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RESTING STATE EEG POWER ANALYSIS IN FILIPINO CHILDREN WITH DYSLEXIA

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Abstract

Dyslexia is a neurocognitive disorder characterized by severe and persistent reading difficulties despite normal intellectual functioning and appropriate schooling. To better understand the neural underpinnings of dyslexia, this study investigated the neurophysiological differences between normal readers (NR group) and readers with dyslexia (DYS group) by analyzing their brain activity at eyes-closed resting state using mobile electroencephalography (mEEG). The results revealed that the DYS group exhibited an overall larger power activation in the theta and beta frequency bands, as well as a dominance of delta, theta, and beta frequencies across all scalp sites. Increased delta and theta activity was found in the left frontal region, whereas significantly stronger beta power was found in the right hemisphere. Moreover, weaker alpha activity was observed in the left frontal and right posterior regions. These findings provide evidence of an atypical and less integrated linguistic network in dyslexia.

Keywords: *Dyslexia, reading, mobile electroencephalography, resting state.*

1. Introduction

Dyslexia is a neurodevelopmental disorder characterized by severe and persistent reading deficits in both children and adults despite normal intellectual functioning and having been provided with educational opportunities (Pina Rodrigues et al., 2017). As a multifaceted and heterogeneous disorder that persists across the lifespan, it has been carefully and intensively studied by researchers who have attempted to determine its genetic, neurobiological, and cognitive components (Snowling, 2013).

One approach to understanding dyslexia is through analyzing resting state activity, an area of interest in cognitive neuroscience wherein intrinsic functional connectivity at rest permits the brain to allocate resources and prepare itself for changes stemming from the internal or external environment. This allows researchers to make predictions about the resting state network as a determining factor of underlying neural activity. Research in this area has provided valuable evidence on deviant network organization for neurological disorders and generated much understanding about the neural characteristics of healthy brain development (Alcauter et al., 2017; Gracia-Tabuenca, Moreno, Barrios, & Alcauter, 2018). Brain activity can be obtained using mobile electroencephalography (mEEG), a neuroimaging tool that allows researchers to observe patterns of brain frequencies. Each frequency band has a purpose and an underlying function: A dominance of slow frequencies (i.e., delta and theta) when one is engaged in a cognitive task would suggest slow brain activity and possibly even cognitive dysfunction (Kamel & Saeed Malik, 2015), whereas faster frequencies (i.e., beta and gamma) are dominant when the brain is actively processing information (Magazzini & Singh, 2018). The alpha band, which is dominant at resting state, is associated with cortical and behavioral inhibition (Bastos et al., 2015, Marshall, O'Shea, Jensen, & Bergmann, 2015). These frequencies are used to explain the differences in brain activation between normal controls and those with neurological deficits.

Results from resting state EEG studies on dyslexia and other learning disorders have typically reported greater delta and theta power as well as weaker alpha and beta power (Papagiannopoulou & Lagopoulos, 2016; Roca-Stappung, Fernandez, Bosch-Bayard, Harmony, Ricardo-Garcell, 2017). Studies generally indicate remarkably elevated low frequency activity, particularly in the theta band, in the left hemisphere which reflects an atypical linguistic network, implicating the presence of brain abnormalities in children with dyslexia prior to reading acquisition (De Vos et al., 2017; Fraga González et al., 2016; Morillon, Liégeois-Chauvel, Arnal, Bénar, & Giraud, 2012; Pagnotta et al., 2015; van der Mark et al., 2011). Babiloni et al. (2012) reported abnormal alpha rhythms, whereas a number of studies have observed abnormally stronger beta power in the right hemisphere, indicating task-related overexcitability (De Vos et al., 2017; Dimitriadis et al., 2016, 2018; Hoeft et al., 2011; Jiménez-Bravo et al., 2017; Lizarazu et al., 2015; Power, Colling, Mead, Barnes, & Goswami, 2016; Simos et al., 2011).

