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The Neurophysiology of Human Visual Perceptual Learning

It is currently still a subject of research, which brain areas are involved in visual perceptual learning. There are various models that attribute either higher or lower areas to perceptual learning. To identify the involved brain areas and to understand the underlying brain networks, brain signals must be investigated in relation to the given stimuli and in combination with the respe behavioural results. It is well known that perceptual learning is related to the task, placement of the stimulus and the difficulty of the task. The attention of the subject also seems to influence the involved stages and areas of visual processing[7].
Electroencephalography (EEG) and near-infrared spectroscopy (NIRS) are used to identify the networks and brain structures involved. Ding et al. (2003) used a visual orientation learning task with EEG and indicated that training induced event-related potentials at specific electrode positions in the occipital and parietal brain area[2,3].

Electroencephalography (EEG)

- non-invasive method
- measures electrical brain activity from the surface of the scalp
- acquires timeseries of global activity of the cerebral cortex, in the range of µV[8]
- electrical activity results from currents that flow during synaptic excitation of the dendrites of many pyramidal neurons in the cerebral cortex[8]

Fig. 1) Electrode configuration of the used EEG and NIRS system.

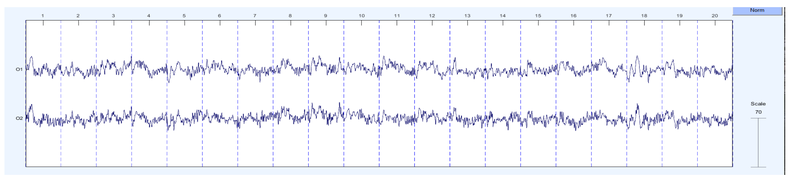

Fig. 2) EEG timeseries data of the two occipital electrodes O1 and O2 created with eeglab[5].

Visual Perceptual Learning (VPL)

Definition [1,2,3,4] : VPL is definded as an improvement in performance on perceptual tasks after training with stimuli related tasks. VPL has been found in a wide variety of animal models and humans.

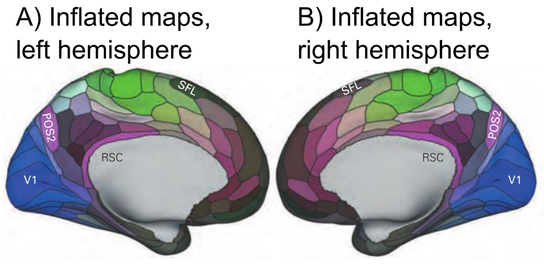

Fig. 3) Regions of the human brain. Colored areas indicate different sensory modalities. red: auditory system, green: somatomotor system and blue: visual system. (modified from Kandel et al.[8])

Learning Effects [1,2,3,4] :

- selective for stimulus orientation, spatial frequency, retinal location
- retained for a few days and retained partially after >6 months

Models of VPL [3]

- task relevant[7]
  - reversed hierachical model[7]
  - external and internal noise method[6,7]
- task irrelevant VPL[7]

Categorisation Tasks

- go/no-go task with only two stimuli and response options
- Stimulus flashed for only 20 ms in central visual field
  - Only noise (NA) or
  - A with noise (A)

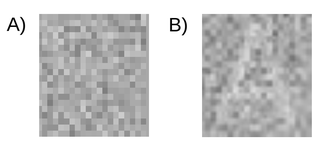

Fig. 4) Representation of the two stimuli.
A) Presentation of noise only B) Presentation of the “A” with noise.

Results Categorization Task – Pilot Measurement

Methods:

- event related potential (ERP) of the two stimuli (averaged over all trials). ERPs are spikes of brain signal shortly after stimulus onset. They occur rapidly and posses different polarities[2].
- reference: average of all electrodes
- bandpass filtered between 1 and 40 Hz

Results:

- observed differences
  - in level of the amplitudes and
  - in activity onset after stimulus presentation
- electrode position O2 shows different levels of the second activity peak over time
- electrode position O1 shows nearly equal level of the second activity peak over total trials

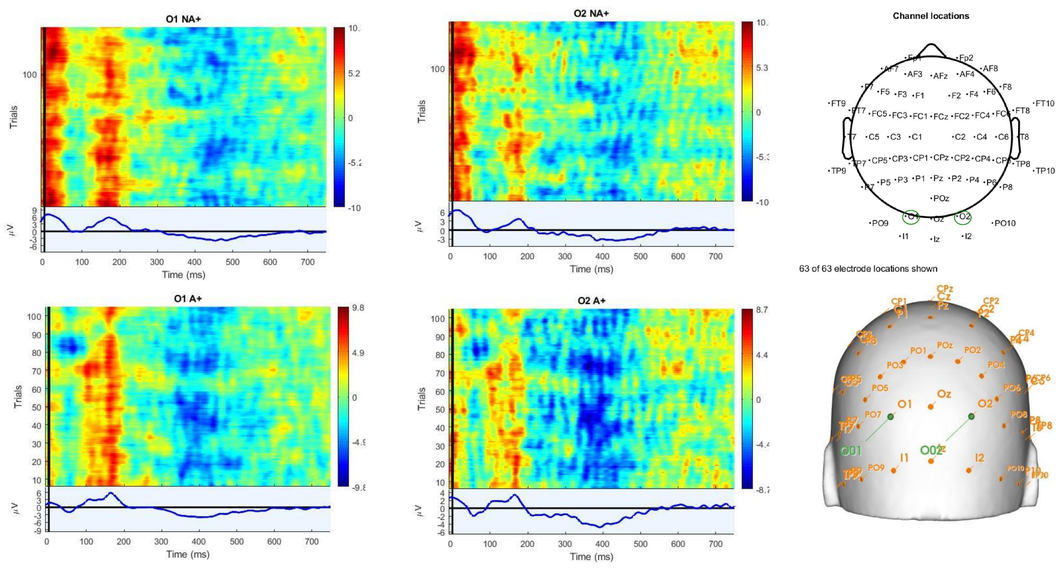

Fig. 5) ERPs for specific events over all trials at different positions on the scalp. There is a clear difference between the stimuli with and without noise. The rows indicated the shown stimuli, with (NA+) or without noise (A+). The columns indicate the plotted electrode position O1 and O2. „+“ indicate correct answer by the subject (created with eeglab[5]).

Future Prospect:

- Analysing the involved brain networks (e.g. attention networks)
- Finding models that reflect the decision of the subjects and use them for prediction of:
  - the resulting ERPs or
  - the underlying brain activity (e.g. frequency range)
- Measuring more subjects, trials and NIRS

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[6] Dosher, B. A., & Lu, Z. L. (2005), DOI: 10.1016/B978-012375731-9/50082-3 [7] Watanabe, T., & Sasaki, Y. (2015), DOI: 10.1146/annurev-psych-010814-015214
[8] Kandel, E. R. et al. (2021). Principles of Neural Science. In *Mc Graw Hill*. ISBN: 978-1-25-964224-1