Lecture 10:Invasive techniques & Non-invasive techniques

The Lecture Contains:

- Non-invasive Techniques
- Electroencephalogram (EEG)
- Computarized Transaxial Tomography (CT scan)
- Positron Emission Tomography (PET)

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Before the advent of the modern sophisticated non-invasive techniques brain research was dependent on invasive techniques such as ablation, lesions, and knife cuts. Because of forensic importance and non-availability of the modern day technology, brain autopsy was used for long. Besides them electrical and chemical s timulation were also used to infer to brain control mechanism. Before the development of sophisticated equipments micro and macroelectrode techniques were the advanced available options. The microelectrode technique was used to study activities of a single neuron. For this a tiny glass microelectrode was placed within a neuron with the help of a conducting liquid. It recorded the electrical changes taking place within the neuron and was thus very helpful in understanding the dynamics of normal conduction in a neuron. It was also helpful to understand the effect of toxins on the neurons.

Non-invasive techniques have helped researchers and practitioners understand epilepsy and movement disorders. With technological advancement several non-invasive techniques have come into being and thus the usage of non-invasive techniques has stopped.

Non-invasive Techniques

Our present understanding of the functions performed by the nervous system heavily depends upon the imaging techniques. This has literally made it possible to look into a function brain. Beginning with X-rays, which is not used for brain research, the non-invasive techniques available now, includes EEG, CT Scan, MRI (magnetic resonance imaging), PET (positron emission tomography), SPECT (single photon emission computerized tomography), and MEG (magnetoencephalography). The video below shows the X-ray used to examine the skull.

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X-ray of head

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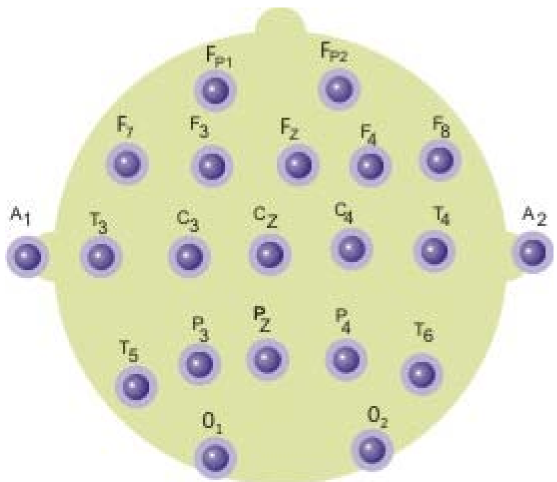
Module 2:Methods for understanding human psychophysiological activity

Lecture 10:Invasive techniques & Non-invasive techniques

Electroencephalogram (EEG)

Although Richard Caton recorded the electrical activity from the brain for the first time in 1875, Hans Berger was the first to record brainwaves from human beings in 1924. EEG recording is done by placing electrodes at designated places on the scalp or using cap fitted with electrodes (as shown in the figure below). Each electrode is connected to an input of a differential amplifier and a common electrode is connected to the other input of each amplifier. Thus, the voltage between the active electrode and the reference gets amplified.



Sites of electrode placement

See video on web

Four types of brain waves are recorded from the scalp of normal human beings using EEG— a lpha waves (8-13 Hz), beta waves (>13 Hz), theta waves (4-7 Hz), and delta waves (<4 Hz). Each of these waves appears as a single line representing the summated electrical field resulting from the activity of the neurons. These records can be unipolar or bipolar in nature. When an electrode is placed on the scalp and another on some other part of the body the obtained potential differences are called unipolar records whereas potential fluctuations between two cortical electrodes are termed as bipolar records.

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With a rate of 8-12 cycles per second alpha waves have the highest amplitude with an average of 50 microvolts. It is observed in the occipital, frontal and parietal regions of the cortex and cannot occur without the connection of RAS . It is prominent in darkness and/ or when eyes are closed and abolished with visual stimulation or mental concentration. Beta waves are usually found in parietal and frontal regions. It ranges between 18 and 60 (maximum) cycles per second with amplitude varying between 5-10 microvolts. Human scalp emits two types of beta waves- ß I and ß II. The frequency of ß I is twice that of a waves. While ß I disappears during mental activity ß II is apparent during stress and intense activation of CNS . Theta waves are primarily found in the parietal and temporal regions and are prominently observed in children between the ages of 2-5 years. Its rate ranges between 4-8 cycles per second with amplitude of 10 microvolts. With a rate of minimum 0.5-3.5 cycles per second and amplitude that varies between 20-200 microvolts, delta waves are rarely found in normal adults during working hours. It is observed during deep sleep, organic brain diseases, hypoxia and hypoglycemia. It is understood as a byproduct of separation of the cortex and RAS .

