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INTERFACE BETWEEN NEUROIMAGING AND BRAIN MAPPING IN COGNITIVE PSYCHOLOGY

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Abstract
All neuroimaging can be considered part of brain mapping. Brain mapping can be conceived as a higher form of neuroimaging, producing brain images supplemented by the result of additional (imaging or non-imaging) data processing or analysis, such as maps projecting measures of behaviour onto brain regions (fMRI). Brain Mapping techniques are constantly evolving, and rely on the development and refinement of image acquisition, representation, analysis, visualization and interpretation techniques. Functional and structural neuroimaging are at the core of the mapping aspect of Brain Mapping.

Key words:
Neuroimaging, Brain mapping, MRI, fMRI, Sagittal MRI, Diffuse optical imaging, Event-related optical signal, Sagittal MRI, Axial MRI, Electroencephalography, Magnetoencephalography, Single photon emission computed tomography, Computed Axial Tomography, Positron emission tomography

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Neuroimaging includes the use of various techniques to either directly or indirectly image the structure, function/pharmacology of the brain. It is a relatively new discipline within medicine and neuroscience/psychology.
Neuroimaging falls into two broad categories:

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- Structural imaging, which deals with the structure of the brain and the diagnosis of gross (large scale) intracranial disease (such as tumor), and injury, and
- Functional imaging, which is used to diagnose metabolic diseases and lesions on a finer scale (such as Alzheimer's disease) and also for neurological and cognitive psychology research and building brain-computer interfaces.

Functional imaging enables, for example, the processing of information by centers in the brain to be visualized directly. Such processing causes the involved area of the brain to increase metabolism and "light up" on the scan. One of the more controversial uses of neuroimaging has been research into "Thought identification" or mind-reading.[1]

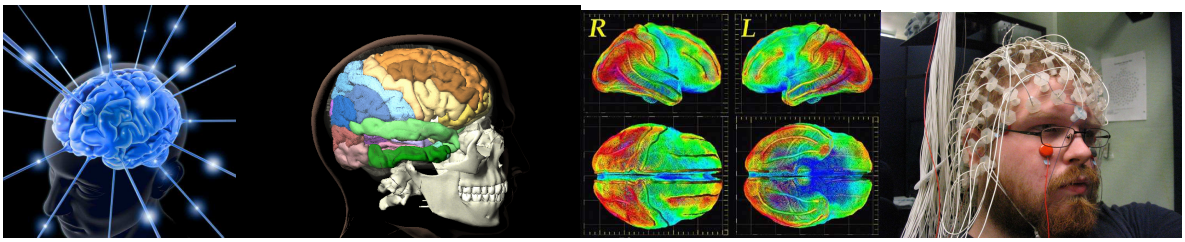

Figure-1 : Neuroimaging

Brain mapping is a set of neuroscience techniques predicated on the mapping of biological quantities or properties onto spatial representations of the human or non-human brain resulting in maps. The brain is in a continuous state of producing electrical impulses in the brain tissue. Many conditions can alter the normal flow of these impulses. Conditions such as OCD, ADD, depression, anxiety and others have distinctive signatures noted in recorded brainwaves.

What is Brain Mapping?

Brain Mapping is the laymen's term for a Quantitative Electroencephalogram (QEEG). This is a comprehensive analysis of the brainwave frequency bandwidths that are recorded in an EEG (Electroencephalogram).

Other brain mapping studies such as CT, MRI, and PET scans measure things like the blood flow to the cerebral area of the brain or structural integrity. QEEG measures the electrical activity in the brain. Sometimes the only signs of a problem early in a disease process may be subtle disruptions of the electrical flow and connectivity in the brain. These can be identified with a QEEG.

How is Brain Mapping done?

The test is painless for the patient. An elastic cap equipped with sensors is placed on the subjects head. The 19 sensors are then attached to a device that will record the brain activity. A special gel, much like those used in ultrasounds is used to improve conduction and this gel is squeezed onto each of the sensors on the cap. The total test time is usually about 45 minutes, taking approximately 15 minutes for preparation and about 15 to 30 minutes for the testing. During the test the subject is asked to remain very still, you may be asked to keep your eyes closed and then open for different parts of testing. Most of the time you are asked to perform mental tasks such as simple math problems or asked to read a passage in a book. These tasks cause your brain to access certain areas of function to complete them. During these tasks recordings are of those areas the brain has accessed to perform those specific tasks.

The recordings are interpreted and documented as the raw data is digitized and analyzed by a computer and reviewed by a skilled analyst to recognize any artifacts.

