 DOI:10.3217/978-3-85125-260-6-47

Brain-Computer Interface Supported Collaborative Work

C. S. Nam[1], J. Lee[1], S. Bahn[1], Y. Li[1], I. Choi[1]

[1] *Department of Industrial and Systems Engineering, North Carilina State University, Raleigh, NC, USA*

Correspondence: C. S. Nam, North Carolina State University, Raleigh, NC, USA. E-mail: csnam@ncsu.edu

Abstract. BCIs hold the promise for the restoration of communication and control ability to users with severe motor disability, but BCI research has not yet fully addressed the social burdens of their disabilities (i.e., interaction with other people). This study investigated and found differences in performance and brain activity patterns when people perform a task jointly with each other under different collaborative work conditions. We suggest that supporting interaction in BCI-supported collaborative work provide greater benefits for users, including people with severe motor disability.

Keywords: EEG, SSVEP, Turn-by-turn collaborative work, Collaborative BCI, Brainbot

1. Introduction

Despite a considerable amount of ongoing research, current efforts in the area of BCI research and development still have significant gaps [Lebedev and Nicolelis, 2006]. Most existing BCIs are still single-user applications, which do not meet the needs of users who want to work together. Working together and collaboration is common and natural for people in order to complete a job faster or to share expertise for a complex task [Heer et al., 2008]. Collaboration can help to foster the sharing of knowledge, ideas, and skills [Isenberg and Carpendale, 2007]. Due to the rapid advance of BCI technology and aforementioned advantages of collaboration, we envisage that in the near future people, including those with severe motor disability, will be able to perform tasks with other people only through their brain activity. However, there has been a general lack of understanding regarding how BCIs should support collaborative work under various task conditions. As the first step to address these research issues, this study investigated differences in performance when people perform a task jointly with other people only through means of their brain activity under different collaborative work conditions.

2. Material and Methods

2.1. Participants

Two right-handed healthy subjects (mean age: 28.4±1.5; 2 males) volunteered to participate in the study. Subjects had normal or corrected-to-normal vision with no prior experience related to SSVEP-based BCIs. Subjects were not given any financial reward for their participation.

2.2. Data Acquisition and Processing

EEG data was recorded using an EEG cap with 16 electrodes, according to the extended International 10-20 system. Signals were amplified with a g.USBamp amplifier. Fpz and right ear lobe were used as ground and reference, respectively. The EEG signals were digitized at a sampling rate of 512 Hz, with band-pass filtering from 5 Hz to 60 Hz. In order to determine a user's SSVEP responses, we used a harmonic sum decision (HSD) method using signals from two occipital channels (O_1 and O_2) with the target frequencies of 6, 7, 8, 9, and 11 Hz.

2.3. Experimental Design and Procedure

We developed *BrainBot,* a SSVEP-based collaborative BCI for control, constructed using a LEGO Mindstorms NXT kit. Participants were asked to perform a sequence of six activities (G→St3→R→G→St1→R) by controlling *Brainbot,* in which they grasped (G) and released (R) a ball to one of the three target locations (St 1, St2, and St3) beginning at St2 (i.e., Grasping a ball at station 2).

The type of collaborative work (co-work) was manipulated as a within-subject independent variable: (a) individual work where participants perform a task alone, (b) Co-Work 1: turn-based co-work with self-error correction where a pair of users takes turns to perform a task and any error is corrected by the person who made, and

(c) Co-Work 2: turn-based co-work with error correction by partner where a pair of users takes turns to perform a task and any error is corrected by the partner.

3. Results

To investigate differences in performance and brain activity when a pair of users performs a task jointly with each other under different collaborative work conditions, this study employed several dependent measures, which can be categorized into two types of variables: (a) task performance (task completion time in second, the number of error, and maximum power spectrum in V_{rms}^{2}) and (b) brain activity pattern in the time-frequency domain.

