Title:

Impact of closed-loop control and auditory beats on human attention

Attention-deficit/hyperactivity disorder (ADHD) is a neuropsychiatric disorder. It is characterized by, inter alia, inattention, hyperactivity and impulsivity. Visual attention reflects a certain degree of alertness and it has been shown experimentally in adult ADHD patients that pharmacological medication may well improve the ADHD patients' visual processing speed. Since pharmacological medication typically yields cognitive adverse side effects, an alternative non-pharmacological neurofeedback or performance feedback may represent an alternative light treatment. The current project proposes a combination of auditory stimulation and the performance feedback to demonstrate that non-pharmacological feedback may also improve visual attention deficits in ADHD. To this end, optimization, control feedback and experimental psychophysics will be employed.

Feedback schemes are well-known to improve visual attention. The most prominent approach is neurofeedback [1], which feeds back features of measured neural activity, such as the visualized spectral power distribution of brain activity or its power in certain frequency bands. Neurofeedback is known to entrain brain activity in certain frequency band and improve visual attention. However, such neurofeedback requests costly neural electronic devices capturing brain signals. These devices may be available to patients in experimental laboratories only or may be purchased privately for a high price. The aim of our project is to develop a computational feedback tool, that does not need specialized costly electronic devices but may be implemented as a software utility. A good candidate for a non-neural feedback is *performance feedback* [2], which feeds back the real-time behavioral performance. This performance may be the subjects reaction time or accuracy of performed trials. It is fed back to the subject synchronously with the experimental tasks. In such a setting, visual attention is reflected in the behavioral performance: for instance, the faster the subject responds to the stimuli, the higher is the subjects visual attention.

Moreover, it is well-known that auditory stimulation improves visual attention. We will employ binaural beats [3] which have been proposed to remedy visual attention deficits in adolescents and adults [4]. The optimal combination of performance feedback and auditory stimulation permits to improve visual attention optimally.

Psycho-physical experiments follow a specific pre-defined protocol including, e.g., the duration of a single experimental trial, inter-trial intervals, number of repetitions. An optimal choice of these parameters may yield an optimal experimental performance, such as maximum attention with a extended long-term effect. Optimal parameters are hard to find in standard protocol setups. The Postdoctoral researcher will employ numerical optimal search strategies and will implement these in psycho-physical experiments applied on healthy subjects and subjects showing light attention deficits. The psycho-physical experiments will be performed in the INRIA-team MIMESIS and in the team INSERM1114, both located in Strasbourg.

In sum, the project proposes to extend the current research on the cognitive impact of performance feedback by providing an optimal protocol scheme. Neurofeedback is known to improve visual attention in ADHD patients but requests the patient to visit an experimental lab due to extensive technological requests. Our project will combine experimental psycho-physical experiments with optimal parameter search. The long-term aim of our project is to develop a Python software package, that permit to control cognitive experiments with performance feedback that may replace electrophysiological neurofeedback and, in the future, may be applicable at home by installing a software.

[1] Ordikhani-Seyedlar et al. (2016) Neurofeedback Therapy for Enhancing Visual Attention: State-of-the-Art and Challenges. *Front. Neurosci*. 10:352.

[2] Mensen, et al. (2022) The effects of real-time performance feedback and performance emphasis on the sustained attention to response task (SART). *Psychological Research* 86 :1972–1979

[3]Chaieb et al. (2015) Auditory beat stimulation and its effects on cognition and mood states. *Front. Psychiatry* 6:70.

[4] Aparecido-Kanzler et al. (2021) Effects of binaural beats and isochronic tones on brain wave modulation: Literature review. *Rev Mex Neuroci.* 22(6):238-247

The team:

The project will be located in the INRIA-team MIMESIS (https://mimesis.inria.fr/). The Principal Investigator will be Axel HUTT (https://mimesis.inria.fr/members/axel-hutt/), who has been working on neurostimulation methods for several years (see also publication list https://www.geocities.ws/digitalbath/). Please contact A. Hutt (axel.hutt@inria.fr) for more details.