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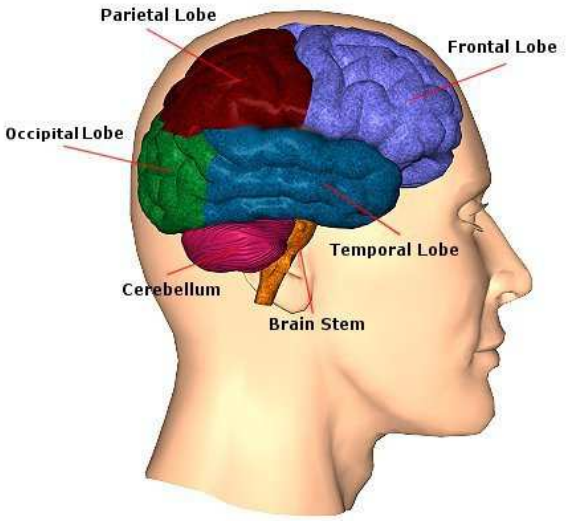

Figure-2: Lobes of brain

Brain Mapping in the Overall Assessment

The QEEG is a very useful study for pinpointing locations in the brain which could represent problems, but it is not able to determine exactly how much cognitive function has been diminished in the area. It is best used with other testing such as neuropsychological testing or MRI, SPECT or CT scans for full assessment and diagnosis.

In traumatic brain injury the brain may be injured in a specific location or the injury may be diffused to many different parts of the brain. It is this indefinite nature of brain injury that makes treatment unique for each individual patient. In the past twenty years, a great deal has been learned about brain function, and we learn more everyday. We can make guesses about the nature of the problems an individual may have from knowing the location of a lesion. Diagnostic procedures such as **CT** scans and **MRI's** can also provide information about brain injury. As rehabilitation specialists, however, we can also learn about an injury by observing the day to day activities of the patient. All the activities we perform each day, whether physical or mental, are directed by different parts of our brains. It is important that you become familiar with brain function to better understand how therapies, created by rehabilitation professionals, help brain injured patients. In order for you to better understand how the rehabilitation process works we will guide you through the different parts of the brain and indicate some of the functions and problems resulting from injury. The brain has many parts including the cerebral cortex, brain stem, and cerebellum. By listing some of the functions of each part of the brain, we will provide an overview of what problems occur after injury to these parts. It is important to understand that the brain functions as a whole by interrelating its component parts. The injury may only disrupt a particular step of an activity that occurs in a specific part of the brain. The interruption of that activity at any particular step, or out of sequence, can reveal the problems associated with the injury. Below is a list of functions and deficits or problems revealed when injury occurs at particular locations? The terms in parenthesis are the professional terms used to describe the deficit.[2]

CEREBRAL CORTEX

Frontal Lobe: Most anterior, right under the forehead.

Functions:

- How we know what we are doing within our environment (*Consciousness*). How we initiate activity in response to our environment. Judgments we make about what occurs in our daily activities. Controls our emotional response. Controls our expressive language. Assigns meaning to the words we choose. Involves word associations.
- Memory for habits and motor activities.

Observed Problems:

- Loss of simple movement of various body parts (**Paralysis**). Inability to plan a sequence of complex movements needed to complete multi-stepped tasks, such as making coffee (**Sequencing**). Loss of spontaneity in interacting with others. Loss of flexibility in thinking. Persistence of a single thought

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(**Perseveration**). Inability to focus on task (**Attending**). Mood changes (**Emotionally Labile**). Changes in social behavior. Changes in personality. Difficulty with problem solving.

- Inablility to express language (**Broca's Aphasia**).

Parietal Lobe: near the back and top of the head.

Functions:

- Location for visual attention. Location for touch perception. Goal directed voluntary movements. Manipulation of objects.
- Integration of different senses that allows for understanding a single concept.

Observed Problems:

- Inability to attend to more than one object at a time. Inability to name an object (**Anomia**). Inability to locate the words for writing (**Agraphia**). Problems with reading (**Alexia**). Difficulty with drawing objects. Difficulty in distinguishing left from right. Difficulty with doing mathematics (**Dyscalculia**). Lack of awareness of certain body parts and/or surrounding space (**Apraxia**) that leads to difficulties in self-care. Inability to focus visual attention.
- Difficulties with eye and hand coordination.

Occipital Lobes: Most posterior, at the back of the head.

Functions:

- **Vision**

Observed Problems:

- Defects in vision (**Visual Field Cuts**). Difficulty with locating objects in environment. Difficulty with identifying colors (**Color Agnosia**). Production of hallucinations Visual illusions - inaccurately seeing objects. Word blindness - inability to recognize words. Difficulty in recognizing drawn objects. Inability to recognize the movement of an object (**Movement Agnosia**).
- Difficulties with reading and writing.

Temporal Lobes: Side of head above ears.

Functions:

- Hearing ability. Memory acquisition. Some visual perceptions
- Categorization of objects.

