groups receiving CS-US intervals of 250, 500, 1000 and 2000 msec. Intertrial intervals varied from 1 to 2 min., and were similar for all groups. A total of 100 CS-US pairings was given.

The S was placed in a canvas and lucite sling and suspended from the ceiling of a conditioning box inside a sound-proofed room. A plastic collar immobilized S's head and oriented it toward the CS, a 20/sec. flashing light placed 8 in. away, generated by a Grass PS-2 Photo Stimulator, set at intensity "1" (approximately 12,500 peak candles, flash duration = 10 μ sec.). The duration of the CS was 100 msec. longer than the CS-US interval. Electrodes attached to S's left hind paw delivered the US, a 150 v., 50 msec. pulse. Leg movements were measured using a line looped about the shocked foot and attached to a pulley which turned a potentiometer. A detailed description of this method of recording leg flexion is given elsewhere (McAdam, et al, 1962).

Prior to placement in the apparatus, Ss were given 30 mg of bulbocapnine hydrochloride² intramuscularly, which made them more tractable. On Day 1, Ss were given five presentations of the CS alone, followed by 30 CS-US pairings. On both Days 2 and 3, 30 CS-US pairings were given. On Day 4, 10 additional pairings were presented, yielding a total of 100 conditioning trials. At the end of the conditioning trials on Day 4, 10 presentations of the US alone were given to determine reaction time. All leg flexions initiated before the US, and those having a latency shorter than the shortest reaction time of US alone, although started after the onset of the US, were considered conditioned responses.

Results

Curves relating the incidence of conditioned leg flexion to trials are presented in Fig. 1. An initial analysis of variance gave a significant trial by groups interaction ($F=3.87$, $df=12/80$, $p<.001$). Additional analyses of variance were performed on the separate groups, indicating the trials effect to be significant for the 250 msec. group ($F=10.42$, $df=4/80$, $p<.001$) and for the 500 msec. group ($F=10.44$, $df=4/80$, $p<.001$). No trials effect could be detected for the 1000 msec. group ($F=1.54$, $df=4/80$, $p<.20$) or in the 2000 msec. group ($F=1.77$, $df=4/80$, $p<.20$). A Cochran-Cox test for simple groups within trials effects yielded a

Fig. 1. Percent conditioned leg flexions per block of 20 trials. $N = 6$ for each group.

$t'_{.05} = 2.06$, and a *Critical Difference* between cell means of 4.0 CRs. The trial blocks in which differences between the cell means exceeded the *Critical Difference* are presented in Table 1.

Discussion

Increasing frequency of CRs over trials is evidence that learning has occurred; this could be demonstrated only in the 250 and 500 msec. groups. The significantly higher level of conditioning in the 500 msec. group than in any other group at all levels of training, with the exception of the 2000 msec. group between trials 1-40, shows that conditioning was clearly superior when a 500 msec. CS-US interval was used. Thus, the present data, based on the cat, are concordant with most of the results of eyelid closure and finger withdrawal conditioning in humans.

The results based on 1 and 2 sec. CS-US intervals seem similar to those reported by Noble and Harding in the monkey, using the same interval. However, since no trend over trials could be detected in the present data for those intervals, and since none was reported (or apparent) in their study, some doubt is cast on the phenomena as representing learning *qua* learning.

There is a striking discord between the results of the present study and those reported on the pig by Noble and Adams at 0.5 and 1.0 sec. CS-US intervals, which may be due to the nature of the response being conditioned. Noble and Harding pointed out that they, and Noble and Adams, were probably working with a "diffuse preparatory response" rather than a "precise adaptive response" (Schlosberg, 1937). The response studied here, as well as eyelid closure and finger withdrawal, would fall in this latter category.

Table I

Interval	250	500	2000
250		12345	123
1000	4	12345	23
2000	5	345	

Conclusions

Similar optimal CS-US intervals are found for the formation of temporary S-R connections in both cat and man, when R is a "precise adaptive" (discrete skeletal) response. When other types of responses are studied, such as "diffuse preparatory responses," other optimal delay intervals may prevail.

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Notes

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