 DOI: 10.3217/978-3-85125-467-9-158

Toward a simulator for the development of BCI applications in children: Preliminary steps in validating age-specific EEG simulation in BCI applications

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. Email: e.kinney-Lang@ed.ac.uk

Introduction: Recently, brain-computer interfaces (BCI) have been demonstrated as powerful tools in assistive technology and neurorehabilitation (NR) applications [1]. However, these applications have yet to be fully realized and demonstrated for use with children. Simulating realistic, age-specific electroencephalography (EEG) activity could facilitate the development of BCI for children. To do so, we propose using the neurophysical model developed in [2,3,4] in conjunction with generated *mu*-rhythm stimulations to investigate differences in BCI processing applications at various developmental ages. This paper reflects ongoing work towards such a simulation environment.

Material, Methods and Results: The general model described in [3] was implemented in MATLAB with key age-dependent parameters extracted from [4] through random normal distributions. The model is generative and imitates corticothalamic neuronal interactions through biologically relevant parameters (for a full description see [2,3,4]). Spontaneous EEG time series was simulated for several ages, both pre and post-adolescence, with parameters decided by the original validation datasets in [3,4]. The total power for each simulated EEG decreases with age, while the prominent spectral band shifts towards higher frequencies, illustrating a development consistent with literature reports [5]. Time series for several ages are presented in Figure 1, with relative spectral band power given in Table 1.

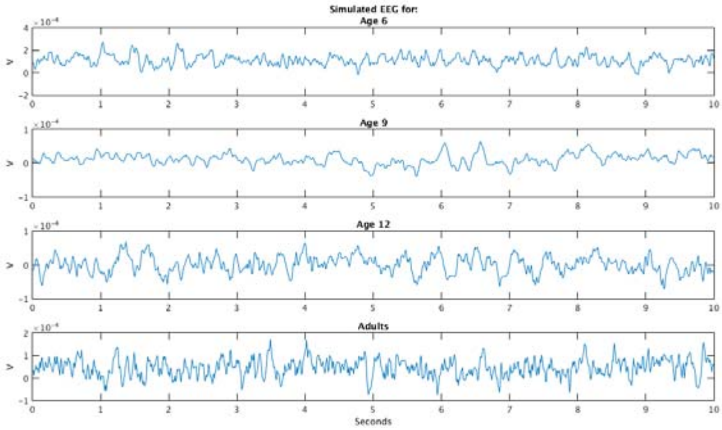

Figure 1. *Time series simulated EEG for ages 6,9,12 and adults (from top to bottom).*

	Relative Power			
Age (years)	**6**	**9**	**12**	**25**
Delta (0.5-4 Hz)	0.960	0.894	0.72	0.863
Theta (4.5-8 Hz)	0.026	0.081	0.159	0.054
Mu (8.5-12 Hz)	0.009	0.016	0.060	0.044
Beta (15.5-30 Hz)	0.004	0.03	0.042	0.027

Table 1. *The relative power for frequency bands for each age in the simulated EEG spectra.*

Mu-rhythm stimulation can be introduced to the model as an impulse stimulus through including a delta-impulse function [3]. Distributing the *mu*-stimulation in controlled age-specific EEG simulations can then mimic motor imagery (MI) paradigms, allowing the simulation to potentially be processed in MI-BCI applications.

Discussion: Simulating age-appropriate EEG data with the option to define evoked-responses, such as *mu* stimulus, provides a critical tool currently unavailable. These simulations provide a flexible environment for examining standard BCI processing chains in children and highlighting areas of improvement in BCI applications on a scale not feasible using direct user recording. Optimizing the MI-BCI tool-set for the developing brain with age-specific simulated EEG data could expand the BCI user base. Further investigations include validation of the EEG simulation and *mu*-rhythm imitation through comparison to real EEG data, with age-specific evaluations done when possible. Additional work includes implementing conditions to translate this model to reflect neurological deficits, potentially allowing access to NR-BCI applications for children via MI-BCI [6].

Significance: The details presented here are a work in progress. Using age-specific, biologically relevant EEG simulations with controlled stimulations allow the optimization and validation of BCI tools for children of various ages. Validating BCI applications for use with children via simulation would help facilitate translation of BCI to children, potentially impacting children suffering from neurological deficits, who may benefit from NR-BCI applications.

References

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

[2] Robinson, P. A., et al. Modal analysis of corticothalamic dynamics, electroencephalographic spectra, and evoked potentials. *Physical Review E* 63-64, 2001. 041909.

[3] Robinson, P. A., et al. "Estimation of multiscale neurophysiologic parameters by electroencephalographic means." *Human brain mapping* 23.153-72, 2004.

[4] Van Albada,S.J., et al. Neurophysiological changes with age probed by inverse modeling of EEG spectra. *Clinical Neurophysiology,* 21-38, 2010.

[5] Segalowitz, Sidney J., Diane L. Santesso, and Michelle K. Jetha. Electrophysiological changes during adolescence: a review. *Brain and cognition* 72.1: 86-100, 2010.

[6] van Dokkum, L. E. H., Ward, T., & Laffont, I. Brain computer interfaces for neurorehabilitation - its current status as a rehabilitation strategy post-stroke. *Annals of Physical and Rehabilitation Medicine*, *58*(1), 3–8. 2015