Observed Problems:

- Difficulty in recognizing faces (**Prosopagnosia**). Difficulty in understanding spoken words (**Wernicke's Aphasia**). Disturbance with selective attention to what we see and hear. Difficulty with identification of, and verbalization about objects. Short-term memory loss. Interference with long-term memory Increased or decreased interest in sexual behavior. Inability to catagorize objects (**Categorization**). Right lobe damage can cause persistent talking.
- Increased aggressive behavior.

BRAIN STEM:

Deep in Brain, leads to spinal cord.

Functions:

- Breathing Heart Rate Swallowing Reflexes to seeing and hearing (**Startle Response**). Controls sweating, blood pressure, digestion, temperature (**Autonomic Nervous System**). Affects level of alertness. Ability to sleep.
- Sense of balance (**Vestibular Function**).

Observed Problems:

- Decreased vital capacity in breathing, important for speech. Swallowing food and water (**Dysphagia**). Difficulty with

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organization/perception of the environment. Problems with balance and movement. Dizziness and nausea (**Vertigo**).

- Sleeping difficulties (Insomnia, sleep apnea).

CEREBELLUM: Located at the base of the skull.

Functions:

- Coordination of voluntary movement Balance and equilibrium
- Some memory for reflex motor acts.

Observed Problems:

- Loss of ability to coordinate fine movements. Loss of ability to walk. Inability to reach out and grab objects. Tremors. Dizziness (**Vertigo**). Slurred Speech (**Scanning Speech**).
- Inability to make rapid movements.

Obtaining a general understanding of the brain and its functions is important to understanding the rehabilitation process. It is very important, however, to understand that the rehabilitation professional is concerned with the whole person. The identification of individual problems gives the rehabilitation team areas in which to focus treatment plans. All of these plans are designed to work toward the rehabilitation of the whole person. Each problem area affects other areas and many times resolving one problem has a major impact on other problems. For example, reestablishing postural balance and eliminating dizziness greatly enhances concentration and attention which allows for improved cognition and problem solving.[3]

Brain Injury Graphics and Animations

History of neuroimaging

In 1918 the American neurosurgeon Walter Dandy introduced the technique of ventriculography. X-ray images of the ventricular system within the brain were obtained by injection of filtered air directly into one or both lateral ventricles of the brain. Dandy also observed that air introduced into the subarachnoid space via lumbar spinal puncture could enter the cerebral ventricles and also demonstrate the cerebrospinal fluid compartments around the base of the brain and over its surface. This technique was called pneumoencephalography. In 1927 Egas Moniz introduced cerebral angiography, whereby both normal and abnormal blood vessels in and around the brain could be visualized with great precision. In the early 1970s, Allan McLeod Cormack and Godfrey Newbold Hounsfield introduced computerized axial tomography (CAT or CT scanning), and ever more detailed anatomic images of the brain became available for diagnostic and research purposes. Cormack and Hounsfield won the 1979 Nobel Prize for Physiology or Medicine for their work. Soon after the introduction of CAT in the early 1980s, the development of radioligands allowed single photon emission computed tomography (SPECT) and positron emission tomography (PET) of the brain. More or less concurrently, magnetic resonance imaging (MRI or MR scanning) was developed by researchers including Peter Mansfield and Paul Lauterbur, who were awarded the Nobel Prize for Physiology or Medicine in 2003. In the early 1980s MRI was introduced clinically, and during the 1980s a veritable explosion of technical refinements and diagnostic MR applications took place. Scientists soon learned that the large blood flow changes measured by PET could also be imaged by the correct type of MRI. Functional magnetic resonance imaging (fMRI) was born, and since the 1990s, fMRI has come to dominate the brain mapping field due to its low invasiveness, lack of radiation exposure, and relatively wide availability. As noted above fMRI is also beginning to dominate the field of stroke treatment. In early 2000s the field of neuroimaging reached the stage where limited practical applications of functional brain imaging have become feasible. The main application area is crude forms of brain-computer interface.

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Brain imaging techniques

Computed axial tomography

Computed tomography (CT) or *Computed Axial Tomography* (CAT) scanning uses a series of x-rays of the head taken from many different directions. Typically used for quickly viewing brain injuries, CT scanning uses a computer program that performs a numerical integral calculation (the inverse Radon transform) on the measured x-ray series to estimate how much of an x-ray beam is absorbed in a small volume of the brain. Typically the information is presented as cross sections of the brain.

Figure-3: Computed axial tomography

In approximation, the denser a material is, the whiter a volume of it will appear on the scan (just as in the more familiar "flat" X-rays). CT scans are primarily used for evaluating swelling from tissue damage in the brain and in assessment of ventricle size. Modern CT scanning can provide reasonably good images in a matter of minutes.