2. Method

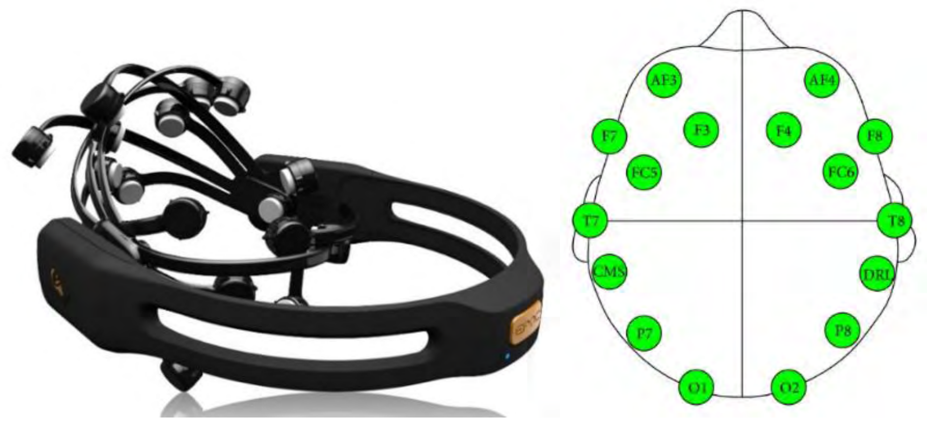
2.1. Participants

The participants were divided the Dyslexia (DYS) group (n = 5; mean age = 9.61; SD = 1.7) and the Normal Reader (NR) group (n = 4 mean age = 9.61; SD = 1.00). For both groups, non-verbal IQ results obtained using the Raven's Colored Matrices (Raven, Raven, & Court, 2003) were found to be within the normal range (at least at 75th percentile). The DYS group had been previously diagnosed with Specific Learning Disorder with an impairment in reading by a professional (medical doctor, clinical/educational psychologist, or special educator/reading specialist). The NR group, on the other hand, presented with no history of reading difficulties. All participants were male, right-handed, with normal vision (as previously assessed by their physicians), and free of any co-morbid conditions, such as attention deficit/hyperactivity disorder, autism spectrum disorders, and any speech/language and visual impairments. Furthermore, parental consent and child assent were obtained before data gathering.

2.2. Data collection and analysis

Brain signals were obtained by the Emotiv EPOC Neuroheadset (Emotiv Systems, Inc., 2013), a non-invasive, high-resolution, neuro-signal acquisition and processing wireless headset designed for contextualized research (see Figure 1). It has 14 channels (AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF42) distributed according to the internationally accepted 10–20 system of electrode placement and includes two references in the CMS/DRL noise cancellation configuration P3/P4 locations. Only 12 channels were included in the study (i.e., T7 and T8 were excluded).

Figure 1. The Emotiv EPOC Neuroheadset and its scalp locations.

