DOI: 10.17165/TP.2018.3.4

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Overview of EEG Research in Early Childhood Education: An International Perspective[4]

The aim of this article is to provide an understanding related to the basics of data collection with electroencephalogram (EEG) technology in the field of early childhood education. With today's rise in lab research with EEG, the commercially available portable EEG machines are being used more readily. With them it is becoming cheaper and easier to conduct research and collect EEG recordings. A review of the literature allows for comparison between research grade EEG technology and portable EEG technology, revealing the validity of portable EEG research. The advantages and disadvantages of portable EEGs vs research grade EEG is reviewed in light of research with the population of young learners.

Keywords: *portable EEG, neuropedagogy, Emotiv, early childhood, electroencephalogram*

Over the past several decades, the use of brain imaging technology has aided in understanding the basic and complex working of the human brain. Nevertheless, neuroscientists are far from a complete understanding of the developed brain (Rueda, Checa & Combita, 2012). As technology has evolved in the field of neuroscience, portable EEG technology has made it possible to have low-cost wireless EEG recordings. This increase in the availability of EEG research has allowed for a variety of new topics to be researched, and new populations to be studied (Lee & Chin, 2014). This article provides an overview of EEG technology with an important comparison of portable EEG recordings with research grade EEG systems. Next, a review of the current research within the field is neuropedagogy is reviewed, and the future direction of neuropedogogical research is discussed in light of the shortcomings of existing research.

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[4] The described article was carried out as part of the „Roadmap for Structural Changes of the University of Sopron" - nr. 32388-2/2017 INTFIN. The Ministry of Human Capacities of the Hungarian Government supported the realization of this project.

What is EEG?

Electroencephalogram (EEG) technology is used to record the electrical signals emitted by neurons as the brain's communication system functions (Lee & Chin, 2014). The communication process of neurons happens by electrical action potentials and chemical neurotransmitters. The more a brain area is activated by a stimulus, the higher the electrical activity in that area of the brain. EEG recordings provide an insight into the electrical activity of the brain areas involved in stimulus processing. EEG recording works with an electrode cap, with 16-128 small electrodes touching the surface of the scalp, these electrodes are connected to an amplifier and the recorded data is digitalized. EEG recording devices are sensitive to electrical activity; therefore research grade recording lab rooms are electronically shielded, in order to decrease disruptive noise (Lee & Chin, 2014). The optimal recording environment for EEG data is a silent dark room, with the participant sitting in a comfortable motionless (with opportunity to rest and blink provided within the stimulus) position located in front of the stimulus source, i.e. computer screen (Lee & Chin, 2014). The recorded data of EEG signals have high temporal resolution, and low spatial resolution. Therefore, the data are able to provide precision to the hundredth millisecond for reaction time. The spatial resolution can be improved by increasing the number of electrodes used for recording. EEG recordings are widely used in research, and utilized as a diagnostic tool in the case of epilepsy and other brain abnormalities (Rueda, Checa & Combita, 2012). EEG is a technique favored by researchers in neuroscience as well as in the medical field because it is pain-free, non-invasive, and low-cost compared to other brain imaging techniques (Lee & Chin, 2014).

The brainwave frequencies obtained by EEG recording are classified into five signal types, depending on the level of activity in the brain. Table 1 shows the classification of the frequencies. Image 1 shows waves as they would appear as part of recorded EEG data.

Signal	Frequencies	Brain State
Gamma	>30Hz	Highly Active
Beta	14-30Hz	Active, Engaged
Alpha	7.5-13.5Hz	Relaxed, Meditation
Theta	3.5-7.5Hz	Light Sleep, Dreaming
Delta	<3Hz	Deep sleep, Coma

Table 1: Classification of Brainwave Frequency

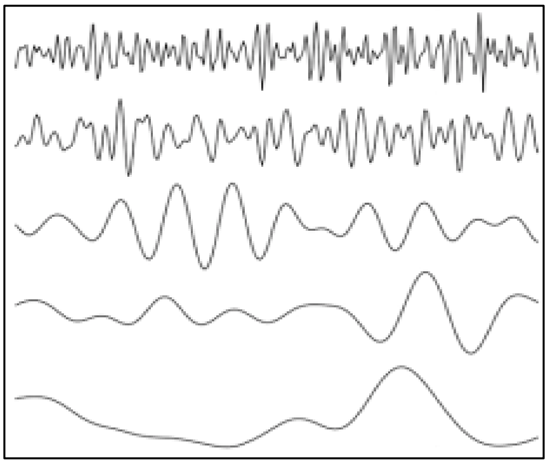

Figure 1: Example of brainwave frequencies: Top to bottom:
Gamma, Beta, Alpha, Theta, Delta
Image Source: brainsync.com

