

Team PhyPA: Developing applications for Brain-Computer Interaction

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A Brain-Computer Interface offers a new communication channel solely based on brain activity. The strong developments in the last decade led to an enormous improvement of the robustness and efficiency of the information flow in such systems. Nowadays, BCIs are used in medical care to establish a communication between the patient and his/her environment in cases where natural channels are no longer available. This has led to developments such as spelling devices [1,2] or control systems for wheelchairs and prostheses [3,4]. By the use of machine learning algorithms, a boost of classification rates and a transfer of the learning effort from the user to the machine could be accomplished [5,6], so a BCI- application is now usable by untrained persons. Consequently, many promising applications for BCIs appear in non-medical fields, too.

The use of Brain-Computer Interfaces in HCI applications appears to be especially promising. But since, until now, BCI research focused primarily on solutions in medical care, new (unsolved) problems have to be faced in the shift to BCI/HCI-research. Team PhyPA aims at transferring technologies from BCI-Research into the context of HCI and thus making BCIs usable for HCI applications. Therefore, our interdisciplinary team consisting of mathematicians, psychologists and engineers is working on currently seven projects investigating non-stationarities, efficiency and general applicability of feature extraction methods, single trial detection of both motor and non-motor patterns such as error-responses, and the coherence of executed and imagined movements.

Influences from modern aspects of cognitive psychology, machine learning, usability research and software engineering on our research are reflected in our current project lineup, which will be discussed below. In our perspective, many aspects of research have to be combined, namely the development of robust and performing algorithms and feature extractions for (online) data analysis, describing the functional states and behaviour of the user by adapting models from the neurosciences and optimizing the interaction aspects of two communicating and adapting systems - the human brain and the machine.

Due to this interdisciplinary approach we have been able to design a game – the RLR-Game – in which a BCI system *significantly* enhances the performance of a player in contrast to another unsupported player [16].

This enables a new kind of research and it is reasonable to think about the usage of BCIs in an everyday scenario. And it leads to a shift in definition and to the term *Brain-Computer Interaction*.

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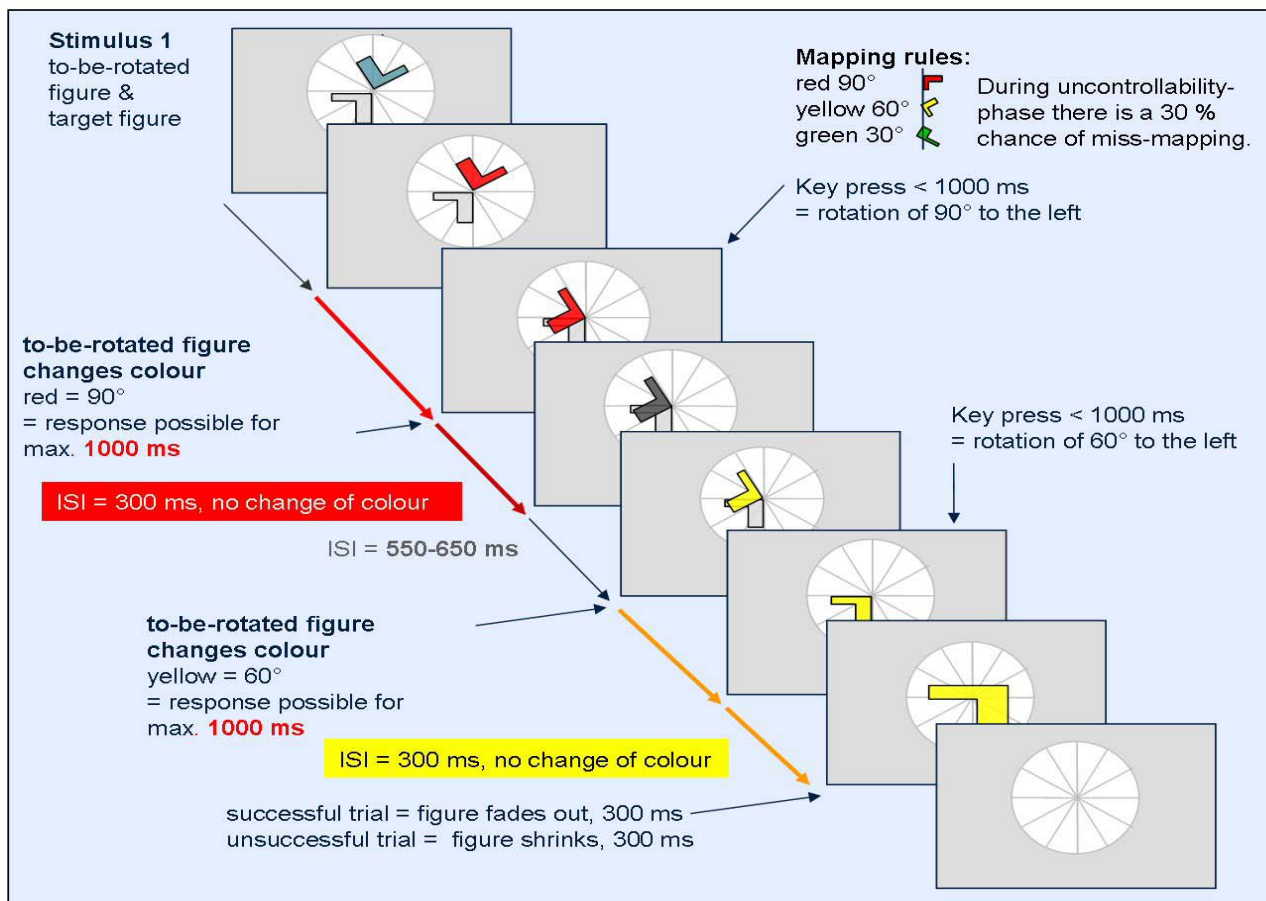