Diffuse optical imaging

Diffuse optical imaging (DOI) or diffuse optical tomography (DOT) is a medical imaging modality which uses near infrared light to generate images of the body. The technique measures the optical absorption of haemoglobin, and relies on the absorption spectrum of haemoglobin varying with its oxygenation status.

Event-related optical signal

Event-related optical signal (EROS) is a brain-scanning technique which uses infrared light through optical fibers to measure changes in optical properties of active areas of the cerebral cortex. Whereas techniques such as diffuse optical imaging (DOT) and near infrared spectroscopy (NIRS) measure optical absorption of haemoglobin, and thus are based on blood flow, EROS takes advantage of the scattering properties of the neurons themselves, and thus provides a much more direct measure of cellular activity.

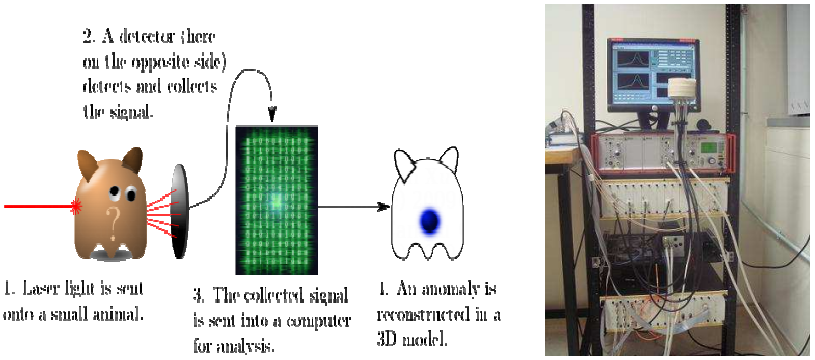

Figure-4: Diffuse optical imaging

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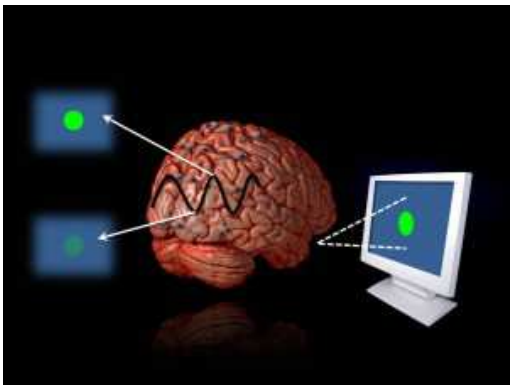

Figure-5: Event-related optical signal

EROS can pinpoint activity in the brain within millimeters (spatially) and within milliseconds (temporally). Its biggest downside is the inability to detect activity more than a few centimeters deep. EROS is a new, relatively inexpensive technique that is non- invasive to the test subject. It was developed at the University of Illinois at Urbana-Champaign where it is now used in the Cognitive Neuroimaging Laboratory of Dr. Gabriele Gratton and Dr. Monica Fabiani.

Magnetic resonance imaging

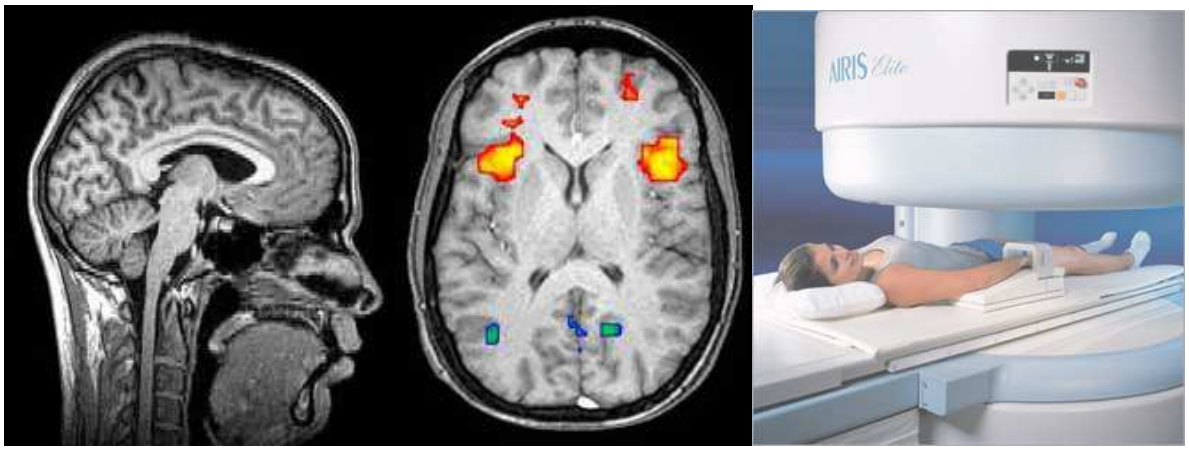

Figure-6: Magnetic Resonance Imaging (Sagittal MRI)