As shown in Table 1, BCI users showed different performance depending on work conditions, in which collaborative work generally took longer time, made more errors and produced higher signal powers compared to individual work. Fig. 1 also illustrates brain activity patterns can be different under different collaborative work conditions.

Table 1. *Task performance by collaborative work types.*

	Step	G	St3	R	G	St1	R	Total	Average
Task Time	Subject 1	0.50	9.00	12.00	17.30	22.30	34.00	95.10	**15.85**
	Subject 2	0.80	5.30	6.80	44.30	49.30	50.30	156.80	**26.13**
	Co-Work 1	0.50	4.00	12.00	15.25	77.25	86.50	195.50	**32.58**
	Co-Work 2	1.00	19.25	20.50	22.00	23.50	40.75	127.00	**21.17**
No. of Error	Subject 1	0.0	0.0	0.0	0.0	2.0	1.0	3.0	**0.5**
	Subject 2	0.0	0.0	0.0	5.0	1.0	0.0	6.0	**1.0**
	Co-Work 1	0.0	1.0	3.0	1.0	28.0	2.0	35.0	**5.8**
	Co-Work 2	0.0	7.0	0.0	0.0	0.0	8.0	15.0	**2.5**
Max. Power	Subject 1	0.03	0.01	0.02	0.02	0.01	0.02	0.11	**0.02**
	Subject 2	0.07	0.68	0.07	0.05	0.10	0.05	1.02	**0.17**
	Co-Work 1	0.04	0.04	0.02	0.03	0.02	0.04	0.19	**0.03**
	Co-Work 2	0.02	0.03	0.04	0.03	0.03	0.03	0.17	**0.03**

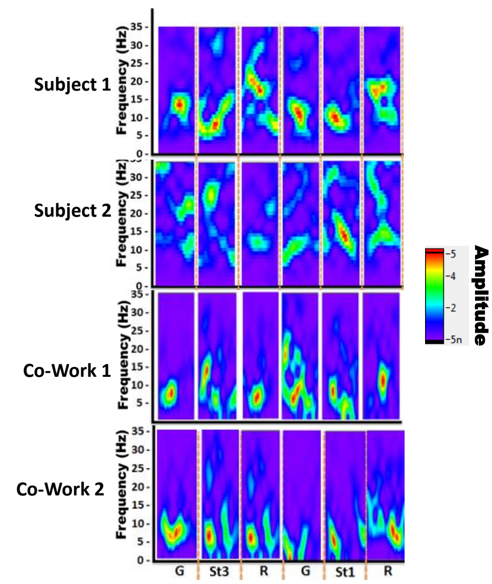

Figure 1. *Short time fourier transform (STFT) analysis by collaborative work types.*

4. Discussion

Through the preliminary analysis of the data collected, we found differences in performance and brain activity pattern between different collaborative work conditions. Working together and collaborating in a group can provide greater benefits for user, including people with severe motor disability. However, little attention has been paid to BCI-supported collaborative work. Thus, this research can be of great significance due to its potential to yield fundamental knowledge of BCI-supported cooperative work, understanding of the support needed for interaction in BCI technology supported group activities, and design considerations for collaborative BCIs.

Acknowledgements

This research was partially supported by the UNC-NCSU Rehabilitation Engineering Center and the National Research Foundation of Korea (Global Frontier R&D Program, NRF-M1AXA003-2010-0029756).

References

Lebedev MA, Nicolelis MA. Brain-machine interfaces: Past, present and future. *Trends Neurosci*, 29(9):536-546, 2006.

Heer J, van Ham F, Carpendale S, Weaver C, Isenberg P. Creation and collaboration: Engaging new audiences for information visualization. *Information visualization. Berlin, Heidelberg: Springer-Verlag*, 92-133, 2008.

Isenberg P, Carpendale S. Interactive tree comparison for co-located collaborative information visualization. *IEEE Trans Vis Comp Graphics*, 13(6):1232-1239, 2007.