Methodology for enhanced and adapted neurofeedback trainings

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Context

The project lies at the interface of behavioural neuroscience, signal and image processing and neurofeedback. Neurofeedback approaches (NF) (see [7] for a complete and actual introduction), also known as restorative brain-computer interface (restorative BCI), consist in providing real-time feedback to a patient about his or her own brain activity in order to learn how self-regulate specific brain regions and help him or her perform a given task. The estimation of neurofeedback scores is done through online brain functional feature extraction relying for the majority on electroencephalography (EEG) or functional magnetic resonance imaging (fMRI). Recent studies [13, 12, 6] have shown the high potential of combining EEG and fMRI in a bi-modal NF training (i.e., NF scores are estimated in real-time from features of both modalities) to achieve an improved self-regulation, by providing a more specific estimation of the underlying neural activity. NF is a very promising brain rehabilitation technique for psychiatric disorders, stroke and other neurological pathologies [12].

Measures of brain activity through fMRI or EEG are ground solutions in the context of NF for brain rehabilitation protocols and EEG is currently the only modality used by NF clinical practitioners. EEG, which directly measures changes in electrical potential occurring in the brain in real time, has an excellent temporal resolution (hundreds of milliseconds), but has a limited spatial resolution (around centimetre) due to cortical currents volume conduction through head tissue. On the other hand, fMRI offers a better spatial resolution (few millimetres) but has slow dynamics (one or two seconds) as it measures neuro-vascular (i.e. changes in the blood oxygenation level) activities, which occurs in general, a few seconds after a neural event [3, 4]. Moreover, using a MRI scanner is costly, exhausting for patients (since staying perfectly still when suffering is challenging), and time-consuming.

Although exceptional progress has been obtained during the past decades to explore the human brain, researches based on different neuro-imaging modalities are crucial to shed light on healthy and disordered human brains, as well as understanding the complex link between anatomical and functional properties of the brain [9, 10].

Before providing NF training of improved quality and adaptable to the participant, one central question is to identify the origin of a failure [1, 8]; it can be due to (1) the signals feature extraction, (2) a too difficult task, (3) the patient's inability to learn via NF [11], or (4) a lack of attention from the patients (are they actively trying to change their brain activity?) during the task [2]. Also, motivation should be enhanced, if possible, and the prevailing attention of the participants should be monitored [5]. As highlighted in [1], **to have the best success in NF sessions, it is suggested to personalise and adapt NF session to the participant, which is the main objective of this PhD thesis.**

Main activities

Relying on this context, the goal of this thesis it to investigate and propose methods to provide improved and adaptable NF trainings to participants. This thesis will seek to address the following challenges :

- (1) Monitoring and analysing participant's motivation in real time during NF training.
- (2) Investigating adaptable targets to avoid the too difficult task issue, by proposing new NF scores computation and determining a hierarchy between different NF scores computations based on EEG and fMRI signals.
- (3) Modelling of EEG and fMRI signals to understand the link between those signals and optimise the feature extraction from EEG when used alone.

Required skills

- Signal and Image processing

- Knowledge or interest in machine learning, modelling or statistics
- Knowledge or interest in neuroimaging
- Knowledge or interest in Neuroscience
- Strong experience in programming, especially in Python and/or Matlab will also be valued
- Interest in data aquisition (for new NF training recording)
- Very good understanding of English

This position requires solid background in computer science, signal or image processing and machine learning or statistics. Knowledge in neuroimaging or neuroscience would be appreciated. Strong experience in programming, especially in Python and/or Matlab will also be valued.

Applicants should send their complete application package by including a complete CV, a motivation letter, at least two recommendation letters or names and contact of the mentors. Incomplete applications will not be processed.

Job environment

The successful candidate will join the Unit/Project Empenn – U1228. This research team is jointly affiliated with Inserm (national institute of health and medical research), Inria (national institute of computer science research) and belongs to the IRISA institute (UMR CNRS 6074, University of Rennes I). The team is located in Rennes, France and has offices in both the medical and the physical sciences campuses. More information can be found at: `https://team.inria.fr/empenn`. The project will also benefit from transverse collaborations with clinical projects through the Neurinfo experimental platform located at the University Hospital in Rennes (cf. `http://www.neurinfo.org/`).

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