Sagittal MRI slice at the midline. Functional magnetic resonance imaging

Magnetic resonance imaging (MRI) uses magnetic fields and radio waves to produce high quality two- or three-dimensional images of brain structures without use of ionizing radiation (X-rays) or radioactive tracers. During an MRI, a large cylindrical magnet creates a magnetic field around the head of the patient through which radio waves are sent. When the magnetic field is imposed, each point in space has a unique radio frequency at which the signal is received and transmitted (Preuss). Sensors read the frequencies and a computer uses the information to construct an image. The detection mechanisms are so precise that changes in structures over time can be detected. Using MRI, scientists can create images of both surface and subsurface structures with a high degree of anatomical detail. MRI scans can produce cross sectional images in any direction from top to bottom, side to side, or front to back. The problem with original MRI technology was that while it provides a detailed assessment of the

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physical appearance, water content, and many kinds of subtle derangements of structure of the brain (such as inflammation or bleeding), it fails to provide information about the metabolism of the brain (i.e. how actively it is functioning) at the time of imaging. A distinction is therefore made between "MRI imaging" and "functional MRI imaging" (fMRI), where MRI provides only structural information on the brain while fMRI yields both structural and functional data.[3]

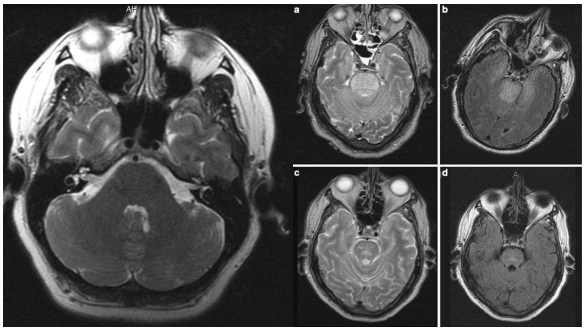

Figure-7: Axial MRI

Axial MRI slice at the level of the basal ganglia, showing fMRI BOLD signal changes overlayed in red (increase) and blue (decrease) tones. Functional magnetic resonance imaging (fMRI) relies on the paramagnetic properties of oxygenated and deoxygenated hemoglobin to see images of changing blood flow in the brain associated with neural activity. This allows images to be generated that reflect which brain structures are activated (and how) during performance of different tasks.

Most fMRI scanners allow subjects to be presented with different visual images, sounds and touch stimuli, and to make different actions such as pressing a button or moving a joystick. Consequently, fMRI can be used to reveal brain structures and processes associated with perception, thought and action. The resolution of fMRI is about 2-3 millimeters at present, limited by the spatial spread of the hemodynamic response to neural activity. It has largely superseded PET for the study of brain activation patterns.

