# RESPONSE LATENCY AS A FUNCTION OF BRAIN STIMULATION VARIABLES[1]

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It has been demonstrated that electrical stimulation of certain brain structures in the cat (Delgado, Roberts, & Miller, 1954) and rat (Bower & Miller, 1959) produces an aversive effect; that is, the animal will perform an escape response which turns off stimulation to these sites. The present study reports the effects on escape behavior of rats of variations in certain parameters of brain stimulation, viz., current intensity, pulse duration, and pulse frequency of a square-wave stimulus. In the present situation, brain stimulation was turned on by *E* and the behavioral measure was the time that elapsed before a lever-press by *S* terminated the stimulus.

## METHOD

### *Subjects*

Three male albino rats, 120 days old, were housed in individual living cages and maintained on ad lib. water and Purina Lab Checkers. In each *S* two unipolar electrodes, aimed at hypothalamic sites, were chronically implanted using a Kreig stereotaxic instrument. A small screw, attached to the skull and contacting surrounding tissue, served as the indifferent electrode. Details of the electrode preparation are described elsewhere (Miller, Coons, Richter, & Jensen, in press).

### *Stimulation Equipment*

Electrical stimuli were provided by a Grass S-4 stimulator set to deliver repetitive monophasic pulses. The implanted electrode was always connected to the cathodal lead. A 50,000-ohm resistor in series with the stimulator provided a relatively constant current source. Current flow was monitored with a calibrated cathode ray oscilloscope connected across a 1000-ohm resistor in series with the stimulating lead.

### *Apparatus*

A bar 4 in. wide, 1.5 in. above the floor, protruded 2 in. into a 10-in. by 24-in.-high enclosure. A standard timer, starting with the onset of brain stimulation, timed the latency of the escape response. When *S* depressed the bar .25 in., the brain stimulus terminated and the clock stopped. Escape latencies were measured to the nearest .01 sec.

### *Procedure*

Preliminary tests were performed with each electrode; the electrode which seemed to give the stronger aversive effect was used throughout the experiment. Subjects were initially trained (with at least 500 trials) to press the bar to turn off a high-intensity brain shock. During this pretraining *S*s learned to maintain a posture close to the bar. This pretraining minimized orientation and learning factors which might have confounded performance in the parametric tests, which were conducted in the three days following preliminary training.

For the parametric tests, a triplet of values of pulse frequency, pulse duration, and current intensity was used to stimulate *S*. On a test trial, stimulation continued until *S* pressed the bar or until 30 sec. had elapsed; in the latter case, a value of 30 sec. was arbitrarily assigned for that trial. At each triplet of values, *S* received 10 test trials spaced 60 to 90 sec. apart. Current or pulse duration was varied from low to high values over a test series, the other two parameters remaining constant. Blocks of 10 test trials at successive values of a variable were separated by at least 20 min. This spacing between successive test blocks reduced any gross sequence effects since it was possible to reproduce points on the curves obtained with the low-to-high procedure by giving the test blocks in random order.

Two families of curves were obtained from each *S*: In one curve family escape latency was related to pulse duration, different curves being obtained at different pulse frequencies; in the second family of curves escape latency was related to current intensity with pulse frequency again being the parameter of the family. The values were selected for each *S* to yield smooth, regular curves.

## RESULTS

The curves for each *S* are plotted in Figure 1. Each point is the average escape latency of 10 test trials. Figure 1 shows a smooth inverse function relating escape latency to current intensity and pulse duration. Also, for particular values of current intensity and pulse duration, escape latency is an inverse function of pulse frequency over the values reported in Figure 1. However, recent work varying pulse rate over a larger range indicates that very high pulse