The table given below illustrates a comparative review of the four brain waves.

	Alpha waves	Beta waves	Theta waves	Delta waves
Frequency	8-13 Hz	14-30 Hz	4-7Hz	5-3.5 Hz
Amplitude	20-60 µV	2-20 µV	20-100µV	20-200µV
Easily produced when	Relaxed sitting position with closed eyes	During mental thought and activity	More common in children than adults	During deep sleep in most people

EEG has diagnostic application for epileptic cases. Before being replaced by CT scans and MRI , it was also used as first-line diagnosis for tumors and other brain disorders. It is useful as a n on-invasive technique and indicates the active brain area, but cannot precisely indicate where the signal came from. The EEG records electrical activities only from the cortical surface close to the skull and hence reflects the functional state of about 35% of the cortex only. The above description is of the normal EEG pattern. Minor differences have been observed in the EEG records of 5-7% of normal population but they have no clinical significance. EEG is also age-dependent; younger the child slower the activities. Elderly people have slower pattern indicating that with the increase in age the EEG pattern becomes slower.

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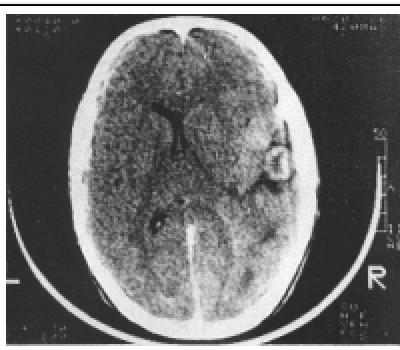
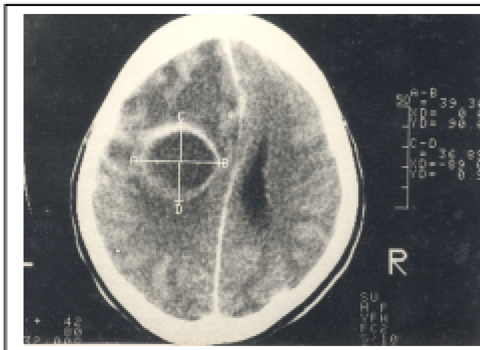
Computarized Transaxial Tomography (CT scan)

This technique was developed by Nobel Prize winner Sir Geoffrey Hounsfield. This non-invasive technique generates computerized images with the help of X-rays to provide a three dimensional measured density of the brain. Compared to ordinary X-rays where a single X-ray is sent out through the body, in CT scan several beams are simultaneously sent from different angles. This generates a series of two-dimensional images. Though this technique is used to scan any part of the human body, in terms of brain it provides clear images of bony structures. CT scans have been useful in evaluating strokes, tumors, vascular accidents, head injuries, and intracranial lesions or atrophy.

In the recent years the technology behind CT scans has advanced and now it is possible to obtain the scans in seconds. Newer scanners known as spiral or helical scanners take fraction of seconds to produce three-dimensional scans. Scientists at ANURAG (Advanced Numerical Research and Analysis Group), a Defense Research and Development Laboratory at Hyderabad , India , have come forward with software named ANAMICA (ANURAG's Medical Imaging and Characterization Aid) that generates three-dimensional images (grid). The two images given below show CT scans of a right temporal lobe damaged patient and a left parietal lobe damaged patient, respectively.



CT scan of right temporal lobe damaged patient



CT scan of left parietal lobe damaged patient

Courtesy: Bhushan, B. (1999). The right hemispheric locus of visuospatial processing in focal brain-damaged patients and normal subjects. Ph.D. thesis submitted to BRAB University, India.

The visualisation has been largely used to study different types of cranial injuries and their effect of human behaviour. You may find CT scan technique used for studying elderly psychiatric patients (Rozenbilds & Gilchrist, 1989) and other behavioural studies too.

