Different neuronal responses in the cochlear nucleus of a cat during classical and instrumental conditioning¹

EDWARD S. HALAS and JAMES V. BEARDSLEY, *University of North Dakota, Grand Forks, N. Dak. 58201*

Multiple-unit neuronal responses were recorded from the cochlear nucleus of a cat during classical and instrumental conditioning. Results indicate that different configurations of neuronal responses occurred during classical and instrumental conditioning.

Within the last several years, various investigators have attempted to correlate single- (O'Brien & Fox, 1969a, b) and multiple-unit neuronal activity (Galín, 1965; Buchwald, Halas, & Schramm, 1965, 1966) with classical conditioning. The positive results obtained in these studies would suggest that the recording of neuronal responses provides some useful information on the functions of various brain structures during conditioning. As an example, it was observed that the classical auditory pathway played a significant role during conditioning when an auditory stimulus was used as a CS, while the visual pathway was essentially nonfunctional (Buchwald, Halas, & Schramm, 1966). The present study attempts to determine if there are any differences in the multiple-unit responses of the cochlear nucleus during classical and instrumental conditioning.

METHOD

The S was an adult male cat with chronically implanted electrodes. The procedure for implanting an electrode in the dorsal cochlear nucleus has been described elsewhere (Buchwald, Halas, & Schramm, 1966; Halas & Beardsley, 1968). The multiple-unit neuronal activity was displayed on a Tektronix 565 oscilloscope and photographed with a Grass C4 camera. A modified version of the Weber & Buchwald (1965) electronic integrator was used to count the frequency of the multiple-unit activity. The integration of the frequency count was displayed on the scope and photographed simultaneously with the neuronal activity. Pin lights mounted on the scope recorded the duration of the CS and US, which consisted of a 1,500-Hz tone paired with a mild electric shock to the hindpaw of the cat. The CS lasted 1.5 sec, and the US lasted 0.5 sec. The US overlapped the last third of the CS.

The S was given 500 habituation trials to the tone at the rate of 39 trials per day (32

trials on the last day), followed by 800 trials of paired tone and shock during classical conditioning. The S was then given 500 extinction trials followed by a 6-week rest period. After a second habituation of 500 trials, the S was given 1,000 instrumental avoidance trials. If the S lifted its hindpaw during the first 1.0 sec of the tone, shock was not given. Five hundred extinction trials followed the avoidance training. Intertrial intervals ranged randomly from 20 to 50 sec.

RESULTS

The results clearly indicate that a different configuration of neuronal responses developed for instrumental as compared to classical conditioning. The neuronal responses are illustrated in Fig. 1. During habituation and the first 41 trials of classical conditioning, no behavioral or neuronal responses were observed (Traces A and B). Starting with Trial 42, a positive sustained response was observed (Trace C). Conditioned neuronal responses appeared 85% of the time from Trials 42 through 324, while conditioned behavioral responses were observed on 34% of the trials. The configuration of the neuronal response remained essentially unchanged throughout the remainder of the classical-conditioning procedure (Traces D and E). From Trials 325 through 800, neuronal responses occurred 78% of the time, while behavioral responses appeared 57% of the time. When the cat was extinguished, the neuronal response gradually diminished (Trace F). After extinction, the animal was given 6 weeks of rest followed by a second habituation period of 500 trials. Positive neuronal responses were observed in 21% of the habituation trials.

For the first 72 trials of instrumental conditioning, no neuronal or behavioral responses were observed (Trace H). On Trial 73, a positive sustained response (Trace I) appeared. This response occurred 81% of the time from Trials 73 through 324, while the conditioned behavioral response appeared 47% of the time. On Trial 325, the response changed to a positive onset (Trace J) that was not sustained as in the earlier trials. From Trials 325 through 396, this onset response occurred 67% of the time. The behavioral response was elicited 73% of the time. Starting with Trial 397, the neuronal response evolved into a brief onset followed by a marked inhibition of the neuronal activity (Trace K). This response

persisted (65%) through Trial 1,000 when the cat was extinguished. The behavioral response appeared 81% of the time. Extinction was also characterized by different responses. During early extinction, the previously observed complex conditioned neuronal response disappeared, and a positive sustained response (Trace L) appeared that was very similar to the response observed in Trace I. This response remained throughout extinction (500 trials).

DISCUSSION

Although the overt behavioral conditioned response (hindleg flexion) was essentially the same for both classical and instrumental conditioning, the neuronal responses were different for the two conditioning procedures. The neuronal response during classical conditioning was a positive sustained response that varied its amplitude somewhat but did not change its configuration. The neuronal response during instrumental conditioning revealed three different configurations during the training procedure. Rather interestingly, the first configuration to appear early in instrumental conditioning (Trace I) was very similar to the configuration that appeared in classical conditioning (Traces C, D, E). As instrumental training progressed, the configuration of the neuronal response changed. There is a considerable amount of behavioral data (Shapiro & Miller, 1965) to suggest that the early stages of instrumental conditioning are identical to classical conditioning. The present neuronal data supports the position that the early phases of instrumental conditioning involve a classical-conditioning paradigm.

Furthermore, these results clearly indicate that the neural mechanism responsible for classical and instrumental conditioning involve the lower levels of the brain stem. What is perhaps more interesting is that the differentiation of classical and instrumental conditioning does occur so low in the brain stem. Whether this differentiation is mediated solely by neural mechanisms within the cochlear nucleus or is influenced by a feedback system from such higher structures as the cortex cannot be determined by the present data.

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CLASSICAL CONDITIONING

INSTRUMENTAL CONDITIONING

Fig. 1. Different configurations of neuronal responses recorded from the cochlear nucleus. The left half of the figure shows the neuronal responses recorded during habituation, classical conditioning, and extinction. The right half shows the neuronal responses recorded during habituation, instrumental conditioning, and extinction.

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NOTE

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