Cognitive Neuroscience for AI Developers (CNAID)

SS 2023

Week 6, Imaging Techniques (MRI, fMRI, PET, online lecture of Prof. Maier)

Exercise sheet by Achim Schilling

Multiple Choice Exercise

(Please mark the right answer with a cross. Only one answer is correct!)

Q1: Which statement on imaging techniques is correct?

- o fMRI has a temporal resolution of approximately 100 Hz False
- o EEG has a better spatial resolution than fMRI False: EEG has a low spatial resolution (cm scale, Million neurons) fMRI good resolution (sub-mm)
- o fMRI measures neural activity and is well suited to measure gamma-waves False: fMRI has a low temporal resolution (gamma waves: above 30 Hz)
- X In fMRI studies the blood oxygenation level is measured in order to draw conclusions on the underlying neural activity True
- o PET was developed to measure small currents in the brain False: Tracer is injected in blood. Positrons from tracer annihilate with electrons. Photons are emitted by annihilation -> blood flow is measured -> no electrical signal

Q2: Which statement on imaging techniques is **not** correct?

- o CT (computed tomography) and MRI are used to measure the structure of the brain and take advantage of the different physical properties of the brain tissue True
- o fMRI in contrast to standard MRI is used to draw conclusions on neural processing True
- o In CT, a 3D volume is reconstructed from 2D x-ray images True
- o MRI exploits the effect that hydrogen nuclei have a spin that creates a tiny magnetic dipole True
- X The magnetic field strength in MRI scanners is approximately 10 fT False: MRI uses field strengths of up to 7 T; MEG measures small field strengths on fT scale

Q3: Which statement on PET is **not** correct?

- X PET like MRI relies on the spin of hydrogen nuclei False: PET measures photons from annihilation process of electrons and positrons (coincidence detection)
- o For PET measurements a radioactive tracer is injected True
- o The tracer decays and emits positrons that annihilate with the electrons of the tissue to be measured True
- o The annihilation of an electron and a positron emits two photons that move in opposite directions True
- o PET can be used to draw conclusion on neural activity as it measures local variations in cerebral blood flow which are correlated to mental activity True

Q4: Which statement on fMRI is correct?

- o BOLD stands for blood overcompensation duration False: blood oxygenation dependent response
- o fMRI exploits the magnetic properties of acetylcholine False: of hemoglobin (transports oxygen in blood)
- o fMRI has a very high temporal resolution comparable to MEG False: MEG has better temporal resolution
- X in fMRI the fraction of oxygenated and deoxygenated hemoglobin is measured called the blood oxygen level-dependent (BOLD) effect True
- o fMRI measurements are highly suited for auditory neuroscience as it simple to present auditory stimuli in an MRI scanner False: fMRI scanners are very loud; no magnetic earphones are allowed in the scanner

Discussion Exercise

1) Why we need several imaging techniques

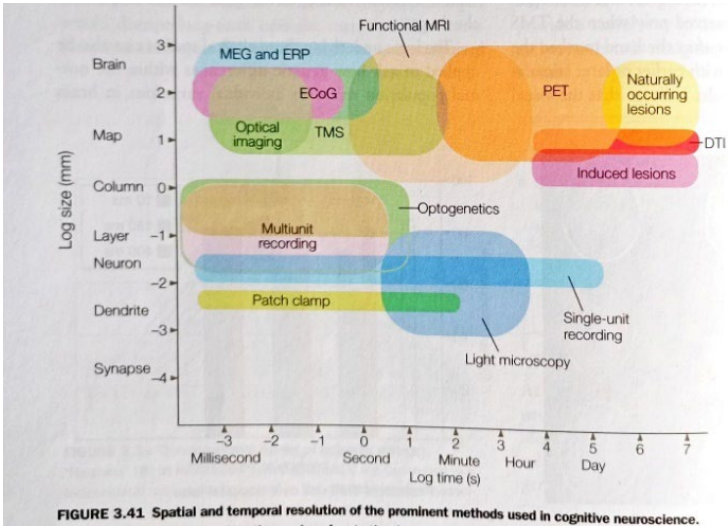


FIGURE 3.41 Spatial and temporal resolution of the prominent methods used in cognitive neuroscience.

from Gazzaniga, Ivry, Mangun, Cognitive Neuroscience, The biology of the mind, 2014

Think about and reason why we need so many different imaging techniques with the help of the following illustration.

