Probing EEG activity evoked by non-stationary dynamic visual textures

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Domain The internship is one piece of a bigger project aiming at the development of a Brain Computer Interface (BCI). A BCI is generally a closed-loop circuit composed of a human wearing a brain activity recording device connected to a computer. This computer is equipped with software that is able to convert brain activity to instructions in order to control another software or a hardware (video games, regular desktop activity, artificial arm/leg, etc., . . .). The resulting action on the software or hardware is perceived by the human observer who in turn should be able to modify their own brain activity to try to achieve a desired control over the software or hardware.

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Objective The aim of this internship is to to collect and to analyze the EEG signal evoked by dynamical changes in textures. The goal is then to establish a direct link between the visual stimulus features and their corresponding EEG signatures. Such signatures could potentially be turned into sharp and reproducible markers utilizable for BCI calibration.

Candidate profile The ideal candidate is interested in perception in all aspects from experimental work to data analysis and models. The work will involve the design of an experimental task, data collection and analysis. The candidate is familiar with `python` or `matlab`.

Details *Context* A growing number of studies is dedicated to the decoding of brain activity evoked under various conditions using a variety of machine learning pipelines [1]. Yet, the studies that focus on visual perception are scarce [2, 3]. The decoding of brain activity is crucial to the development of BCI and some key paradigms rely on visual stimulation (visual P300) for the calibration of the BCI [4, 5].

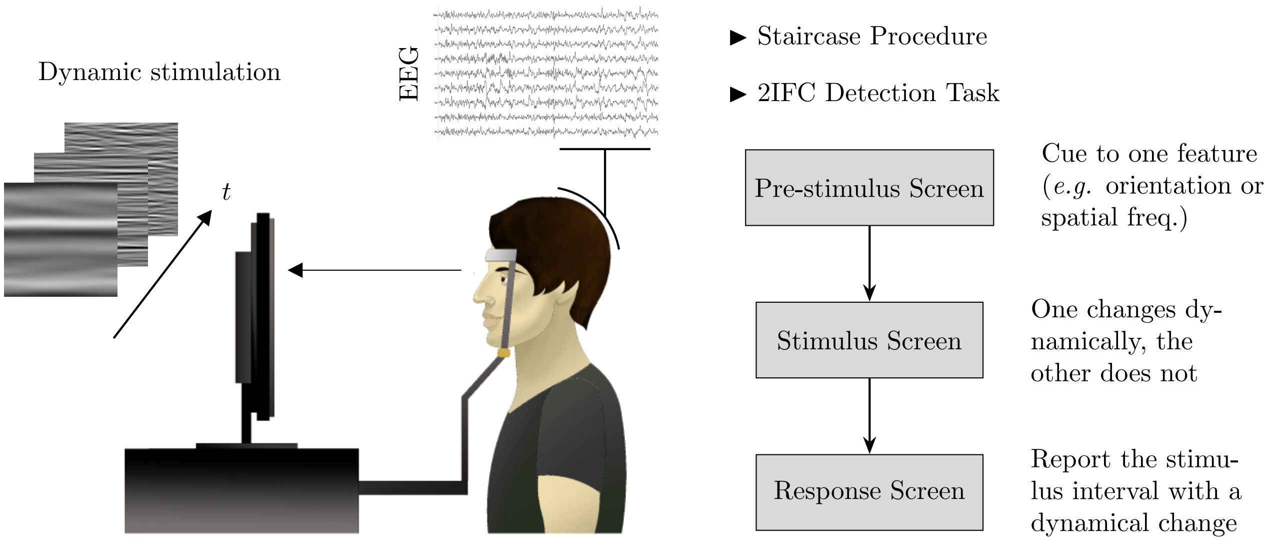

Figure 1: Left: simplified sketch of the experimental protocol. Right: experimental protocol ensuring a proper manipulation of the participant visual attention.

Classification of EEG Signals Evoked by Dynamic Texture Changes The main objective of this internship is to collect preliminary data. More precisely, we intend to collect two preliminary datasets. The first dataset will be composed of EEG signal recorded at the surface of the skull of a human participant who is passively looking at non-stationary dynamic textures (see Figure 1 left). We will explore the full parametric space of the dynamic textures *i.e.* we will test dynamical changes in spatial frequency, orientation and their bandwidth. The second dataset will be composed of similar EEG signal but collected on human participants whose feature-based attention (attention allocated to specific features of the stimulus in the absence of eye movements) is manipulated. This requires a well-controlled experimental protocol precisely manipulating attention and ensuring that the manipulation was successful. The protocol is as it follows (see also Figure 1 right).

(i) Run a standard staircase procedure in which the feature of interest is parametrically modulated to obtain a first estimate (for each participant) of the perceptual sensitivity to dynamical changes in this feature.

(ii) Run a two interval forced choice (2IFC) detection task in which attention is cued to a specific feature and then participants are instructed to report a dynamical change of a target stimulus feature.

   (a) Pre-stimulus screen: give instruction to the participant to attend to a specific feature (*e.g.* stimulus orientation or spatial frequency).

   (b) Stimulus screen: after a short delay, present a sequence of two stimuli; one has a dynamical change over a feature (*e.g.* stimulus orientation or spatial frequency), the other has no change.

   (c) Response screen: ask to the participant which of the two stimuli was dynamically changed.

In this task, we expect the participant to have high hit rate (*i.e.* a high sensitivity) when attention is cued to the feature that is actually changing in the stimulus screen. In contrast, when attention is cued to a feature that is different from the one that is changing, the participant is expected to have a low hit rate (*i.e.* a low sensitivity). This result will confirm feature-based attention was successfully manipulated, a necessary step before interpreting any related neural activity. The staircase procedure is necessary to get an estimate of the participant sensitivity in order to be able to observe lower and higher sensitivity.

After collecting the data, we will evaluate the decoding performance (*i.e.* the classification performances obtained in the supervised learning problem of predicting the perceived stimulus from the recorded neural activity) using several machine learning methods readily available in scikit-learn ([6, 1], `https://scikit-learn.org/`).

References

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