 DOI: 10.3217/978-3-85125-467-9-93

Programming for Pediatrics: A literature review of brain-computer interfaces for neurorehabilitation in children

E. Kinney-Lang[1*], J. Escudero[1]

[1]*University of Edinburgh, School of Engineering, Edinburgh, United Kingdom*

*Institute for Digital Communications, University of Edinburgh, Edinburgh, EH9 3FG, UK. E-mail: e.kinney-Lang@ed.ac.uk

Introduction: The past decade has seen brain-computer interfaces (BCI) emerge for a myriad of applications, including as assistive technology and for BCI neurorehabilitation (NR) [1]. Despite the breadth of research into BCI applications, the majority of work has been restricted to the mature brain and adults. In this context, this paper investigates current BCI tools and explores the literature for evidence about the need and practicality of translating NR-BCI techniques to children.

Material, Methods: Articles were obtained from databases Pubmed.org and Google Scholar using key search phrases including, but not limited to, 'BCI in children', 'BCI neurorehabilitation', 'BCI developmental disorders', and 'BCI motor disorders'. Articles highlighting BCI in pediatrics, for rehabilitation, and corresponding reviews were then examined in depth. Relevant references were investigated for potential insight and information. In total, 80 articles were examined. Figure 1 illustrates the diverse manuscripts considered, separated and categorized by year of publication.

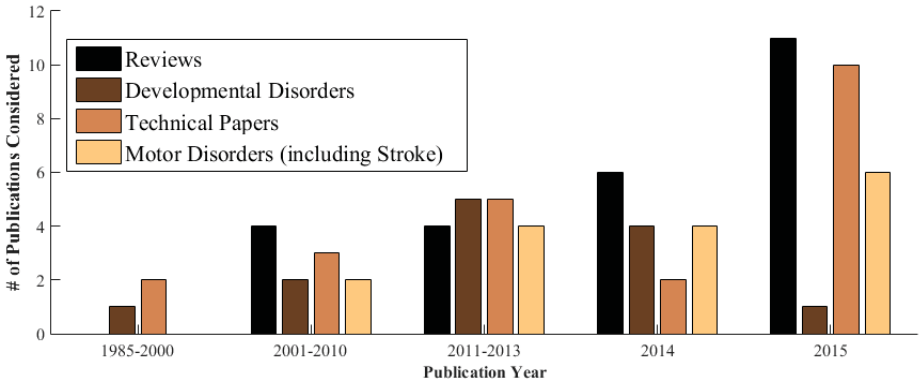

Figure 1. Distribution of supporting manuscripts considered in this review, grouped by publication year and category.

Results: Examining the literature reveals relationships between neuroplasticity, age and NR-BCI which supports possible advantages to earlier BCI intervention and exposure [2,3,4,5]. Further evidence shows BCI can capitalize on neural plasticity, demonstrated by motor-imagery NR for post-stroke patients and neurofeedback applications [3,6]. Given the remarkable neuroplasticity in children [7] and that pediatric motor cortex signals can be decoded [8], it is feasible, and possibly beneficial, to develop BCI applications for early-life NR [4,9].

Discussion: Surveying BCI literature illustrates NR-BCI use in children not been fully developed, and it is feasible to develop NR-BCI for children. However, challenges such as the dynamic signal spectrum in developing brains need to be addressed when designing such BCI applications.

Significance: Examination of current BCI literature highlights a current under served BCI population, children, and uses literature evidence to demonstrate feasibility of designing BCI-NR for children.

References

[1] Nicolas-Alonso, L. F., & Gomez-Gil, J. Brain computer interfaces, a review. *Sensors*, 12(2), 1211–1279. 2012.

[2] Grosse-Wentrup, M., Mattia, D., & Oweiss, K. Using brain-computer interfaces to induce neural plasticity and restore function. *Journal of Neural Engineering*, 8(2), 025004. 2011.

[3] Pichiorri, F., De Vico Fallani, F., … Mattia, D. Sensorimotor rhythm-based brain–computer interface training: the impact on motor cortical responsiveness. *Journal of Neural Engineering*, 8(2), 025020. 2011.

[4] Daly, I., Faller, J., Scherer, R., Sweeney-Reed, C. M., Nasuto, S. J., Billinger, M., & Müller-Putz, G. R. Exploration of the neural correlates of cerebral palsy for sensorimotor BCI control. *Frontiers in Neuroengineering*, 7, 20. 2014.

[5] Allison, B., Lüth, T., Valbuena, D., Teymourian, A., Volosyak, I., & Gräser, A. BCI demographics: How many (and what kinds of) people can use an SSVEP BCI? *IEEE Transactions on Neural Systems and Rehabilitation Engineering*, 18(2), 107–116. 2010.

[6] Ros, T., Baars, B. J., Lanius, R. A., & Vuilleumier, P. Tuning pathological brain oscillations with neurofeedback: A systems neuroscience framework. *Frontiers in Human Neuroscience*, 8, Article 1008. 2014.

[7] Johnston, M. V. Clinical disorders of brain plasticity. *Brain and Development*, 26(2), 73–80. 2004.

[8]Breshears, J. D., Gaona, C. M., Roland, J. L., Sharma, M., Anderson, N. R., Bundy, D. T., … Leuthardt, E. C. Decoding motor signals from the pediatric cortex: implications for brain-computer interfaces in children. *Pediatrics*, 128(1), e160–e168. 2011.

[9] Lim, C. G., Lee, T. S., Guan, C., Fung, D. S. S., Zhao, Y., Teng, S. S. W., … Krishnan, K. R. R. A Brain-Computer Interface Based Attention Training Program for Treating Attention Deficit Hyperactivity Disorder. *PLoS ONE*, 7(10), e46692. 2012.