The scope of interpretation of EEG data is important to consider when designing a research project with EEG technology. EEG data are able to provide information about the general area of brain activation in response to a stimulus, and highly specific temporal data with regards to the speed of processing of stimuli (Lee & Chin, 2014). For example, two event-related potentials (ERPs) which are often investigated are the P300 and N400 components. The P300 is a positive peak, approximately 300ms after the onset of a stimulus in the case of an oddball paradigm. An oddball paradigm is a set of stimulus in which there is a strict pattern followed with a rule break on 20% of the trials. The N400 component is a negative peak approximately 400ms post-stimulus in response to anomaly words and other meaningful stimuli such as images, sounds and smells. Overall the frequency and the peaks of the recorded data are able to be interpreted to understand the brain-state of the participant and the reaction to a variety of stimuli (Lee & Chin, 2014).

Research Grade EEG Technology vs. Commercially Available Emotiv EPOC

Commercially available EEG machines are making EEG research more widespread and accessible to smaller research labs. The portable EEG technology systems are more attainable due to its price, wireless features and ability to use outside of a controlled lab setting (Xu & Zhong, 2018). Studies have shown the portable EEG machines, such as those manufactured by Emotiv Inc., can yield similar results as compared to research grade laboratory findings (Xu & Zhong, 2018). For example, Barham, Clark, Hayden, Enticott, Conduit, and Lum (2017) reported a comparative study of research grade EEG system compared with a modified Emotiv

EPOC and the NeuroScan SynAmps RT EEG system. Overall, their findings revealed that the low-cost wireless versions of EEG recordings were statistically similar to the N200 and P300 recoded by the research grade EEG system. It is important to note that due to the previous concern raised for the signal-to-noise ratio, some modifications are suggested in order to obtain more valid data from the Emotiv. The modification to the Emotiv EPOC was originally implemented by Debener et al. (2012); the modifications included "removing the Emotiv wireless transmitter from the plastic electrode arms, along with the felt electrodes, [t]he transmitter was then connected to research-grade Ag/AgCl electrodes via shielded wires" (Barham, et al., 2017). This process aids in improving the signal-to-noise ratio; therefore, the Emotiv system is able to provide more accurate data with regards to detecting ERPs (Barham et al., 2017). With this modification, the ERPs in relation to an auditory oddball paradigm could be recorded and were comparable to those recorded by the research grade EEG system.

In summary, the use of portable EEG systems allows for a larger variety of lab settings to complete research comparable to that of professional research grade laboratories. Some of the benefits of portable EEG systems includes the low-cost upfront, low-cost maintenance, easy mobility due to wireless set-up, and simple portability compared to research grade EEG technology system set-up (Xu & Zhong, 2018). With portable, cheaper EEG data collection it may be simpler to explore a variety of phenomena, on the other hand research grade EEG systems may be more effective for diagnostic purposes, and more precise and reliable for data collection.

Current Research with EEG System with Children

Portable EEG systems can be used to study a wide variety of research topics, from neuromarketing to neuropedagogy. With regards to educational research, portable EEG technology tends to be focused on online learning, motor skill acquisition, and topics of literacy with a focus on reading (Xu & Zhong, 2018). More specifically, some of the cognitive aspects which have been evaluated within this research field are attention, motivation, self-regulation and meditation (Xu & Zhong, 2018). Attention is frequently targeted topic for investigation in research labs with access to portable EEG technology because the brainwave frequency is one of the more visible elements to interpret from the data and design stimuli. The differences in active, attention brainwaves is easily distinguishable from a distracted, relaxed, or inattentive brainwave pattern (Xu & Zhong, 2018).

The Emotiv EPOC system has been utilized for use in determining whether a participants is engaged in the stimulus task (Cernea, Kerrren & Ebert 2011; Kuber & Wright, 2013). For example, Lee and Chin (2014) used the Emotiv neuroheadgear to investigate varying levels of engagement to identify the level of boredom or engagement by power frequency spectrum. Overall, the results were interpreted to show that engagement levels could be gauged by the activity in the frontal lobe (Image 1), and that children were more engaged when presented with a lesson containing interactive visual stimuli as compared to a lesson without an interactive visual component (Lee & Chin, 2014).