Figure 1: In the RLR paradigm a stimulus in some starting position has to be rotated by a left or right key press until it corresponds to a given grey target figure. The stimulus is either the letter L or R and thereby indicates the key that has to be pressed to start the rotation (left or right Ctrl key), as well as the rotational direction. Every 1000 ms the letter changes into one of three colours, indicating whether it can be rotated by a key press and by what angle it will rotate when a key is pressed. The Loss of Controllability was induced by a 30% chance of a wrong mapping between colours and angles.

Project 1: Benchmarking common BCI algorithms

To reach an acceptable level of usability, it is very important how well a BCI is applicable for an untrained user. Hence, it is necessary to find a robust method which works for most users with a well defined performance. Therefore, we have carried out a benchmarking study on EEG datasets from 40 healthy and naïve subjects performing imagined and executed hand movements.

This highlights a central goal of classical BCI research: The discrimination of EEG patterns correlated to activity of the motor cortex. Over the past decade, a great deal of specialized feature extraction methods for BCI applications have been developed and commonly evaluated in offline analyses [5,6]. But, the well-known facts of inter- and intra-individual variability in EEG recordings and the significant influence of inhomogeneous experimental designs [7] lead to the question of comparability of the classification results provided in the respective studies. Our study hopefully gives an answer. The results for executed hand movements can be found in [8,9]. The complete results are under review at this time. All data and findings are going to be published on a website for public access.

Project 2: The Loss of Controllability

In the course of BCI sessions, slow shifts in performance are usually witnessed [10]. Particularly, there are consecutive blocks where the user loses control over the device. This reduces the reliability of the system and hence is crucial for almost every application.

Non-stationarities, such as changes in the *statistical* properties of the BCI signal, have been identified as causes for this problem. Dealing with non-stationarities is a current and important challenge for the implementation of BCIs both in the clinical and in the HCI domain. Unfortunately, up to now it is unclear whether some element of the experimental design induces these non-stationarities or if they are results of inherent user-states. In our study we have been able to find a factor inducing a non-stationarity which is relevant for classification: The Loss of Controllability (LoC). This effect of an internal cognitive change in the person has been induced by the newly introduced RLR-paradigm (Rotation-Left-Right, see figure 1). It is in some respects an executed-hand-movement version of the classical online Basket paradigm [11] and therefore allows for the manipulation of a wide variety of interfering cognitive factors.

The effect of the non-stationarity varies over different feature extraction methods and hence offers some insight into the robustness of online-classifications based on them. The exact results of this study can be found in [12,13] and are under review for journal-publication.

Project 3: The RLR-Game

While most of the available BCI applications are based on voluntary motor imaginary tasks, it is also possible to exert control via EEG patterns induced by exogenic factors. This might be the primary mode of input, as in some spellers [1] or secondary, as in user state detection, or detection of error-potentials [14] and other, more general, errors responses [15]. The latter might lead to an indirect, *passive* control of a system, which can even be more robust than active motor control. This is due to the lack of instabilities and variations often associated with conscious actions.

For investigating this, we have designed a simple game, based on the RLR paradigm of the LoC study, where each miss mapping leads to a clear disadvantage for the player. The only way to correct this misbehaviour of the system was by a correct BCI classification of the pattern correlating to the perception of the mapping error. Thus, the user acts as a *sensor* allowing the system to precept an error.

We have been able to show that this BCI based assistance significantly enhances the performance of each player – both in a laboratory environment and in a real world example (Open House of the TU Berlin, ‘Lange Nacht der Wissenschaften’ 2007). The results of this study can be found in [16] and will hopefully be published by the end of this year.

Our possible contribution to this Workshop

Since we have successfully tested our BCI based error correction for the RLR-Game on 22 subjects, we would happily like to present this in some online sessions during the workshop. For this, we could bring along our BCI system and the necessary equipment for the demonstration.

The machine learning session and the user training could be combined into one session, so that the preparation for each player (including EEG setup) should easily be done in one hour.

It is possible to contrast the functionality of the system while letting two people playing against each other – first both without BCI system, then one with BCI enhancement and the other one without. If you are interested in letting us present our RLR-Game and/or have any suggestions, please feel free to contact us for further planning (thorsten.zander@mms.tu-berlin.de).

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