Classical conditioning of the hindlimb flexion reflex in the acute spinal cat¹

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Acute spinal cats were prepared by partial decerebration and spinal section using ether. Animals were given training (hindlimb flexor muscle reflex response) in a classical conditioning situation using shocks to thigh and paw of hindlimb as the CS and UCS. The conditioning group, given paired CS-UCS training, showed significant increase in response amplitude over conditioning trials relative to a control group given the same number and kind of stimuli unpaired.

Conditioning of the flexion reflex in the acute spinal carnivore was first reported by Shurrager & Culler (1940). The ensuing controversy (see Kellogg et al, 1947) left the issue unresolved, particularly for the acute preparation. It has recently been demonstrated that the hindlimb flexion reflex of the acute spinal cat exhibits habituation and sensitization in a manner strikingly parallel to responses of the intact organism (Thompson & Spencer, 1966). These behavioral phenomena are at least partially amenable to analysis in terms of basic neurophysiological processes (Thompson & Spencer, 1966; Spencer, Thompson, & Nielson, 1966a, b, c). In the pilot experiments reported here the same general techniques are extended to the study of classical conditioning.

Method

Twenty adult cats were used. All animals were pretreated with atropine, anesthetized with ether, intubated, and partially decerebrated. The latter procedure, accomplished by RF coagulation of midbrain tegmentum at stereotaxic plane zero, results in a comatose unanesthetized preparation. The spinal cord was then transected at T12 and the animal allowed to recover from ether. The left hindlimb was rigidly fixed and the distal tendon of the tibialis anterior muscle was detached, led out through a small skin incision and connected by heavy thread to a Grass model FT 10C force-displacement transducer. Resting muscle tension was adjusted to an intermediate level. The reflex contractions of the muscle, calibrated in grams tension, were recorded on a polygraph.

Animals were assigned at random to conditioning and control groups (10 cats in each group). All animals were first given four UCS alone trials, followed by a series of CS alone trials, followed by either a series of paired CS-UCS trials (conditioning group) or unpaired alternations of CS and UCS (control group), followed by a series of CS alone trials (extinction). The CS was a weak 1 sec shock train to the skin overlying the dorsal portion of the upper left thigh, and the UCS was a strong shorter duration shock train to

the left foot pads. In the conditioning phase the CS and UCS terminated simultaneously for the conditioning animals. In control animals the CS and UCS were alternated at equal intervals which were half the duration of the corresponding conditioning group intertrial intervals. Thus during the conditioning phase, the conditioning and control animals received an equal number and kind of stimuli, paired for conditioning and unpaired for control. In these pilot experiments there was deliberate interanimal variation (parallel for the two groups) of stimulus and training parameters over limited ranges: shock pulse width, 1-6 msec; shock train frequency, 100-625 cps; UCS duration, 0.5 to 0.8 sec; CS-UCS interval, 0.2-0.6 sec; inter-trial interval, 30-120 sec; number of conditioning trials, 25-50.

Results

Results of the experiment are shown in Fig. 1. Individual responses of each animal during acquisition and extinction were converted to a percentage measure relative to mean control level for that animal. These converted scores were then vincentized into 10 trial blocks for acquisition and 10 for extinction for each animal. The data of Fig. 1 are the mean performance over trial blocks for the conditioning and control groups during acquisition and extinction, with control levels set equal to zero. Response amplitude for the conditioning group rises rapidly for the first several trial blocks of acquisition training and remains high. During extinction the conditioning group scores decrease toward the control level. Overall response amplitude for the conditioning group is

Fig. 1. Performance of the conditioning and control groups during acquisition and extinction plotted as percent change from initial control level.

significantly higher than for the control group during acquisition ($t=2.55$, $df=8$, $p<.05$, based on individual animal median trial block scores) but the two groups do not differ in extinction ($t=0.2$, $df=18$, not significant).

Interanimal variability was considerable, particularly for the conditioning group during acquisition training. Individual animal scores ranged from no apparent increases in response amplitude to marked increases. Effects of the deliberately introduced variations in stimulus and training parameters in these pilot studies (see methods) cannot of course be evaluated quantitatively. Nonetheless some tentative observations may be noted. Number of conditioning trials is probably relatively unimportant, at least insofar as asymptotic response strength during conditioning is concerned. Most of the increases in response strength during acquisition occurred within the first 20 trials, and the greatest increases were during the first few trials. The only other variable that appeared to show a consistent effect was CS-UCS interval; 0.5 sec seemed to yield better conditioning than 0.2 sec. However, it must be emphasized that effects of this and other stimulus and training variables are confounded in these pilot experiments; at best they serve only as suggestions for subsequent investigation.

Discussion

The data presented here demonstrate the occurrence of classical conditioning of the hindlimb flexion reflex in the acute spinal cat. Increases in response strength during acquisition for the conditioning group cannot be due to sensitization from the strong UCS; this effect would be more pronounced in the control group where time between UCS and next CS is only half as long as in the conditioning group. No such sensitization occurred.

The significance of spinal conditioning lies not so much in its possible occurrence in the normal organism but rather in its use as a model system for the study of neuronal substrates of learning. In other experiments not involving conditioning, the "excitability" of the CS channel was tested (by a 1 msec shock pulse) at varying times after a brief (100 msec)

shock train to the same electrodes. There is a marked increase in flexion response amplitude that reaches a maximum 0.5 sec after the onset of the brief shock train and then declines exponentially to control level in less than 20 sec. It may be suggested that this brief increased responsiveness following a CS represents a period of increased "plasticity;" during this period there would be an increased tendency for presentation of a UCS to yield conditioning. Such a period of increased plasticity or conditionability may in turn reflect processes analogous to the presynaptic hyperpolarization of afferent fiber terminals described by Mendell & Wall (1964) (see also discussions by Kozak & Westerman, 1966; Thompson & Spencer, 1966). Such a possibility, which is to some extent amenable to direct experimental test, would provide support for a variation of the traditional view that learning may involve alterations in axon terminals.

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Note

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