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Special Issue: Brain-computer interface (BCI) and ergonomics

Chang S. Nam. *Brain–computer interface (BCI) and ergonomics.* Pages 513-515.

Stefanie Blain-Moraes, Riley Schaff, Kirsten L. Gruis, Jane E. Huggins & Patricia A. Wren. *Barriers to and mediators of brain–computer interface user acceptance: focus group findings.* Pages 516-525.

Brain–computer interfaces (BCI) are designed to enable individuals with severe motor impairments such as amyotrophic lateral sclerosis (ALS) to communicate and control their environment. A focus group was conducted with individuals with ALS (n=8) and their caregivers (n=9) to determine the barriers to and mediators of BCI acceptance in this population. Two key categories emerged: personal factors and relational factors. Personal factors, which included physical, physiological and psychological concerns, were less important to participants than relational factors, which included corporeal, technological and social relations with the BCI. The importance of these relational factors was analysed with respect to published literature on actor-network theory (ANT) and disability, and concepts of voicelessness and personhood. Future directions for BCI research are recommended based on the emergent focus group themes.

Practitioner Summary: This manuscript explores human factor issues involved in designing and evaluating brain–computer interface (BCI) systems for users with severe motor disabilities. Using participatory research paradigms and qualitative methods, this work draws attention to personal and relational factors that act as barriers to, or mediators of, user acceptance of this technology.

- **Keywords:** brain–computer interface, amyotrophic lateral sclerosis, focus group, actor-network theory, qualitative research

Elizabeth A. Felton, Justin C. Williams, Gregg C. Vanderheiden & Robert G. Radwin. *Mental workload during brain–computer interface training.* Pages 526-537.

It is not well understood how people perceive the difficulty of performing brain–computer interface (BCI) tasks, which specific aspects of mental workload contribute the most, and whether there is a difference in perceived workload between participants who are able-bodied and disabled. This study evaluated mental workload using the NASA Task Load Index (TLX), a multi-dimensional rating procedure with six subscales: Mental Demands, Physical Demands, Temporal Demands, Performance, Effort, and Frustration. Able-bodied and motor disabled participants completed the survey after performing EEG-based BCI Fitts' law target acquisition and phrase spelling tasks. The NASA-TLX scores were similar for able-bodied and disabled participants. For example, overall workload scores (range 0–100) for 1D horizontal tasks were 48.5 (SD = 17.7) and 46.6 (SD 10.3), respectively. The TLX can be used to inform the design of BCIs that will have greater usability by evaluating subjective workload between BCI tasks, participant groups, and control modalities.

Practitioner Summary: Mental workload of brain–computer interfaces (BCI) can be evaluated with the NASA Task Load Index (TLX). The TLX is an effective tool for comparing subjective workload between BCI tasks, participant groups (able-bodied and disabled), and control modalities. The data can inform the design of BCIs that will have greater usability.

- **Keywords:** brain–computer interface (BCI), mental workload, NASA Task Load Index, NASA-TLX, Fitts' law, electroencephalogram (EEG)

Fabio Aloise, Pietro Aricò, Francesca Schettini, Angela Riccio, Serenella Salinari, Donatella Mattia, Fabio Babiloni & Febo Cincotti. *A covert attention P300-based brain–computer interface: Geospell.* Pages 538-551.

The Farwell and Donchin P300 speller interface is one of the most widely used brain–computer interface (BCI) paradigms for writing text. Recent studies have shown that the recognition accuracy of the P300 speller decreases significantly when eye movement is impaired. This report introduces the GeoSpell interface (Geometric Speller), which implements a stimulation framework for a P300-based BCI that has been optimised for operation in covert visual attention. We compared the Geospell with the P300 speller interface under overt attention conditions with regard to effectiveness, efficiency and user satisfaction. Ten healthy subjects participated in the study. The performance of the GeoSpell interface in covert attention was comparable with that of the P300 speller in overt attention. As expected, the effectiveness of the spelling decreased with the new interface in covert attention. The NASA task load index (TLX) for workload assessment did not differ significantly between the two modalities.

Practitioner Summary: This study introduces and evaluates a gaze-independent, P300-based brain–computer interface, the efficacy and user satisfaction of which were comparable with those off the classical P300 speller. Despite a decrease in effectiveness due to the use of covert attention, the performance of the GeoSpell far exceeded the threshold of accuracy with regard to effective spelling.

- **Keywords:** brain–computer interface (BCI), (C)overt visual attention, P300, workload, electroencephalogram (EEG)

Roberta Carabalona, Ferdinando Grossi, Adam Tessadri, Paolo Castiglioni, Antonio Caracciolo & Ilaria de Munari. *Light on! Real world evaluation of a P300-based brain–computer interface (BCI) for environment control in a smart home.* Pages 552-563.

Brain–computer interface (BCI) systems aim to enable interaction with other people and the environment without muscular activation by the exploitation of changes in brain signals due to the execution of cognitive tasks. In this context, the visual P300 potential appears suited to control smart homes through BCI spellers. The aim of this work is to evaluate whether the widely used character-speller is more sustainable than an icon-based one, designed to operate smart home environment or to communicate moods and needs. Nine subjects with neurodegenerative diseases and no BCI experience used both speller types in a real smart home environment. User experience during BCI tasks was evaluated recording concurrent physiological signals. Usability was assessed for each speller type immediately after use. Classification accuracy was lower for the icon-speller, which was also more attention demanding. However, in subjective evaluations, the effect of a real feedback partially counterbalanced the difficulty in BCI use.

