A framework for user training adaptation in Brain-Computer Interfaces based on mental tasks (MT-BCIs)

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Introduction: Mental Task (MT-)based BCIs allow for spontaneous and asynchronous interactions with external devices solely through mental tasks such as motor imagery or mental math. Such BCIs require their users to develop the ability to encode mental commands that are as stable, clear and distinct as possible - making them easy to recognize by a computer. Despite their promises and achievements, traditional closed-loop training programs are suboptimal [1] and could be further improved. Some aspects of training programs were studied in depth in light of methods from the fields of educational sciences, ergonomics, or user-centered design [1, 2]. However, the best way to train users is still unknown and some aspects of user training protocols possibly impacting skill acquisition may not have been sufficiently explored yet. Although successful additions of a human perspective in the traditional BCI interaction model were already possible (e.g. [3, 4, 5]), these representations might not sufficiently depict the many aspects that could be improved/adapted in BCI human training protocols. Therefore, we propose a framework identifying and defining the various parameters composing a BCI user training program.

Method, Results: Based on the existing literature [6], we propose a framework describing, at different time scales, the different aspects of BCI user training. As seen in Fig. 1, training is composed of one or more sessions (days) whose order, number or duration can vary. Sessions are themselves composed of runs that can vary as well, etc. In this framework, a training program consists of practicing *exercises,* which refer to *what* MT-BCI users are expected to do and *how* to practice it. Although traditional training usually requires users to practice the same exercise over and over, exercises can vary in many ways across experiments and they can also be adapted within trials, runs or sessions. This representation emphasizes the multiple entry points that allow for training adaptation, for example what skill users should practice (e.g. training for speed or accuracy, etc.), in which spontaneity mode (e.g. cue-based vs. self-decided, synchronous trials vs. self-paced exercise), with which instructions or feedback (e.g. content, modality, timing), or in which environment (i.e. the context in which training takes place).

Discussion: Not only the properties of training aspects should be questioned, but also their presence. For example, there is no indication that the uniform presence of feedback at each step throughout the entire training is the best way to train users. Besides, rather than universally refining training parameters, it may be preferable to adapt the choice of parameters to the user before and/or throughout sessions [5] based e.g. on changes in users' understanding, perceptions, motivation, fatigue, performances, etc.

Significance: Future work should investigate further whether the variation of different training aspects has an influence on behavioral BCI performance, user-related metrics [4] or users' understanding of instructions, self-instructed cognitive strategy, perception of trial-specific quality, willingness to change/redo tasks, etc. This is a preliminary step on the way to designing new training programs composed of exercise sequences adapted to human learning and/or adaptive according to users' experience or performances.

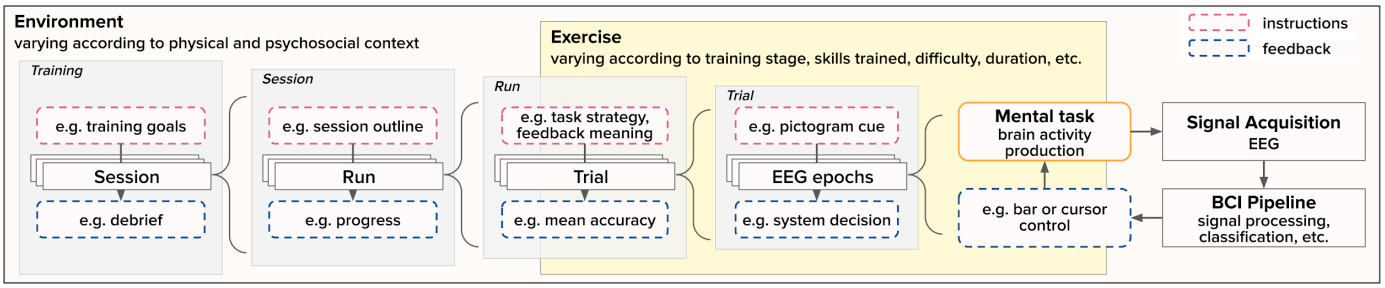

Figure 1. *Representation of MT-BCI training in decreasing order of time scales. Different aspects of the training feedback, instructions or exercises can be modulated - including their goal, modality, content, duration, variety, frequency, number and/or order.*

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