Spinal conditioning*

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A classical conditioning paradigm was performed on acute paralyzed cats which had undergone spinal section at T-12. Electrical stimulation to the superficial peroneal nerve served as the CS and to the ankle skin as the UCS. Responses from the deep peroneal motor nerve indicated in two separate studies that CS-UCS pairing produced response amplitude increases not seen in unpaired or CS-only controls. A third study indicated that long-lasting sensitization due to the UCS could not account for the results.

The effect of a classical conditioning paradigm on spinal reflexes has long been controversial. Numerous studies (e.g., Shurrager & Culler, 1940) have presented evidence indicating apparent spinal reflex "conditioning," while others (e.g., Kellogg, Pronko, & Deese, 1946) have been unable to show any effect. In many of the studies (e.g., Fitzgerald & Thompson, 1967) showing positive results, the data reveal marked variability, possibly due in part to the types of preparations used.

The major significance of the spinal conditioning paradigm lies in its use as a model system for the analysis of neural mechanisms underlying learning. To be maximally useful as a "model," the spinal preparation should be capable of undergoing conditioning and extinction in a single session, should be physiologically stable, and immobilized to prevent movement artifacts. The present preparation was developed to meet these criteria. A more detailed account of the preparation and experiments, complete results, and discussion will appear in a subsequent article in press (Patterson, Cegavske, & Thompson, 1973). Preliminary reports have appeared earlier (Cegavske, Patterson, & Thompson, 1972; Patterson, Cegavske, & Thompson, 1972; Thompson, 1971; Thompson, Patterson, & Teyler, 1972).

Experiment I was designed to test the effects of stimulus pairing on the hindlimb flexion response in an acute paralyzed spinal animal, utilizing a fixed intertrial interval (ITI) to include any cyclic or temporal effects. Experiment II excluded temporal or cyclic effects through the use of a variable ITI, and a CS-only control group was added to assess preparation stability.

METHOD

Subjects and Apparatus

In Experiments I and II, 20 and 25 adult male and female cats, respectively, of unknown origin were used.

In both experiments, a tape timer controlled ITI and gated stimuli. Standard Tektronix pulse and waveform generators coupled with a Grass S8 stimulator delivered the stimuli through isolation transformers. Gross nerve volley responses were recorded with bipolar electrodes and photographed from an oscilloscope for later analysis.

Procedure

Following ether anesthetization and endotracheal intubation, a T-12 spinal section was performed on each S. Subsequently, ether was discontinued, Flaxedil injected I.V. for complete paralysis, and artificial respiration begun. The left leg deep peroneal motor and superficial peroneal sensory nerves were then dissected free and tied to the distal electrode of each electrode pair. Each S was then tested with the UCS, a 500-msec train of 25-Hz 2-msec 50-V pulses to the skin of the left ankle, and Ss showing a UCR of less than .080 mV were discarded due to possible nerve damage. Intensity of the 750-msec CS, a train of 10-Hz 1-msec pulses, was set to give a response of about .020-.040 mV. In Experiment I, after a 60-min rest period, CS intensity was readjusted and Ss assigned randomly to paired or unpaired groups until there were 10 Ss per group. The paired group received 15 CS-alone, 75 paired, and 50 extinction trials, with CS and UCS coterminous at a 60-sec ITI. The unpaired Ss received similar training, except that CS and UCS were presented in a random sequence and separated by 30 sec.

Experiment II was similar to Experiment I, except that the ITI was randomized around 60 sec (50, 60, or 70 sec) in the paired and 30 sec (20, 30, or 40 sec) in the unpaired group, and an additional CS-only group of five Ss was given only CS presentations at an average 60-sec ITI.

RESULTS

Response amplitude to the first pulse of each CS train in acquisition and extinction were converted to a percentage of the mean preacquisition CS-alone response amplitude. The conversion compensated for differences in initial response level to the CS caused by variations in the initial CS level. Initial CS level was shown to have no correlation with behavior during the experiment. Figure 1 presents acquisition and extinction functions in five trial blocks for all groups in both experiments. It is evident that response amplitude in only the paired conditions rose rapidly over the initial 15-20 trials, remaining fairly stable thereafter. In extinction, the paired groups showed general decreases to base levels.