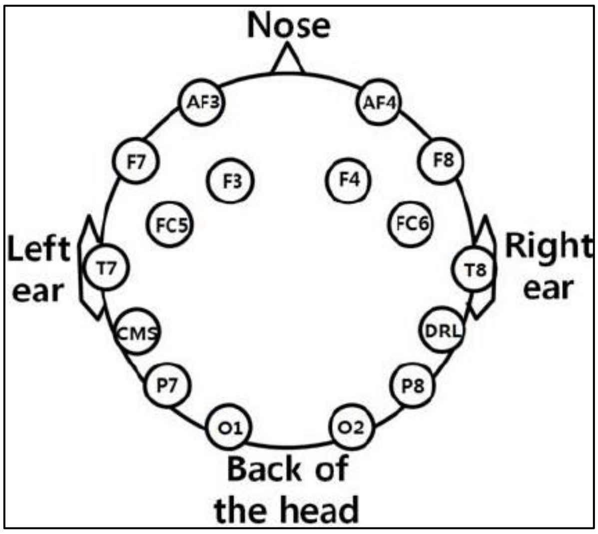

Image 1 Placement of sensors of Emotiv Headset
Source: www.emotiv.com

Research about the process of learning in early childhood has investigated the role of motivation and engagement in correlation to the rate of learning. More specifically, studies about motivation in learning have targeted the levels of engagement as a measure of interest and gauge of the participant's level of learning (Bandura, Caprara, Barbaranelli, Gerbino, & Pastorelli 2003). In addition, other research studies about learning has targeted thevarious aspects of reading, for example, the effect of quality reading as a shared activity (Hutton, et al., 2017). This study included participants from low socioeconomic status families and investigated the effect of maternal shared reading time on the brain functioning of the children while listening to stories. The results revealed that the maternal attention had a positive influence on the brain activation of the child during the shared reading activity (Hutton et al,. 2017).

Portable EEG technology can be used to provide automatic feedback and information about immediate influence of the learning process in early childhood. Huang and colleagues (2014) used the Emotiv EEG system to augment attention during reading assignments. With participants' age ranging from 6 to 8.5 years the Emotiv was used as a brain-computer interface (BCI) in order to redirect children's attention during the reading of passages. When the participants' engagement level decreased, they were triggered to redirect their attention and maintain a higher level of engagement in reading. As the data showed, the BCI improved the overall engagement of the participants; however, the researchers pointed out the need for reducing noise of the EEG signals recorded with the Emotiv (Huang et al., 2014). Overall, there is a growing number of research studies in which scientists are aiming to conduct meaningful research with young children with use of portable EEG technology systems to better understand young children's behavior in learning and the ways educators and parents can further promote development and learning.

Future Research

Research with portable EEG technology is on the rise with an increasing amount of published information about the possibilities and capabilities of the developing technology (Lee & Chin, 2014). In order to improve the validity of research with portable EEG technology, it is important to replicate previous studies and improve upon the methodological design and strength of data. The review of the literature indicates a need for larger sample sizes, especially with young children (Xu & Zhong, 2018). However, EEG research with young children is exceptionally difficult due to the necessity for a large number of trials, electrical noise shielded lab setting, and the importance of limited motion during the recording. It can be difficult for young children to maintain attention and limit their movement for 20-40 minutes of repetitive trials. For these reasons, there is a significant lack of reliable portable EEG research data reported with young participants. Nevertheless these obstacles can be overcome and meaningful data can be recorded with proper measures taken to ensure reliable data collection. It is possible to have shorter trial groupings with breaks for stretching and fidgeting and the stimulus during the data collection can be exciting and engaging.

It is necessary to advance currently available findings with new research questions and appropriate research designs for using portable EEG systems. It is important to have large sample sizes in order to reduce the effect of noise in the data. Portable EEG systems are making EEG research more widely available to labs and possible early childhood classrooms, and allow for larger participant pools, and larger populations represented in the data. As portable EEG research data collection increases it is imperative to maintain proper steps taken to ensure the proper lab settings for EEG research, such as a quite environment, shielding from electrical noise of the surroundings and reducing the movement of participants during data collection.

Overall, the field of neuropedagogy is in its early years of development. Due to the key relevance of early childhood brain development, it is important to conduct research with brain imaging technology. Therefore, it is essential to continue the growth of this field of study with solid methodological study designs, reasonable conclusion of results, and to create reproducible studies. As the review of studies indicated the portable EEG technology systems allow for high quality data collection attainable for research labs with limited resources. This unique and invaluable addition to research allows for more data to be collected and analyzed in the light of recent findings. Neuropedagogy is a promising field for evolving the understanding of the developing brain.

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