Effect of Stimulation of the Human Thalamus and Parietal and Temporal White Matter on Short-Term Memory

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Clinical and experimental observations indicate that the preservation of memory traces is dependent on specific cerebral mechanisms. Electrical excitation and lesions in the hippocampal formation and mesial thalamus have been related to memory deficits in man. Recent evidence has also implicated the ventral lateral thalamus as an anatomic correlate for the storage of memory events. This report describes an attempt to determine whether other lateral thalamic and subcortical structures participate in memory functions.

In a previous study a task of naming and short-term memory for pictorial memoranda was presented to patients with electrodes implanted in the thalamus for treatment of motion disorders. Electrical stimulation in the left pulvinar and deep parietal white substance in both hemispheres disrupted verbal behavior and elicited anomia. The effect of stimulation on the memory performance of these patients with thalamic electrodes and additional patients with temporal lobe electrodes is the subject of this report.

Methods

Subjects. Seventeen patients undergoing thalamotomy for the relief of motion disorders were selected according to criteria described later in this report. The left thalamic group consisted of eight patients, the right thalamic group, 10 patients; one patient had an electrode implanted in each hemisphere and was assigned to both groups. For this patient, stimulation study and therapeutic coagulation in the left thalamus occurred 2 weeks prior to implantation and stimulation in the right. Another patient in the right thalamic group had undergone an earlier left thalamotomy. Diagnostically, the thalamic groups included 13 patients with Parkinsonism, two with torticollis, and two with dystonia. The temporal lobe group consisted of five seizure patients with electrodes implanted in medial temporal structures for diagnostic purposes. The indwelling electrode was placed in the left for two patients, in the right for one patient. Two patients were studied with bilateral temporal electrodes.

The mean Wechsler intelligence (IQ) and memory (MQ) quotients for the left thalamic group were: IQ 111, MQ 112; for the right thalamic group: IQ 106, MQ 100; for the total temporal group: IQ 108, MQ 114. The mean age for the left thalamic group was 45 years; for the right thalamic group, 48 years, and for the temporal group, 31 years. All patients were right-handed and were free from medication at the time of testing.

Electrodes. The thalamic electrodes were directed through a medial parietal burr hole toward a ventralis oralis target area according to an established technique. The electrodes were constructed with a silver coagulating slug (8 mm long \( \times \) 1 mm in diameter) at the distal end. Six individual ring contacts were located above the slug at 5 mm intervals. The temporal lobe electrodes were passed through an anterior temporal burr hole and directed toward the hippocampus and amygdala. These electrodes had one contact point at the tip and three separate ring contacts at 5 or 10 mm intervals along the shaft.

The method and anatomic charts used to plot stimulation points for the thalamic elec-
trodes were described in the earlier investigation, the stimulation points in the temporal lobe were plotted according to the same procedure. Briefly, the coordinates for each pair of electrode contacts were determined by measurements of the midpoint of adjacent ring contacts to the following references: anterior or posterior commissure (whichever was nearer), the intercommissural line, and the midline of the third ventricle. These measurements were then transferred to anatomic charts of the human brain that outlined the mean location and range of variation of borders for subcortical structures in relation to the reference structures.

Coordinates selected for the present study that fell within the inner limit of variation of the thalamic border were considered to be in the lateral thalamus. This area was divided by the following planes: a coronal plane 3 mm anterior to the posterior commissure, a horizontal plane 7.5 mm above the intercommissural plane, and a parasagittal plane 12.5 mm from the midline. Thalamic coordinates that were situated posterior, superior, and lateral to these planes were assigned to the pulvinar. Electrode points located anterior, inferior, and medial to these planes were designated as the remainder lateral thalamus.

The parietal white matter group consisted of those electrodes inserted through a parietal burr hole with coordinates located outside the range of thalamic border variation. These points were primarily situated in medial parietal white matter lateral to the splenium of the corpus callosum. The temporal white matter group included electrodes with coordinates which fell outside the range of variation of the borders of temporal cortex, amygdala, and hippocampus. The coordinates for each anatomic group are presented in Table 1.

Task. The test and procedure were described in the original investigation. The test stimuli consisted of 36 chromatic photographs of familiar objects alternated with a photograph of the word “and.” Three different arrangements of the pictorial objects were presented in a balanced order on a continuous 35 mm filmstrip. Each frame was presented for 4 sec by a Graflex projector, pulsed by an interval timer. The image appeared on a 5½ × 7 in. rear projection screen positioned approximately 4 ft from the patient. The patient was instructed to say each “and” and to name each object. The patient was also required to recall the name of the preceding object immediately after identifying the object in view. For example, if the following frames were serially presented: “hat”, “and”, “cow”, “and”, “window”, the correct response would be “hat”, “and”, “cow, hat”, “and”, “window, cow”. With each frame advance, the patient pressed a telegraph key (1.5 in. in diameter) with his preferred hand. This response and the carrier word “and” were used to evaluate possible motor or expressive difficulties during stimulation. The memory portion of the task included a hold interval (at least 4 sec from input to retrieval) containing verbal and motor responses which may be regarded as distractional stimuli.

Procedure. Testing was conducted from 3 to 6 days after electrode implantation and before therapeutic coagulation. The patients were trained on the ward and received additional practice in the testing room before stimulation. Patients who failed to achieve a criterion of at least 50% accuracy in recall during the final rehearsal were excluded from the analysis.

Each test trial consisted of a continuous presentation of seven or eight objects and the intervening “ands.” Stimulation was introduced at the appearance of the third or fourth object and was maintained through the following frames of “and” and object, for a total of 12 sec. The patient was interrogated at the end of each trial regarding stimulation effects. Thus, each trial yielded at least two recall responses before, two responses during, and three responses following stimulation. Approximately 45 sec separated each test trial; the total testing procedure lasted about 1 hr. The stimulation event and a pulse indicating each frame advance were recorded simultaneously with the patient’s verbal and press response by a Sanborn-Ampex Recorder (Model 2007). Concurrent electroencephalographic activity from the scalp and selected contact points on the electrode shaft were also monitored during the testing session.

The electrical stimulation consisted of a 60 cps symmetric biphasic square wave