We need a variety of methods to measure the brain, as all techniques have a different temporal and spatial resolution. Thus, methods like standard MRI and CT are used to measure only physical properties of the brain tissue (static properties). fMRI and PET can be used to measure some processes (change of blood flow or oxygenation level). However, the temporal resolution is low (second-scale). Nevertheless, large parts of the brain can be measured in one measurement session. MEG and EEG can also be used to measure large parts of the brain in one session. The temporal resolution is better, but the spatial resolution is worse. To get a better spatial and temporal resolution one could for example place glass capillaries (patch-clamp) or electrodes (single-unit recordings) in the brain (animal studies). However, each ion channel resp. neuron has to measured individually (no overview over brain). Many of these methods or even better a combination of these methods is useful.

2) Diffusion Tensor Imaging

"[…] diffusion tensor imaging (DTI) is performed with an MRI scanner that measures the density and motion of water contained in the axons." (Gazzaniga et al., 2014)

Gazzaniga, Ivry, Mangun, Cognitive Neuroscience, The biology of the mind, 2014

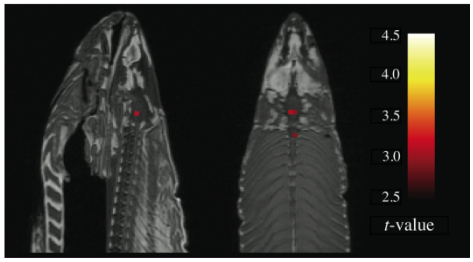
DTI is useful to find out how brain parts are connected via axons (for example corpus callosum). Furthermore, in neurology damages of the axons can be determined.

For which purposes DTI can be used in neuroscience and Neurology?

3) The dead salmon and statistics

"Subject. One mature Atlantic Salmon (Salmo salar) participated in the fMRI study. The salmon was approximately 18 inches long, weighed 3.8 lbs, and was not alive at the time of scanning.

Task. The task administered to the salmon involved completing an open-ended mentalizing task. The salmon was shown a series of photographs depicting human individuals in social situations with a specified emotional valence. The salmon was asked to determine what emotion the individual in the photo must have been experiencing.



A *t*-contrast was used to test for regions with significant BOLD signal change during the photo condition compared to rest. The parameters for this comparison were $t(131) > 3.15$, p(uncorrected) < 0.001, 3 voxel extent threshold.

from (Bennett et al., 2009)

Design. Stimuli were presented in a block design with each photo presented for 10 seconds followed by 12 seconds of rest. A total of 15 photos were displayed. Total scan time was 5.5 minutes." (Bennett et al., 2009)

Bennett, C. M., Miller, M. B., & Wolford, G. L. (2009). Neural correlates of interspecies perspective taking in the post-mortem Atlantic Salmon: An argument for multiple comparisons correction. *Neuroimage*, *47*(Suppl 1), S125.

This a is a part of the Methods section of a scientific poster published in 2009.

1) Is this at a first glance funny experiment useful and if yes why?
2) Compare the idea behind this study also with the idea behind the publication. "Could a neuroscientist understand a microprocessor" from Jonas and Kording.

Jonas, E., & Kording, K. P. (2017). Could a neuroscientist understand a microprocessor?. *PLoS computational biology*, *13*(1), e1005268.

1) The experiment is useful. The authors of the study use a model system (dead salmon) to test their methods. The authors find out that the statistics they use is insufficient, as even in a dead salmon significant brain activity can be found. Thus, the statistical methods have to be reworked and improved. It is a standard procedure in science to apply methods on models, which are fully understood to test these methods.
2) Thus, the dead salmon in the study of Bennett and coworkers is the same as the microprocessor in the publication of Jonas and Kording. Jonas and Kording test methods widely used in neuroscience to find out, if these methods are sufficient to unravel how the microprocessor works. They conclude that these methods are not sufficient to explain the function of a microprocessor and thus are also not sufficient to understand the brain..