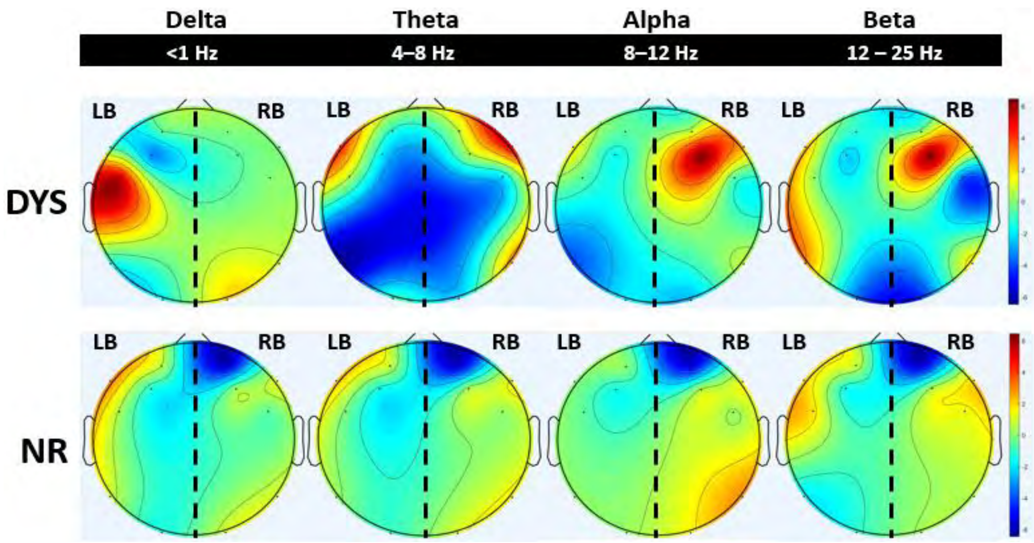


Data were transferred via Bluetooth to the computer and raw EEG data were acquired using the EmotivPRO software. Further signal processing was carried out using EEGLAB, an open source MATLAB toolbox for processing data from EEG. The EEG recordings were segmented into epochs to be extracted, visually inspected, and cleaned for artifacts. Absolute power analyses using fast Fourier transform (FFT) for delta (1–4 Hz), theta (4–8 Hz), alpha (8–12 Hz), and beta (12–25 Hz). Mann–Whitney U tests were performed using IBM SPSS Statistics version 25.0. The participants wore the EPOC headset throughout the experiment. Before putting on the headset, the 14 electrode recesses were fitted with a moist felt pad. The headset was then placed on the participant's head and subjected to software set-up. After verifying that the built-in battery was fully charged and the wireless signal reception was reported as good, the experiment began. Each participant wore the headset for five minutes.

3. Results

Significant group differences were observed for the theta (U = 1, p = .03) and beta (U = 0, p = .01) frequency bands, wherein the DYS group exhibited overall stronger power for these bands. Tests comparing electrode sites indicate that the DYS group obtained significantly stronger theta power in the frontal and left parietal regions. Stronger beta power was mostly observed in the right frontal and left parietal region. On the other hand, the NR group demonstrated stronger alpha power values in the left frontal and right occipital regions. Significant inter- and intra-hemispheric differences were limited to the delta, theta, and alpha bands (see Figure 2). For the DYS group, delta power is significantly left-lateralized in the frontal region, whereas theta power is bilaterally distributed. Alpha and beta power are notably right-lateralized. The NR group, on the other hand, demonstrate a more stable resting network.

Figure 2. Power distributions according to frequency band for Resting State. Power (in dB) is represented by colors (dark red = very high, orange = high, yellow = average, light blue = low, dark blue = very low).



4. Discussion

The results revealed that the DYS group exhibited an overall larger power activation in the theta and beta frequency bands, as well as a dominance of delta, theta, and beta frequencies across all scalp sites. In the DYS group, increased delta and theta activity was found in the left frontal region. Abnormalities in the theta band (i.e., overactivation) at resting state have been implicated as a distinct neural signature in dyslexia, suggesting a less integrated network, as well as reduced communication in readers with dyslexia compared to controls. Thus, the observed increase in low frequency activity during eyes closed resting state in children with dyslexia is a strong indicator of the presence of an atypical network (De Vos et al., 2017; Fraga González et al., 2016; Pagnotta et al., 2015; Papagiannopoulou & Lagopoulos, 2016). The frontal reading network involves the left inferior frontal gyrus which plays a key role in speech articulation. Left-hemispheric hypoactivation characterized by an abnormal modulation of delta and theta frequencies is reflective of altered connectivity patterns that have been found to have crucial consequences in processing speech input (van der Mark et al., 2011).

An attenuation of beta frequencies was observed in the left hemisphere as compared to the right hemisphere. The current findings agree with other studies that have reported abnormally stronger beta power in the right hemisphere (De Vos et al., 2017; Dimitriadis et al., 2013, 2016, 2018; Jiménez-Bravo et al., 2017; Lizarazu et al., 2015; Power et al., 2016). At rest, this right-lateralized overexcitability may be attributed to task-related overactivation in the right hemisphere (Hoeft et al., 2011; Simos et al., 2011). Moreover, weaker alpha activity was observed in the DYS group compared to the NR group, especially in the left frontal and right posterior regions. Comparable results were obtained by Babiloni et al. (2012) and Papagiannopoulou and Lagopoulos (2016).

5. Conclusion

Analyzing eyes-closed resting state EEG rhythms is essential to better understand the role of abnormal cortical sources in brain-based deficits. The findings of this study confirmed a less integrated language network as evidenced by a dominance of theta activity in the left frontal region at resting state in children with dyslexia. Moreover, atypical alpha and beta activity were also observed. More studies are needed to further explore the neurophysiological characteristics of resting state activity in children with dyslexia.

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