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Electrophysiology and Undergraduate Research at the University of North Carolina at Asheville

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Abstract

Neuroscientific methods and explanations increasingly dominate contemporary research in human behavior. At the undergraduate level, neuroscience is gaining a prominent place amongst the liberal-arts curriculum at UNCA. Recently, Drs. Foo and Neelon of the Department of Psychology have established the first full-scale human neuroimaging lab at the university and in western North Carolina through the acquisition of a 64-channel electroencephalography (EEG) recording system for research and training in neuroscience at UNCA. This system augments a growing bank of available equipment designed to record and measure emotional and physiological arousal (e.g. ECG, Blood Pressure, GSR), and to locate areas of the brain involved in cognitive tasks (EEG). This paper will present ongoing data collection on the roles of attention and inhibition in a Visual Evoked Potential task. Full-head EEG was recorded while participants either 1) passively observed a visual checkerboard 2) performed a congruent reaction time task by pressing a button on the same side (L vs. R) as the checkerboard, or 3) performed an incongruent task by pressing the opposite button as the checkerboard. Results and implications will be discussed.

1. Introduction

The traditional fields of Psychology, Anthropology, Sociology and other social sciences have long been interested in understanding how human behavior is generated, and what factors influence what we do, and also how we think. These disciplines have often been criticized because the relevant variables are hard to define, measure, and test reliably. In contrast, natural sciences like Physics, Chemistry, and Biology are more amenable to objective, quantitative methods, yet the data can appear too remote to adequately explain cognitive function. Recently, a new interdisciplinary field of Neuroscience attempts to bridge the gap between these so called “soft” vs. “hard” sciences, in explaining and predicting human thought and action.

Neuroscience is gaining a prominent place in the undergraduate curriculum in behavioral science. Formerly, students at UNC-Asheville did not have the research training and practical skills to remain on a competitive level with other undergraduate research universities. After a long gestation, UNC-Asheville began a Neuroscience minor in 2008. While theoretical and classroom instruction in the field were initially used, opportunities for natural science style laboratory work remained scarce. For example, the neuroscience curriculum included comparative neuroanatomy and neurophysiology information limited to color-coded images in textbooks. Consequently, graduates of UNC-Asheville had a difficult time getting admitted into neuroscience graduate programs, even as UNCA began to add hands-on lab experiences in comparative neuroanatomy, comparative neurophysiology, and human physiology (ECG & GSR) in the curriculum. In 2010, the UNCA neuroscience minor acquired a 64-channel BioSemi EEG system, the same equipment that other prominent institutes with undergraduate researchers utilize such as Princeton, California Institute of Technology, UNC Chapel Hill, UC Berkeley, and Carnegie Mellon

University use for their neuroscientific research. This paper represents exploratory pilot work incorporating full-head electrophysiology (EEG) to understand the workings of the human brain.

The primary driver for beginning with recording visual neuroanatomy is practicality. As a new program, we want to start with a well-known target to increase our chances of success. It has been estimated that approximately 50% of the brain in non-human primates and almost as much in humans is devoted to perceiving the visual world[1]. Light is transduced in the retina, collected in the thalamus, and passed to the primary visual cortex in the occipital lobe. It then divides into two ventral and dorsal processing streams, through a series of complicated intervening recursive feedback loops, seemingly redundant functions, and species-specific details that complicate inferences (e.g. areas V2-V4, MT, MST, etc.) [2,3].