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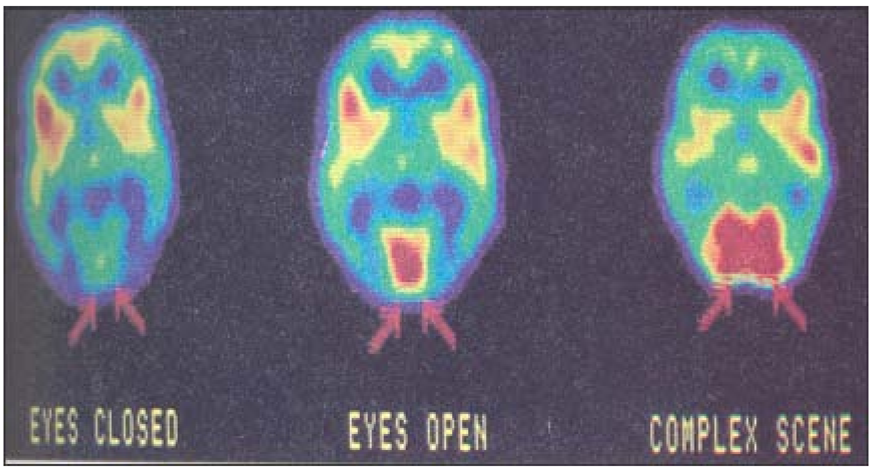
Positron Emission Tomography (PET)

Positron Emission Tomography (PET) was developed by Michael Phelps. It depends on the introduction of tracers into the body by either injection or inhalation. PET shows images of the amount and localization of these radioactive molecules. It could be neurotransmitters, drugs, tracers for blood flow or glucose. As a matter of fact, it produces images of normal as well as diseased living biological processes in the body. The major application of PET is in the assessment of metabolic activities and neurotransmitters.

The PET of brain records the metabolism of radioactively labeled glucose (such as fluorodeoxyglucose) in different regions of the brain. As you know, glucose is the only source of energy that the brain uses. Since fluorine 18 has a half-life of about 17 minutes, it is quickly transported to the brain and positrons are emitted. The collision of these positrons with electrons generates gamma rays. A computer maps these rays and produces images of the brain. Given below are the PET images during visual stimulation.



PET of visual stimulation (Source: UCLA School of Medicine)

A large number of published studies have used PET images and reported brain-behaviour association for whole range of activities.

Some examples of use of PET in behavioural studies are elaborated here.

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Martin et al. (1996) conducted a study to explore the role of motor region of the neo cortex in observing, remembering and imagining movements. PET images were used to identify brain regions active while various words were silently rehearsed. An increase in blood flow was observed in the hand region of motor cortex when subjects named tools. The researchers concluded that a connection exist between the hand region of motor cortex and knowledge about the tools and its usage.

Frey et al. (2000) performed PET study where the participants heard sound of violent car crash or familiar abstract sounds generated from an electronic keyboard. In another study novel abstract visual designs were presented to the participants and they had to memorize or just view them. Increased activation was observed in area 13 as a response to the unpleasant auditory stimuli. This area is connected to amygdale and hypothalamus. On the other hand, new visual information activated area 11. This has medial temporal cortical connections. A generalized prediction based on the study was that those with damage to area 13 would show weak response to threatening stimuli.

Maguire et al. (1997) performed PET scan for imaging hippocampus of the London taxi drivers. The taxi drivers were supposed to describe the route between two points in greater London and recall landmark buildings not in London and not visited. PET scan was performed while this process was on. Occipitotemporal areas, medial parital cortex, posterior cingulate cortex, parahippocampal gyrus and right hippocampus were activated during this spatial test. These drivers were also supposed to recall plot of a film and the result indicated that the non-spatial task did not activate the right hippocampus. A very important finding of this study was that the right posterior hippocampus increased in size as a function of years spent as a taxi driver. This shows the effect of topographic memory on human brain.

Drevets et al. (1997) studied mood disorder using PET. Cerebral blood flow of unmedicated unipolar, bipola and control subjects was examined using PET. 12% decrease in cerebral blood flow was recorded in the medial frontal region below the anterior region of the corpus callosum. The largest difference was observed in control and depressive groups.

PET scans have also been used for diagnosis of Alzheimer's and Parkinson's disease. It has emerged that certain regions of the brain show reduced blood flow (and hence metabolism) in the early stage of the disease. This pattern can be recorded years before the patient is diagnosed by a physician. The advantage of PET is that it provides visual image analogous to the brain anatomy and is helpful for functional and biochemical studies. It can also be useful to identify specific receptors associated with certain neurotransmitters. However, it exposes you to low levels of radioactivity. Also, it is not able to trail changes faster than 30 seconds. In addition, it has poor resolution as compared to MRI .

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