Analysis of variance performed on the percentage data of Experiment I indicated a significant blocks effect ($F = 2.67$, $df = 9/162$, $p < .01$) in extinction, supporting the impression from the figure. The rapid response amplitude increase over initial acquisition trials seemed likely to conceal an interaction effect. Analysis of the absolute amplitude of the CS-alone blocks and initial three acquisition blocks revealed a significant Groups by Blocks interaction effect ($F = 2.75$, $df = 4/72$, $p < .05$).
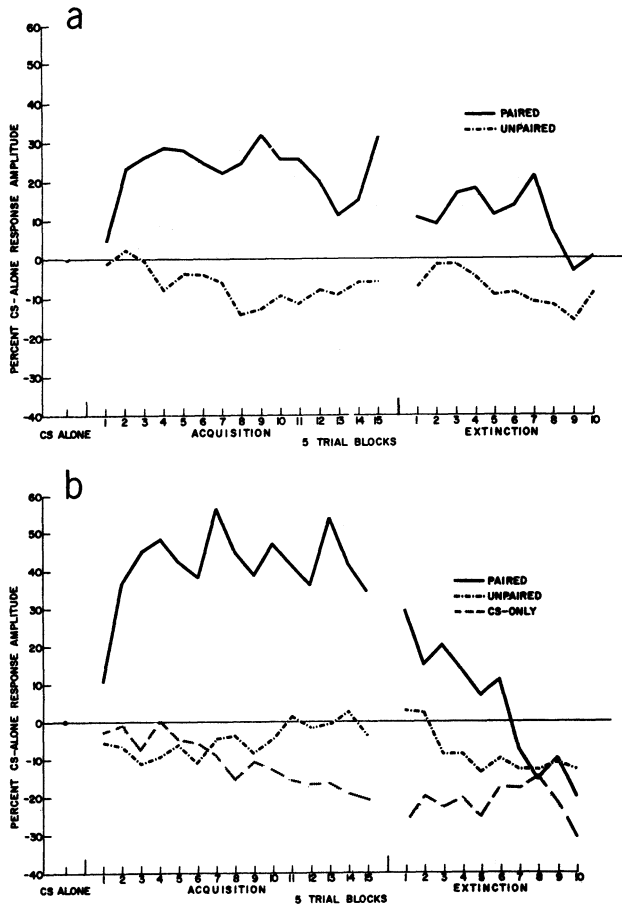
Fig. 1. Mean response amplitudes in acquisition and extinction over five-trial blocks as a percentage of CS-alone response amplitude. (a) Experiment I paired and unpaired groups. (b) Experiment II paired, unpaired, and CS-only groups.

Analysis of variance on the Experiment II data revealed a significant acquisition group main effect (F = 13.26, df = 2/22, p < .01), supporting the impression of a rapid increase in the paired group to a stable level. A Dunnett's t test showed differences in acquisition between the paired and unpaired groups (t = +2.74, df = 22, p < .020) but none between unpaired and CS-only groups. In extinction, a blocks (F = 4.33, df = 9/198, p < .01) and a Blocks by Groups interaction effect (F = 2.36, df = 18/198, p < .01) reflected the more rapid decrease in the paired group.

DISCUSSION

The results indicated that the CS-UCS pairing resulted in response increases not seen in the unpaired controls and not attributable to alterations in the animal's condition or to cyclic temporal effects. Due to the paralysis, artifacts from muscle activity were ruled out, as were major contributions from the gamma system. The paralysis, coupled with neural CS application and CR recording, effectively limited the site of observed effects to the spinal cord, greatly simplifying further neural analysis. The possibility that the effects were due to substantial sensitization produced by the UCS was examined (see Patterson, Cegavske, & Thompson, 1973, Experiment III). The results showed that, while the UCS produced a complex pattern of sensitization, no long-lasting sensitization which could account for the effects was found.

The present studies are in substantial agreement with earlier observations (e.g., Shurrager & Culler, 1940). The rapidity of the response increases do not, however, parallel response rate increases usually observed in classical conditioning of skeletal systems but are reminiscent of autonomic system conditioning and may be due to the relative simplicity of the neural circuits involved in the present paradigm.

It should be emphasized that the observed effects were not robust, great care being required in surgical and experimental procedures. The most important feature of the present preparation is to provide a paradigm showing some formal aspects of learning usually associated with the intact organism, but in a simplified, stable preparation suitable for neural analysis. Further studies are planned to determine how closely the "model" parallels other features of conditioning in the intact organism, such as retention, spontaneous recovery, and discrimination.

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