Practitioner Summary: Since inclusive BCIs require to consider interface sustainability, we evaluated different ergonomic aspects of the interaction of disabled users with a character-speller (goal: word spelling) and an icon-speller (goal: operating a real smart home). We found the first one as more sustainable in terms of accuracy and cognitive effort.

- **Keywords:** advanced human–machine interfaces, user needs analysis, controls and input devices, physiology, mental fatigue

Marieke E. Thurlings, Jan B.F. van Erp, Anne-Marie Brouwer, Benjamin Blankertz & Peter Werkhoven. *Control-display mapping in brain–computer interfaces.* Pages 564-580.

Event-related potential (ERP) based brain–computer interfaces (BCIs) employ differences in brain responses to attended and ignored stimuli. When using a tactile ERP-BCI for navigation, mapping is required between navigation directions on a visual display and unambiguously corresponding tactile stimuli (tactors) from a tactile control device: control-display mapping (CDM). We investigated the effect of congruent (both display and control horizontal or both vertical) and incongruent (vertical display, horizontal control) CDMs on task performance, the ERP and potential BCI performance. Ten participants attended to a target (determined via CDM), in a stream of sequentially vibrating tactors. We show that congruent CDM yields best task performance, enhanced the P300 and results in increased estimated BCI performance. This suggests a reduced availability of attentional resources when operating an ERP-BCI with incongruent CDM. Additionally, we found an enhanced N2 for incongruent CDM, which indicates a conflict between visual display and tactile control orientations.

Practitioner Summary: Incongruency in control-display mapping reduces task performance. In this study, brain responses, task and system performance are related to (in)congruent mapping of command options and the corresponding stimuli in a brain–computer interface (BCI). Directional congruency reduces task errors, increases available attentional resources, improves BCI performance and thus facilitates human–computer interaction.

- **Keywords:** BCI, ERP, CDM, congruency, mapping, conflict, attention, P300, N2, interface, navigation

Chang S. Nam, Jincheol Woo & Sangwoo Bahn. *Severe motor disability affects functional cortical integration in the context of brain–computer interface (BCI) use.* Pages 581-591.

The purpose of this study was to investigate cortical interaction between brain regions in people with and without severe motor disability during brain–computer interface (BCI) operation through coherence analysis. Eighteen subjects, including six patients with cerebral palsy (CP) and three patients with amyotrophic lateral sclerosis (ALS), participated. The results showed (1) the existence of BCI performance difference caused by severe motor disability; (2) different coherence patterns between participants with and without severe motor disability during BCI operation and (3) effects of motor disability on cortical connections varying in the brain regions for the different frequency bands, indicating reduced cortical differentiation and specialisation. Participants with severe neuromuscular impairments, as compared with the able-bodied group, recruited more cortical regions to compensate for the difficulties caused by their motor disability, reflecting a less efficient operating strategy for the BCI task. This study demonstrated that coherence analysis can be applied to examine the ways cortical networks cooperate with each other during BCI tasks.

Practitioner Summary: Few studies have investigated the electrophysiological underpinnings of differences in BCI performance. This study contributes by assessing neuronal synchrony among brain regions. Our findings revealed that severe motor disability causes more cortical areas to be recruited to perform the BCI task, indicating reduced cortical differentiation and specialisation.

- **Keywords:** electroencephalography, EEG coherence, motor disability, brain–computer interface

Joshua I. Ekandem, Timothy A. Davis, Ignacio Alvarez, Melva T. James & Juan E. Gilbert. *Evaluating the ergonomics of BCI devices for research and experimentation.* Pages 592-598.

The use of brain computer interface (BCI) devices in research and applications has exploded in recent years. Applications such as lie detectors that use functional magnetic resonance imaging (fMRI) to video games controlled using electroencephalography (EEG) are currently in use. These developments, coupled with the emergence of inexpensive commercial BCI headsets, such as the Emotiv EPOC (http://emotiv.com/index.php) and the Neurosky MindWave, have also highlighted the need of performing basic ergonomics research since such devices have usability issues, such as comfort during prolonged use, and reduced performance for individuals with common physical attributes, such as long or coarse hair. This paper examines the feasibility of using consumer BCIs in scientific research. In particular, we compare user comfort, experiment preparation time, signal reliability and ease of use in light of individual differences among subjects for two commercially available hardware devices, the Emotiv EPOC and the Neurosky MindWave. Based on these results, we suggest some basic considerations for selecting a commercial BCI for research and experimentation.

Statement of Relevance: Despite increased usage, few studies have examined the usability of commercial BCI hardware. This study assesses usability and experimentation factors of two commercial BCI models, for the purpose of creating basic guidelines for increased usability. Finding that more sensors can be less comfortable and accurate than devices with fewer sensors.

- **Keywords:** brain-computer interface (BCI), comfort, usability