Infrared Mapping of the Cerebral Cortex

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•This paper describes new approaches to functional mapping of the cerebral cortex using an infrared high-speed scanning camera and high-power digital image processing. The technique is capable of analyzing temperature changes of 0.002C. The instrumental spatial resolution is 70 microns/pixel and its temporal resolution is up to 40 msec (25 thermal displays/second). The technique provides images of the thermal responses of the cerebral cortex to sensory, photic, or other stimulations imaged on the skull in intact animal models. Photic stimulation of the retina activates a thermal response in the occipital lobe. Our study indicates that the technique may be applicable in neuropsychological investigation of the cerebral cortex in experimental as well as clinical conditions.

Introduction

Recent applications of computers to neuronal information have introduced a variety of neuroimaging techniques, such as multichannel EEG mapping, positron emission tomography (PET), and magnetic resonance imaging (MRI). Each modality has its own field of investigation, but the functional phenomena that they investigate overlap. The technique introduced here is a neuroimaging modality based on thermal responses of the cortex of the brain.

Principle and Methods

Like all living biological tissues, the cortex produces heat, which reaches its surface by conduction through tissue and convection in blood flow. As the heat reaches the surface of the cortex, it gives off electromagnetic radiation, which can be detected in a wavelength range of 3 to 5 or 8 to 14 microns by electric infrared detectors. The thermal signals detected are converted to electric signals, which are then used for analog display or digital analysis.

The device used for this study* has 40 msec scanning time (25 scans/sec) and differential thermal sensitivity of 0.2C, which is not sensitive enough for analysis of the heat generated by cerebral cortex. To solve this problem, the random background noise from instrumental and biological sources was reduced by repeated averagings and subtractions, thereby increasing thermal sensitivity 10 to 100 times (0.02C to 0.002C). This was achieved by use of computerized digital image processor Pericolor-2000E (Numelee, France)[1] and a fast interface made by the authors was also used to connect the thermographic device and the processor. A digitalized thermal image (DTI), consisting of 10880 pixels (128 × 85), was used.

Subtraction was carried out within the selected region of interest (ROI). Temperature estimation by the computer took 40 msec for each ROI and 2.4 microsec for a pixel. Computer processing was carried out on successive DTI up to 9 sets of 72 DTI each. For example, this might be done for image processing during sequential electrical stimulation of a peripheral nerve. Spatial and temporal digital filtrations were used for improvement of the signal-to-noise ratio. In practice, 40 msec to 10 sec were needed between each DTI. The electrical stimulations were carried out at 2–4-minute intervals. Synchronization of stimuli and DTI was also possible through an output interface.

Instrumental spatial resolution was 7–100 microns/pixel. It can be easily changed by adapting intermediate rings between camera and lens.

For selected points on the image, it was possible to display a calibrated curve of thermoresponse. During a typical experiment, a thermovisor camera was focused on the dorsal surface of the skull of, for example, a white rat previously scalped under Nembutal (40 mg/kg). Under local anesthesia (Novocain Sol., 0.5%) the animal was immobilized by d-tubocurarine (1 mg/kg) and was kept on artificial respiration. Body temperature was stabilized by heating. The head was fixed. (Studies were performed on white rats, rabbits, cats, and monkeys.)

Results

Stimulation of the Vibrissae

Shortly after electrical stimulation of the skin at the right side of the vibrissae of the rats, a thermal response was observed in the primary sensory cortex (Figure 1). Initially the cortex was cooler, then it rapidly changed

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* AGA Model 780M Infrared Systems, Danderyd, Sweden.