Event-related (De)synchronization (ERD/ERS) during motor imagery tasks: Implications for brain–computer interfaces

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Abstract
The primary aims of this research were to examine (1) mu and beta event-related desynchronization/synchronization (ERD/ERS) during motor imagery tasks with varying movement duration and (2) the potential impacts of movement duration on ERD/ERS patterns. Motor imagery tasks included brief and continuous imagined hand movements. During an imagery task, participants imagined an indicated movement for 1 s (i.e., brief movement imagery) or 5 s (i.e., continuous movement imagery). The results of the study support (1) that mu and beta ERD/ERS patterns are elicited during imagined hand movements and (2) that movement duration affects ERS and does not affect ERD patterns, during motor movement imagery. Additionally, brief movement imagery had a greater impact on mu and beta ERD; continuous movement imagery had a greater impact on mu and beta ERS. This research will be useful for designing future brain–computer interfaces as it provides valuable insight into the dynamics of electroencephalographic (EEG) oscillatory changes during motor imagery tasks with varying movement duration.

Relevance to industry: Brain–computer interfaces (BCIs) have gained considerable interests by both research and industry communities who want to improve the quality of life for those who suffer from severe motor disabilities, such as amyotrophic lateral sclerosis (ALS), brainstem stroke, and cerebral palsy (CP). The results of this study should be applied to EEG-based BCI system design in order to enhance accuracy and classification performance for BCI system control.

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1. Introduction

As a non-muscular communication and control system (Wolpaw et al., 2002; Morash et al., 2008; Nam et al., 2009; Blankertz et al., 2010), brain–computer interface (BCI) has shown emerging possibilities for people who have lost all voluntary muscle control, but are cognitively intact, by allowing them to write sentences (Birbaumer, 1997; Donchin et al., 2000), move a cursor on the computer screen (Wolpaw et al., 2002), play an electronic ping-pong game (Babiloni et al., 2003), control an orthosis that provides hand grasp (Obermaier et al., 2001), or operate a brain-actuated wheelchair (Galán et al., 2008). During the last two decades, BCI systems have used a variety of electrophysiological signal components (Wolpaw et al., 2002; Parasuraman and Rizzo, 2008; Graimann et al., 2010): visual evoked potentials (Sutter and Tran, 1992; Middendorf et al., 2000), slow cortical potentials (Rockstroh et al., 1989; Birbaumer, 1997), P300 evoked potentials (Farwell and Donchin, 1988; Donchin et al., 2000; Li et al., 2011), mu and beta rhythms (Pfurtscheller and Lopes da Silva, 1999; Neuper and Pfurtscheller, 2006; Neuper et al., 2009), and cortical neuronal action potentials (Kennedy et al., 2000).

The change in amplitude of specific cortical mu and beta rhythms during self-paced voluntary movements has gained considerable interests as a potential electrophysiological signal for EEG-based brain–computer interfaces (Cheyne et al., 2003; Neuper and Pfurtscheller, 2006; Parasuraman and Rizzo, 2008; Morash et al., 2008). These variations of synchronization of cortical rhythms are referred to as an ‘event-related desynchronization/synchronization’ (ERD/ERS; Neuper and Pfurtscheller, 2001). For example, when a self-paced finger movement is performed, the 8–14 Hz alpha band

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