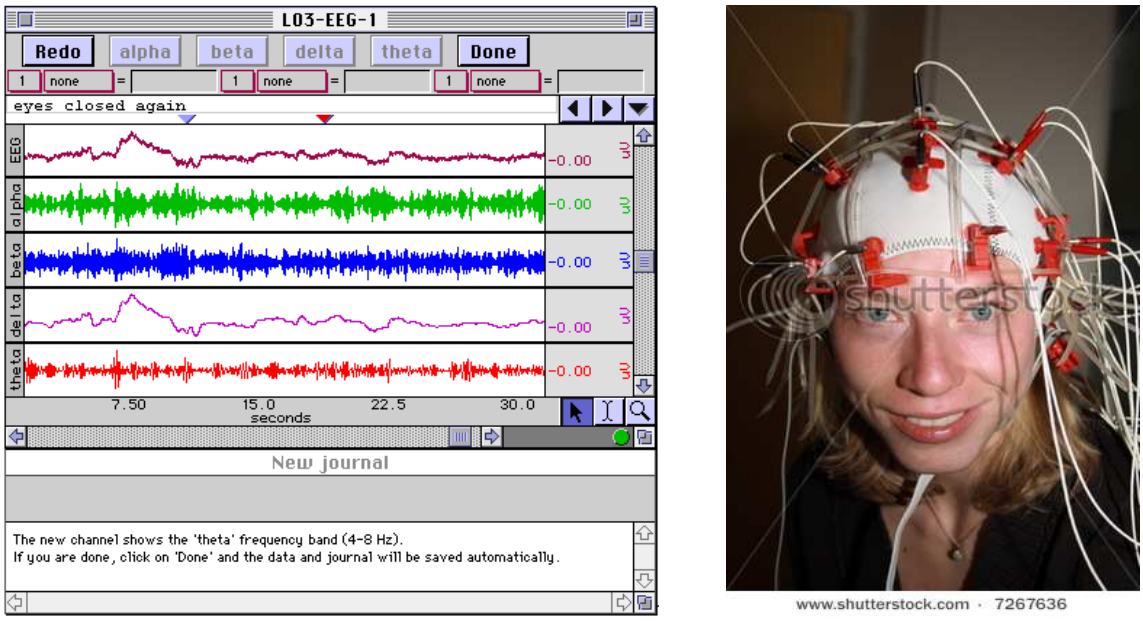

Figure-8: Electroencephalography

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PET, however, retains the significant advantage of being able to identify specific brain receptors (or transporters) associated with particular neurotransmitters through its ability to image radiolabelled receptor "ligands" (receptor ligands are any chemicals that stick to receptors). As well as research on healthy subjects, fMRI is increasingly used for the medical diagnosis of disease. Because fMRI is exquisitely sensitive to blood flow, it is extremely sensitive to early changes in the brain resulting from ischemia (abnormally low blood flow), such as the changes which follow stroke. Early diagnosis of certain types of stroke is increasingly important in neurology, since substances which dissolve blood clots may be used in the first few hours after certain types of stroke occur, but are dangerous to use afterwards. Brain changes seen on fMRI may help to make the decision to treat with these agents. With between 72% and 90% accuracy where chance would achieve 0.8%, fMRI techniques can decide which of a set of known images the subject is viewing.[4]

Electroencephalography

Electroencephalography (EEG) is an imaging technique used to measure the electric fields in the brain via electrodes placed on the scalp of a human. EEG offers a very direct measurement of neural electrical activity with very high temporal resolution but relatively low spatial resolution.

Figure-9: Magnetoencephalography

Magnetoencephalography

Magnetoencephalography (MEG) is an imaging technique used to measure the magnetic fields produced by electrical activity in the brain via extremely sensitive devices such as superconducting quantum interference devices (SQUIDs). MEG offers a very direct measurement neural electrical activity (compared to fMRI for example) with very high temporal resolution but relatively low spatial resolution. The advantage of measuring the magnetic fields produced by neural activity is that they are not distorted by surrounding tissue, unlike the electric fields measured by EEG (particularly the skull and scalp). There are many uses for the MEG, including assisting surgeons in localizing pathology, assisting researchers in determining the function of various parts of the brain, neurofeedback, and others.

Positron emission tomography

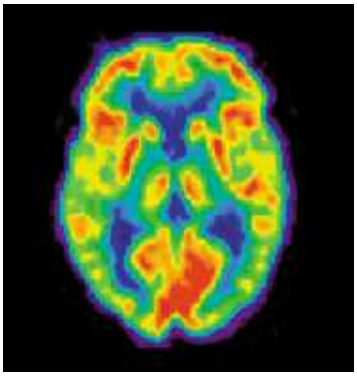

Figure-10: Positron emission tomography

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PET scan of a normal 20-year-old brain.

Positron emission tomography (PET) measures emissions from radioactively labeled metabolically active chemicals that have been injected into the bloodstream. The emission data are computer-processed to produce 2- or 3-dimensional images of the distribution of the chemicals throughout the brain. The positron emitting radioisotopes used are produced by a cyclotron, and chemicals are labeled with these radioactive atoms. The labeled compound, called a *radiotracer*, is injected into the bloodstream and eventually makes its way to the brain. Sensors in the PET scanner detect the radioactivity as the compound accumulates in various regions of the brain. A computer uses the data gathered by the sensors to create multicolored 2- or 3-dimensional images that show where the compound acts in the brain. Especially useful are a wide array of ligands used to map different aspects of neurotransmitter activity, with by far the most commonly used PET tracer being a labeled form of glucose. The greatest benefit of PET scanning is that different compounds can show blood flow and oxygen and glucose metabolism in the tissues of the working brain. These measurements reflect the amount of brain activity in the various regions of the brain and allow to learn more about how the brain works. PET scans were superior to all other metabolic imaging methods in terms of resolution and speed of completion (as little as 30 seconds), when they first became available. The improved resolution permitted better study to be made as to the area of the brain activated by a particular task. The biggest drawback of PET scanning is that because the radioactivity decays rapidly, it is limited to monitoring short tasks. Before fMRI technology came online, PET scanning was the preferred method of functional (as opposed to structural) brain imaging, and it still continues to make large contributions to neuroscience. PET scanning is also used for diagnosis of brain disease, most notably because brain tumors, strokes, and neuron-damaging diseases which cause dementia (such as Alzheimer's disease) all cause great changes in brain metabolism, which in turn causes easily detectable changes in PET scans. PET is probably most useful in early cases of certain dementias (with classic examples being Alzheimer's disease and Pick's disease) where the early damage is too diffuse and makes too little difference in brain volume and gross structure to change CT and standard MRI images enough to be able to reliably differentiate it from the "normal" range of cortical atrophy which occurs with aging (in many but not all) persons, and which does *not* cause clinical dementia.[5]

