User variations in attention and brain-computer interface performance

by

Susan Aliakbaryhosseinabadi

Brain-computer interface (BCI) systems translate brain signals into commands for external devices. In the area of neurorehabilitation, the main aim of these systems is to restore lost function. Since the original reports by Daly and colleagues (2009), several research groups have tested the efficacy of such BCIs in stroke patients. Most of these continue to be confined to the artificial laboratory setting likely as reliable detection of relevant brain signals remains difficult. In real-life conditions, attention diversion from a desired/target task is one of the most crucial factors that affect detection accuracy. Attention is defined as the ability to focus on the relevant/desired stimuli among various stimuli in our surrounding environment. It may be quantified by the size and latency of the event-related potential (ERP), one of the most common types of brain signal modalities used to study attention. Typically, when attending to a task, the P300 amplitude is increased and the latency decreased, while attention deterioration is characterized by a decrease in the P300 amplitude and an increment in the latency.

In the current thesis, the main aim was to design a robust and reliable real-time BCI system for restoration of lost motor function, under conditions where attention is varied. The BCI system implemented, uses the movement-related cortical potential (MRCP) as the control signal. The MRCP is a naturally occurring negative shift in the EEG that commences approximately 1-2 s prior to movement initiation, regardless if the movement is actually performed or only imagined. It is thus possible to detect movement intention at least 1 s prior to actual execution, making this an ideal control signal modality for BCIs. It is however not known how the MRCP is affected by shifts in attention of the user. Through five studies of this thesis, the effect of the users' attention variation was investigated while they performed either cue-based (synchronous) or self-paced (asynchronous) movements. Regarding to the movement detection latency in Study I, an appropriate visual cue was selected to control the timing of motor movement execution (ankle dorsiflexion). Study II revealed that an imposed cognitive task between motor task executions can divert the attention particularly in the case of complex cognitive tasks. The effect of attention drift was greater in stroke patients. A significant finding was that a single channel could be used to reliably detect attention variations, while movement detection from a combination of channels was not deteriorated under attention drifts. It is well known that changes in attention significantly affect plasticity induction and thus restoration of lost motor function in patient populations. It therefor remains vital to detect attention changes within these BCIs to ensure that plasticity is induced effectively. The work in Study II was extended in Study III-V by the introduction of dual task conditions to alter the users' attention. Thus participants were asked to attend to two tasks executed at the same time. Results revealed that movement preparation and thus movement execution deteriorated in both levels of simple or complex dual-task conditions compared to the single-task. In addition, feature spaces of normal and diverted attention levels were distinguished and classified by using a global temporal model. Finally, it was shown that parietal and central channels were more affected under attention changes.

In conclusion, the findings of the work presented in the current thesis provide a source of information to detect the users' attentional state. This information is currently being used to implement a real-time neurofeedback BCI system that will focus the attention of the users on the main task of the BCI and thus optimize the induction of plasticity. It can also be used to improve the performance of assistive BCI devices such as wheelchairs or robotic prosthesis since the users' attention to the main task is controlled. Further, it has major implications for the design of BCIs in the area of neurorehabilitation for patient populations..

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Ph.D. lecture

by

Susan Aliakbaryhosseinabadi

Friday 8 December 2017

DEPARTMENT OF HEALTH SCIENCE AND TECHNOLOGY
AALBORG UNIVERSITY

This thesis is based on Susan Aliakbaryhosseinabadi's research work at:

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To fulfill the requirements for the Ph.D. degree, Susan Aliakbaryhosseinabadi has submitted the thesis: User variations in attention and brain-computer interface performance, to the Faculty Council of Medicine at Aalborg University.

The Faculty Council has appointed the following adjudication committee to evaluate the thesis and the associated lecture:

Professor Benjamin Blankertz
Technical University of Berlin
Germany

Associate Professor Preben Kidmose
Aarhus University
Denmark

Chairman:
Associate Professor Parisa Gazerani
Aalborg University
Denmark

Moderator:
Associate Professor Natalie Mrachacz-Kersting
Aalborg University
Denmark

The Ph.D. lecture is public and will take place on:

Friday 8 December 2017 at 13:00
Aalborg University – Room D2-106
Fredrik Bajers Vej 7 D2
9220 Aalborg East

Program for Ph.D. lecture on

Friday 8 December 2017

by

Susan Aliakbaryhosseinabadi

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Chairman:	Associate Professor Parisa Gazerani
Moderator:	Associate Professor Natalie Mrachacz-Kersting
13.00	Opening by the Moderator
13.05	Ph.D. lecture by Susan Aliakbaryhosseinabadi
13.50	Break
14.00	Questions and comments from the Committee Questions and comments from the audience at the Moderator’s discretion
16.00	(No later than) Conclusion of the session by the Moderator

After the session a reception will be arranged