International Journal of Engineering and Technology Innovation, vol. 5, no. 3, 2015, pp. 165-177

Usability and Performance Measure of a Consumer-grade Brain Computer Interface System for Environmental Control by Neurological Patients

Farzin Deravi[1], Chee Siang Ang[1], M A Hannan Bin Azhar[2], Areej Al-Wabil[3], Malcolm Philips[1, 4], Mohamed Sakel[1, 4, *]

[1] School of Engineering and Digital Arts, University of Kent, UK.

[2] Computing, Digital Forensics and Cybersecurity, Canterbury Christ Church University, UK.

[3] College of Computer and Information Sciences, King Saud University, Saudi Arabia.

[4] Neuro-rehabilitation, East Kent Hospitals University, NHS Foundation Trust, UK.

Received 02 March 2014; received in revised form 07 August 2015; accepted 10 August 2015

Abstract

With the increasing incidence and prevalence of chronic brain injury patients and the current financial constraints in healthcare budgets, there is a need for a more intelligent way to realise the current practice of neuro-rehabilitation service provision. Brain-computer Interface (BCI) systems have the potential to address this issue to a certain extent only if carefully designed research can demonstrate that these systems are accurate, safe, cost-effective, are able to increase patient/carer satisfaction and enhance their quality of life. Therefore, one of the objectives of the proposed study was to examine whether participants (patients with brain injury and a sample of reference population) were able to use a low cost BCI system (Emotiv EPOC) to interact with a computer and to communicate via spelling words. Patients participated in the study did not have prior experience in using BCI headsets so as to measure the user experience in the first-exposure to BCI training. To measure emotional arousal of participants we used an ElectroDermal Activity Sensor (Qsensor by Affectiva). For the signal processing and feature extraction of imagery controls the Cognitive Suite of Emotiv's Control Panel was used. Our study reports the key findings based on data obtained from a group of patients and a sample reference population and presents the implications for the design and development of a BCI system for communication and control. The study also evaluates the performance of the system when used practically in context of an acute clinical environment.

Keywords: stroke, rehabilitation, brain-computer interface, electroencephalography, emotiv EPOC

References

[1] C. Ang, M. Sakel, M. Pepper, and M. Phillips, "Use of brain computer interface in neurological rehabilitation," British Journal of Neuroscience Nursing, vol. 7, pp. 523-528, 2011

[2] W. Wang, J. L. Collinger, M. A. Perez, E. C. Tyler-Kabara, L. G. Cohen, N. Birbaumer, et al., "Neural interface technology for rehabilitation: exploiting and promoting neuroplasticity," Physical Medicine and Rehabilitation Clinics of North America, vol. 21, no. 1, pp. 157-178, 2010.

[3] N. Birbaumer and L. G. Cohen. "Brain-computer interfaces: communication and restoration of movement in paralysis," J Physiol, vol. 579, no. 3, pp. 621-636, 2007.