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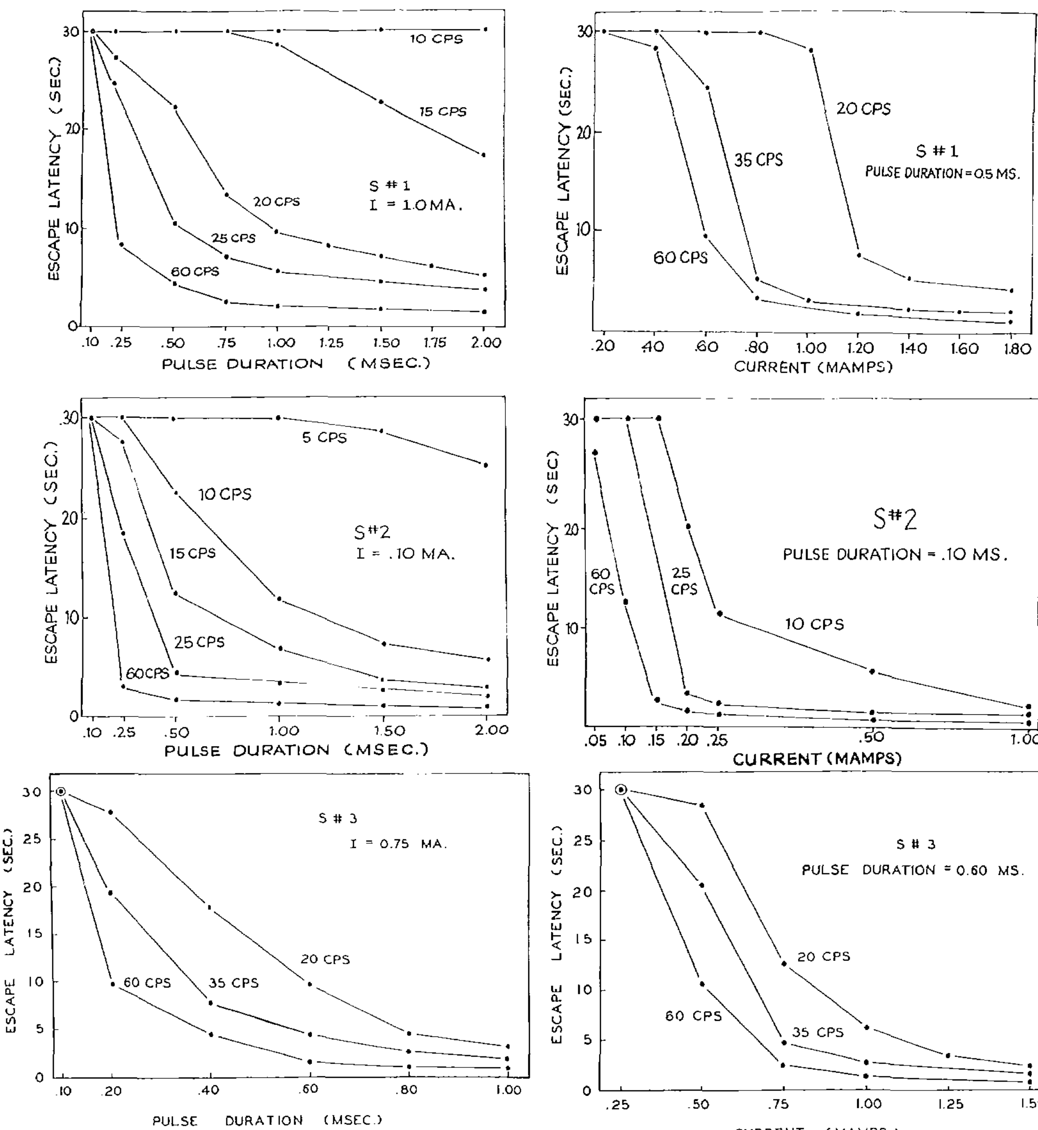


FIG. 1. Average escape latency for three *S*s as a function of pulse duration (obtained at indicated currents, left column) and current intensity (obtained at indicated pulse durations, right column). Pulse frequency, specified in cycles per second, was the parameter in the two curve families for each *S*.

rates (500 to 700 per sec.) are ineffective in producing escape responses.

Figure 1 shows that *S*s differ markedly in their thresholds. For example, the pulse duration curves for *S*1 were obtained at a current of 1.00 ma., whereas the comparable curves for *S*2 could be obtained at 0.10 ma. Because the electrode placements were not identical, possible accounts for these differences include (*a*) structures with different thresholds were stimulated in the three *S*s and (*b*) the electrodes were at different distances from critical structures. These factors cannot be distinguished on the basis of the present results.

*Histology*[3]

Histological examination shows that the electrode of *S*1 was in the optic chiasma near the

[3] Histology was performed by Burton S. Rosner and Judith B. Levine.

tangential nucleus, and it is likely that both structures were stimulated. The electrode of *S*3 was near the ventral medial nucleus, but it is likely that the dorsal medial nucleus was stimulated, too. *S*2 pulled out its electrodes before it could be sacrificed, so histology is not available on this animal.

## DISCUSSION

The results show that the behavioral response varies regularly with variations in the stimulation parameters. Increases in pulse frequency tended to compensate for decreases in current or pulse duration; thus, the energy per second (power) of the brain stimulus appeared to be the important factor in determining escape latency. The systematic variations in escape latency may reflect differences in the aversiveness of the brain stimulus or differences in the time required for the stimulation to become an effective aversive stimulus. The latter interpretation seems more in accord with observations of the *S*s' escape behavior.

The regularity of the curves indicates that the situation is one in which the stimulus exerts considerable control over an *S*'s performance. The value of such a finding is methodological. The stability of the curves recommends the use of this behavioral situation to assess the influence on escape thresholds of different variables (e.g., electrode placement, drugs).

## SUMMARY

Rats were trained to press a bar to turn off an aversive electrical stimulus to subcortical brain structures. The latency of the escape response was found to be inversely related to the current intensity, pulse duration, and pulse frequency of square-wave brain stimulation.

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