Single photon emission computed tomography

Single photon emission computed tomography (SPECT) is similar to PET and uses gamma ray emitting radioisotopes and a gamma camera to record data that a computer uses to construct two- or three-dimensional images of active brain regions. SPECT relies on an injection of radioactive tracer, which is rapidly taken up by the brain but does not redistribute. Uptake of SPECT agent is nearly 100% complete within 30 – 60s, reflecting cerebral blood flow (CBF) at the time of injection. These properties of SPECT make it particularly well suited for epilepsy imaging, which is usually made difficult by problems with patient movement and variable seizure types. SPECT provides a "snapshot" of cerebral blood flow since scans can be acquired after seizure termination (so long as the radioactive tracer was injected at the time of the seizure). A significant limitation of SPECT is its poor resolution (about 1 cm) compared to that of MRI. Like PET, SPECT also can be used to differentiate different kinds of disease processes which produce dementia, and it is increasingly used for this purpose. Neuro-PET has a disadvantage of requiring use of tracers with half-lives of at most 110 minutes, such as FDG. These must be made in a cyclotron, and are expensive or even unavailable if

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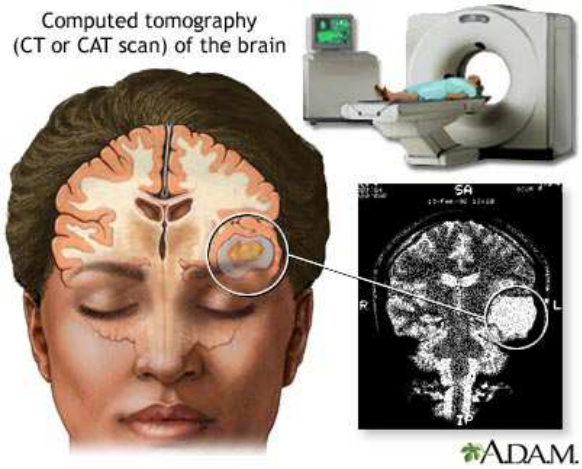
necessary transport times are prolonged more than a few half-lives. SPECT, however, is able to make use of tracers with much longer half-lives, such as technetium-99m, and as a result, is far more widely available.[6]



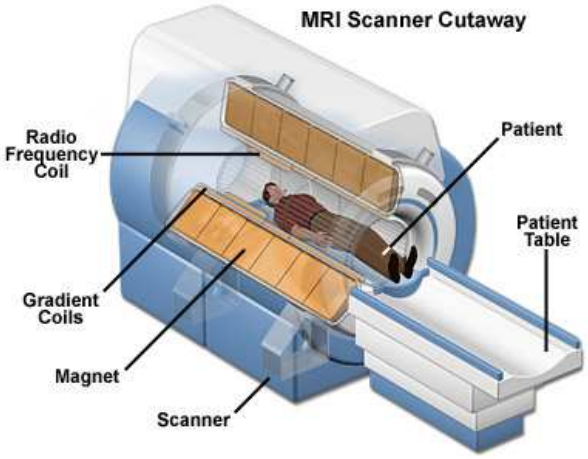


Figure-11: Single photon emission computed tomography

Neuroimaging software

Neuroimaging software is used to study the structure and function of the brain.[7]

- 3D Slicer (from Harvard, multi-purposes processing software including diffusion tensor imaging tractography) (http://www.slicer.org)
- aidScans, tumor volume estimation (http://en.wikipedia.org/wiki/Analysis_of_Functional_NeuroImages)
- Analysis of Functional NeuroImages (AFNI) (http://en.wikipedia.org/wiki/Analyze)
- BrainMagix (http://www.imagilys.com/brainmagix-neuroimaging-fmri-software/)
- BESA (Brain Electrical Source Analysis) (http://en.wikipedia.org/wiki/BESA_(Brain_Electrical_Source_Analysis)
- Bergen EEG-fMRI Toolbox plugin for EEGLab (http://fmri.uib.no/)
- Brain Image Analysis Package (http://en.wikipedia.org/wiki/Brain_Image_Analysis_Package)
- BrainVISA (http://en.wikipedia.org/wiki/BrainVISA)
- BrainVoyager (http://en.wikipedia.org/wiki/BrainVoyager)
- CamBA (http://en.wikipedia.org/wiki/Cambridge_Brain_Analysis)
- Camino Open-source toolkit for diffusion MRI. (http://en.wikipedia.org/wiki/Camino_)(diffusion_MRI_toolkit)
- Caret Van Essen Lab, http://en.wikipedia.org/wiki/CARET_(Computerized_Anatomical_Reconstruction_and_Editing_Toolkit)
- Fiasco/FIAT (from CMU) (http://www.stat.cmu.edu/~fiasco/)
- FMRIB Software Library (FSL) (http://en.wikipedia.org/wiki/FMRIB_Software_Library)
- FMRLAB (http://sccn.ucsd.edu/fmrlab/index.html)
- FreeSurfer (http://en.wikipedia.org/wiki/FreeSurfer)
- ISAS (Ictal-Interictal SPECT Analysis by SPM) http://en.wikipedia.org/wiki/ISAS_(Ictal-Interictal_SPECT_Analysis_by_SPM)

