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Abstract

Neurofeedback training describes a closed-loop paradigm in which a Brain-Computer Interface is typically used to provide a subject with an evaluation of his/her own mental states. As a learning process, it aims at enabling the subject to apprehend his or her own latent cognitive states in order to modulate it. Its use for therapeutic purposes has gained a lot of traction in the public sphere in the last decade, but conflicting evidence concerning its efficacy has led to increasing efforts by the scientific community to provide better explanations for the cognitive mechanisms at work.
We intend to contribute to this effort by proposing a mathematical formalization of the mechanisms at play in this (arguably) quite complex dynamical system.Due to the subjective nature of the task, a representation of the subject and experimenter separate beliefs and hypothesis is an important first step to propose a meaningful approximation. We provide a first model of the training loop based on those considerations, introducing two pipelines. The direct pipeline (subject-> feedback) makes use of a coupling between cognitive and physiological states to infer latent cognitive states from measurement. The return pipeline (feedback-> subject) describes how perception of the indicator impacts subject behaviour.To describe the behaviour of an agent facing an uncertain environment, we make use of the Active Inference framework (1), a bayesian approach to belief updating that provides a biologically plausible model of perception, action and learning.

The ensuing model is then leveraged to simulate computationally the behaviour and evolving beliefs of a neurofeedback training subject in tasks of varying nature and difficulty. We finally analyze the effects of several sources of error such as measurement noise or uncertainty surrounding the choice of the biomarker to conclude on their influence on training efficacy.
(1) Friston et al. Active inference and learning. doi:10.1016/j.neubiorev.2016.06.022

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