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Neuroimaging: the four most important methods:

The various techniques known as «neuroimaging» enable us to see how the brains of test subjects function by means of images. These images are not photographic recordings, but are calculated on the basis of a huge amount of data. Highly sensitive equipment is used to record the requisite data. With the aid of neuroimaging, it is possible to investigate both the structure and functioning of the brain (see Table «Neuroimaging methods»).

1. Magnetic Resonance Imaging (MRI)

This method gives the most detailed information about the structure of the living brain. MRI measures signals in the body that are generated by an extremely strong magnetic field combined with radio waves. The strength of magnetic fields is measured in «tesla» units. The MRI scanners in current use work with a field strength of between 1.5 and 3 tesla, which is equivalent to approximately 50,000 times the Earth's natural magnetic field. Even more powerful scanners are being developed for research.

If someone is exposed to such a strong magnetic field, the nuclei of the hydrogen atoms are aligned in a certain way. Hydrogen is a component of all tissues in the human body. Radio waves also cause these nuclei to emit signals. These signals depend, among other things, on how strongly the magnetic field has deflected the nuclei from their original position. A scanner records the signals. From the measurement data, computers calculate the spatial distribution and the magnetic properties of the hydrogen nuclei that have been activated during the examination. These data are used, in turn, to construct highly detailed images of the tissue being examined.

Based on current knowledge, the magnetic field strengths applied today are not harmful to the human body. Up to now, radio waves have not been shown to have any harmful effect, either.

2. Functional Magnetic Resonance Imaging (fMRI)

In recent years, fMRI has become one of the most important methods used in the cognitive neurosciences. Measurement is done on the same principle as that used in MRI, but the scanners are no longer set up to record the signals from the hydrogen nuclei; instead they measure the signals coming from haemoglobin.

Haemoglobin – a key constituent of blood – transports oxygen from the lungs to the place in the metabolism where it is needed, the brain cells for instance. By releasing oxygen, the haemoglobin alters its magnetic properties. And that is precisely what forms the basis of the fMRI measurement: the scanner can measure the distribution of oxygen-saturated, as well as unsaturated, haemoglobin in the brain. Because every area of the brain that is particularly active is supplied with an abundance of oxygen-rich blood, it is possible to localise a particular area using an fMRI scan. The significance of the results is somewhat reduced by the indirect nature of the measurement; the flow of oxygen in the brain is just one consequence of brain activity, but not the brain activity itself. Linking the activity of the brain cells with the oxygen content of blood is, however, regarded as a sufficient basis for making reliable statements.

3. Positron Emission Tomography (PET)

PET shows up metabolism activities in the tissue. For this purpose, signals given off by radioactively marked substances are measured. Such substances are administered to test subjects immediately prior to measurement. Through the blood circulation, they take about 30 seconds to reach the brain. Their radioactive disintegration produces radiation that is recorded on a measuring device. The measurement data can be used to calculate sectional images or three-dimensional views of the tissue in which the marked substance has been circulating.

Safety precautions are imperative when using radioactivity. Care is taken to use as low a dose of radiation as possible. In general, no substances are used that might accumulate in the body. The preferred compounds are those whose radiological emission quickly subsides. For the test subjects, as well as for the personnel involved, limits are imposed in Switzerland on the maximum permitted level of radiation exposure. For women under 45 years of age, there are particularly strict conditions, and children are generally only examined using PET if there is a clinical reason for doing so.

4. Electroencephalogram EEG

The brain «at work» constantly produces electrical signals, as stimuli are transmitted between the nerve cells electrically. With the aid of electrodes affixed to the scalp, these signals can be recorded and rendered visible by sensitive measuring equipment. However, the signals measured on the scalp allow only an indirect conclusion as to which area of the brain actually triggered them. Only in the last few years has the EEG been further developed into a method that also enables statements to be made about which point in the brain a particular activity occurs at. This localisation requires the use of a large number of electrodes, from whose measurements computers can calculate an image of the spatial distribution of the brain activities measured. This is now possible with increasing precision, which is why the EEG is regarded as a highly promising method.

One major advantage of the EEG lies in the fact that there are virtually no risks involved in using it. The signals measured are those that the brain has produced itself, without the need for any outside influence – be it radiation or chemical compounds.

Table: Neuroimaging methods (selection)

Method	Examination of the structure of the brain	Examination of the function of the brain	Smallest identifiable brain structure	Medium used for the measurement
MRI	Yes	No	1 mm	Magnetic field and radio waves
fMRI	No	Yes	1 mm	Magnetic field and radio waves
PET	No	Yes	2 mm	Radioactively marked substances
EEG	No	Yes	10 mm	None 1)

1) This method measures the electrical current generated by the brain itself

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