* Corresponding author. E-mail address: msakel@nhs.net

Tel.: +886-5-6315368; Fax: +886-5-6314486

[4] R. Scherer, G. R. Müller-Putz and G. Pfurtscheller, "Flexibility and practicality graz brain-computer interface approach," International Review of Neurobiology, vol. 86, pp. 119-131, 2009.
[5] N. Birbaumer, A. Ramos-Murguialday, C. Weber and P. Montoya, "Neurofeedback and brain computer interface clinical applications," International Review of Neurobiology, vol. 86, pp. 107-117, 2009.
[6] B. Blankertz, F. Losch, M. Krauledat, G. Dornhege, G. Curio and KR. Müller, "The Berlin Brain-Computer Interface: Accurate performance from first-session in BCI-naive subjects," IEEE Transactions on Biomedical Engineering, vol. 55, no. 10, pp. 2452-2462, 2008.
[7] N. Birbaumer, A. Kubler, N. Ghanayim, T. Hinterberger, J. Perelmouter, J. Kaiser, et al., "The thought translation device (TTD) for completely paralyzed patients," IEEE Transactions on Rehabilitation Engineering, vol. 8, pp. 190-193, 2000.
[8] G. Pfurtscheller, G. R. Müller, J. Pfurtscheller, H. J. Gerner and R. Rupp, "Thought'-control of functional electrical stimulation to restore hand grasp in a patient with tetraplegia," Neuroscience letters, vol. 351, pp. 33-36, 2003.
[9] DJ. Krusienski and JR. Wolpaw, "Brain-computer interface research at the wadsworth center developments in noninvasive communication and control," International Review of Neurobiology, vol. 86, pp. 147-157, 2009.
[10] S. Weigelt, L. Muckli, and A. Kohler, "Functional magnetic resonance adaptation in visual neuroscience," Reviews in the Neurosciences, vol. 19, no. 4-5, pp. 363-380, 2008.
[11] S. Bermudez, A. M. Garcia , H. Samaha, and P. F. M. J. Verschure, "Using a hybrid brain computer interface and virtual reality system to monitor and promote cortical reorganization through motor activity and motor imagery training," IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 21, no. 2, pp. 174-181, 2013.
[12] M. Gongora, C. Peressutti, S. Machado, S. Teixeira, B. Velasques and P. Ribeiro, "Progress and prospects in neurorehabilitation: clinical applications of stem cells and brain-computer interface for spinal cord lesions," Neurological Sciences, vol. 34, no. 4, pp. 427-433, April 2013.
[13] J. J. Daly and J. R. Wolpaw, "Brain-computer interfaces in neurological rehabilitation," The Lancet Neurology, vol. 7, pp. 1032-1043, 2008.
[14] N. Birbaumer, "Breaking the silence: brain-computer interfaces (BCI) for communication and motor control," Psychophysiology, vol. 43, pp. 517-532, 2006.
[15] J. M. Belda-Lois, S. Mena-Del Horno, I. Bermejo-Bosch, JC. Moreno, J. L. Pons, D. Farina, et al., "Rehabilitation of gait after stroke: a review towards a top-down approach," Journal of NeuroEngineering and Rehabilitation, vol. 10, no. 1, 66 pages, 2011.
[16] T. Isa, E. E. Fetz, and K. R. Müller, "Recent advances in brainmachine interfaces." Neural Netw, vol. 22, pp. 1201-1202, 2009.
[17] J. R. Millan, R. Rupp, G. Mueller-Putz, R. Murray-Smith, C. Giugliemma, M. Tanger-mann et al., "Combining braincomputer interfaces and assistive technologies: State-of-the art and challenges," Front Neuro-Prosthetics, vol. 4, no. 161, September, 2010.
[18] J. R.Wolpaw, "Brain-computer interfaces (ICCs) for communication and control: a mini-review," Clinical Neurophysiology, vol. 57, pp. 607-613, 2004.
[19] T. J. Sullivan, S. R. Deiss, T. P. Jung, and G. Cauwenberghs, "A brain-machine interface using dry-contact, low-noise EEG sensors," IEEE International Symposium on Circuits and Systems, pp. 1986-1989, May 2008.
[20] L. Liao, I. Wang, C. Chang, B. Lin, C. Lin and C. Kevin, "Human cognitive application by using wearable mobile brain computer interface," TENCON, pp. 346-351, 2010.
[21] L. Liao, C. Chen, I. Wang, S. Chen, S. Li, B. Chen, J. Chang, and C. Lin, "Gaming control using a wearable and wireless EEG-based brain-computer interface device with novel dry foam-based sensors," Journal of Neuro Engineering and Rehabilitation, vol. 9, no.5, 2012.
[22] G. Pfurtscheller, G. R. Muller-Putz, R. Scherer and C. Neuper, "Rehabilitation with brain-computer interface systems," IEEE Computer , vol. 41, no. 10, pp.58-65, 2008.
[23] Qsensor, http://qsensor-support.affectiva.com/, last visited in August 2015
[24] Emotiv, https://emotiv.com/store/epoc-detail/, last visited in August 2015.
[25] Techsmit, https://www.techsmith.com/morae-features.html, last visited in August 2015,
[26] L. Seungchan, S. Younghak, W. Soogil, K. Kiseon and L. Heung-No, Review of wireless brain-computer interface systems, brain-computer interface systems - recent progress and future Prospects, Dr. Reza Fazel-Rezai (Ed.), 2013, ISBN: 978-953-51-1134-4, InTech.
[27] A. Setare, F. R. Reza, and A. Vahid, "A review of hybrid brain-computer interface systems," Advances in Human-Computer Interaction, vol. 2013, 8 pages, 2013.