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- Leipzig Image Processing and Statistical Inference Algorithms (LIPSIA) http://en.wikipedia.org/wiki/Leipzig_Image_Processing_and_Statistical_Inference_Algorithms_(LIPSIA)
- LONI Pipeline Laboratory of Neuro Imaging, UCLA (http://pipeline.loni.ucla.edu/)
- Mango, developed at the Research Imaging Center, University of Texas Health Science Center at San Antonio (http://en.wikipedia.org/wiki/Mango)
- MRIcro (http://www.cabiatl.com/mricro/)
- mrVista (http://white.stanford.edu/newlm/index.php/Software)
- MRVision (http://www.mrvision.com/html/main.shtml)
- NeuroLens (http://www.neurolens.org/NeuroLens/Home.html)
- Statistical parametric mapping (SPM) (http://en.wikipedia.org/wiki/Statistical_parametric_mapping)
- http://www.thebrain.com/

Conclusion: Cognition is the scientific term for "the process of thought". Usage of the term varies in different disciplines; for example in psychology and cognitive science, it usually refers to an information processing view of an individual's psychological functions. Other interpretations of the meaning of *cognition* link it to the development of *concepts*; individual minds, groups, and organizations. The term cognition (Latin: *cognoscere*, "to know", "to conceptualize" or "to recognize") refers to a faculty for the processing of information, applying knowledge, and changing preferences. Cognition, or cognitive processes, can be natural or artificial, conscious or unconscious. These processes are analyzed from different perspectives within different contexts, notably in the fields of linguistics, anesthesia, neurology, psychology, philosophy, anthropology, systemics, computer science and creed. Within psychology or philosophy, the concept of cognition is closely related to abstract concepts such as mind, intelligence, cognition is used to refer to the mental functions, mental processes (thoughts) and states of intelligent entities (humans, human organizations, highly autonomous machines and artificial intelligences). Technological advances have led to greater use of both structural and functional brain imaging to assist with the diagnosis of dementia for the increasing numbers of people with cognitive decline as they age. In current clinical practice, structural imaging (CT or MRI) is used to identify space-occupying lesions and stroke. Functional methods, such as PET scanning of glucose metabolism, could be used to differentiate Alzheimer's disease from frontotemporal dementia, which helps to guide clinicians in symptomatic treatment strategies. New neuroimaging methods that are currently being developed can measure specific neurotransmitter systems, amyloid plaque and tau tangle concentrations, and neuronal integrity and connectivity. Successful co-development of neuroimaging surrogate markers and preventive treatments might eventually lead to so-called brain-check scans for determining risk of cognitive decline, so that physicians can administer disease-modifying medications, vaccines, or other interventions to avoid future cognitive losses and to delay onset of disease. The brain's wiring diagram may help us better understand how we learn and adapt. "We start out being less well adapted to our environment than any other animal. By the time we're adults, we can use tools that our genetic heritage couldn't possibly have taught our nervous system to use -- like iPods. No other animal can do that. During our development, we must wire ourselves to use these machines." Brain mapping is also of practical use to doctors. Neurosurgeons use brain mapping to plan safer surgeries. One treatment for epilepsy, for example, removes the affected part of the brain. Using

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functional MRI and EEG, surgeons can locate the seizure center in a patient's brain -- as well as areas that are active during speaking and moving -- down to the millimeter. These images tell doctors what to leave and what to cut out.

Brain imaging is not only used in treatment. It is used to diagnose neurodegenerative diseases like Parkinson's and Alzheimer's. Using tagging techniques like PET, doctors look for drops in certain brain chemicals, or they may use MRI to examine shrinkages in areas show tissue loss. Over time, doctors can map what the brain looks like as diseases progress or as treatments work. Developmental disorders like autism may have a structural basis in the brain. By applying Brainbow to a mouse with autism, researchers might see the wiring diagram evolve to find out how, when and if the wiring goes wrong. Scientists have also sought to illustrate the effects of various mental illnesses in the brain, with some success. Brain imaging on these patients revealed structural abnormalities. For example, structural MRI has shown that schizophrenic patients lose matter in the temporal and prefrontal cortex over time. These findings have yet to lead to treatments.

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