[28] N. S. Diasa, J. P. Carmo, P. M. Mendes, and J. H. Correiac, "Wireless instrumentation system based on dry electrodes for acquiring EEG signals," Medical Engineering & Physics, vol. 34, pp. 972-981, 2012.
[29] B. Z. Allison, C. Brunner, V. Kaiser, G. R. Müller-Putz, C. Neuper and G. Pfurtscheller, "Toward a hybrid brain-computer interface based on imagined movement and visual attention," Journal of Neural Engineering, vol. 7, no. 2, March 2010.
[30] P. Shenoy, M. Krauledat, B. Blankertz, R. P. N. Rao, and K. R. Müller. "Towards adaptive classification for BCI," Journal of Neural Engineering, vol. 3, pp. 13-23, 2006.
[31] C. Brunner, B. Z. Allison, C. Altstätter, and C. Neuper, "A comparison of three brain–computer interfaces based on event-related desynchronization, steady state visual evoked potentials, or a hybrid approach using both signals," Journal of Neural Engineering, vol. 8, no. 2, 2011.
[32] C. Vidaurre, A. Schlögl, R. Cabeza, R. Scherer, and G. Pfurtscheller, "Study of on-line adaptive discriminant analysis for EEG-based brain computer interfaces," IEEE Transactions on Biomedical Engineering, vol. 54, no. 3, 2007.
[33] System Usability Scale - http://www.usability.gov/how-to-and-tools/methods/system-usability-scale.html, last visited in August 2015.

APPENDIX A – SUS SURVEY [33]

System Usability Scale

	Strongly disagree				Strongly agree
1. I think that I would like to use this system frequently	1	2	3	4	5
2. I found the system unnecessarily complex	1	2	3	4	5
3. I thought the system was easy to use	1	2	3	4	5
4. I think that I would need the support of a technical person to be able to use this system	1	2	3	4	5
5. I found the various functions in this system were well integrated	1	2	3	4	5
6. I thought there was too much inconsistency in this system	1	2	3	4	5
7. I would imagine that most people would learn to use this system very quickly	1	2	3	4	5
8. I found the system very cumbersome to use	1	2	3	4	5
9. I felt very confident using the system	1	2	3	4	5
10. I needed to learn a lot of things before I could get going with this system	1	2	3	4	5

APPENDIX B – USABILITY QUESTIONNAIRE

The product evaluation survey completed by the study participants consisted of 12 items with the following choices of responses: 1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree.

The items were as follows:

Item	Strongly disagree	Somewhat disagree	Neither agree nor disagree	Somewhat agree	Strongly agree
I could easily complete the task with the device					
The device helped me to complete the tasks					
It was easy to understand how to operate the device					
The device was comfortable to use					
Using the device was easy					
Using the device felt safe					
Aesthetically, I like the overall look of the device					
As a “disability” product, this device would draw unwanted attention					
I think the idea behind how the device is meant to operate provides a good solution to problems I encounter in everyday life					
It was easier to complete the tasks with the device than it was when using my existing equipment.					
Compared to other products to complete the tasks, the actual functionality of this product is better					
I would be happy to use this device if it were made available to me					