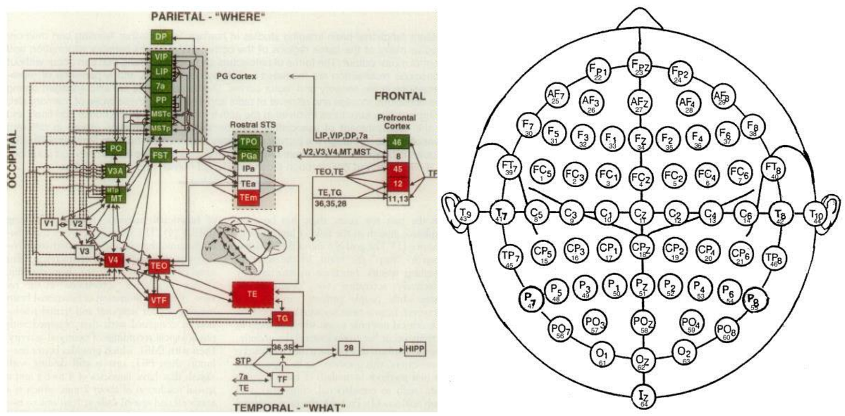

Figure 1. Visual perception areas of the brain[2] and location of 64 EEG sensor positions on the head

For this experiment, the 64-lead BioSemi EEG system was used to measure brain wave activity responses to visual stimuli in three conditions. Our first attempts at this resulted in failure, as we were unable to record any brain signals without an overwhelming amount of environmental electromagnetic noise. In fact, the procedure that we detailed in the abstract for this paper (and reproduced above) was modified to a simpler version in an attempt to troubleshoot the problem. Thus, this paper is a close replication of the visual evoked potential methodology used in research[1] and clinical applications. Therefore, the revised first condition participants were passively exposed to a visual stimulus (e.g. a flashing colored checkerboard). In the second condition participants were asked to focus their attention on responding with a button press as fast as possible, and the pattern of activation was measured. The third condition served as a control where the participants kept their eyes closed and remained passive while the stimulus was being presented. We included this control not only to provide contrast to the other visual, occipital lobe dependent conditions, but also to explore whether this might provide a good window into nondirective (vs. transcendental) meditation, as other authors[4,5] have recently reported.

In line with previous results, we predict activation in primary visual cortex (occipital lobe) during the first visual condition[6,7]. During the reaction time task, we expect activation in primary visual cortex, and contralateral motor cortex[6], as the participant will be actively using their dominant hand to respond to each stimuli. Finally, the eyes-closed control condition should depress visual areas, and enable other cognitive areas, like the frontal lobe to engage[4,5].

Methodology

2.1 Participants

Eight healthy (average age= 23.64 years) participants (n= 4 males; n= 4 females) were recruited from the University of North Carolina Asheville's campus to voluntarily participate in the experiment. All participants signed an IRB consent form before testing and were briefed about the proceedings of the visually evoked potentials experiment.

2.2 Stimuli

A red and green colored checkerboard with a black focus point served as the visual target for participants. The checkerboard was programmed to flash for 200 ms at a time. The interstimulus interval (ISI) was 800ms (±100ms jitter).

2.3 Procedure

The visually evoked potentials experiment was composed of three conditions that each lasted for five minutes, which produced 200 trials each. Total trials collected numbered 4800 (3 conditions X 200 trials X 8 participants). All conditions had the same sequence of randomized flashes, but differed in instruction. In the first condition, the participant was asked to passively watch the checkerboard. The second condition was a visual reaction time task that required the participant to quickly press a button on a hand-held gamepad connected to the computer when the checkerboard flashed. In the last condition, the participant was asked to close their eyes and stay passive without vision. No buttons were pressed in the last or first conditions.

2.4 EEG Recording

Participants were made comfortable in an armchair placed in a room in the Sherrill Center EEG lab in front of a computer screen. An electrode cap was fitted to each participant and conductive gel was placed in each opening of the electrode cap. The 64-channel BioSemi EEG system was used to record electrical signals from the electrodes placed on the scalp, recording at 2048Hz, and later downsampled to 512 Hz. Electrodes were also placed on the mastoids and the infraorbital eye muscles to identify unusable epochs during post-processing. Approximately 45% of experimental epochs were removed prior to analysis, owing probably to our relative inexperience in this protocol. Linked mastoids served as reference. The remaining raw timeseries were bandpass filtered between 0.5 and 40 Hz. For each experimental condition, the 200 individual trials were aligned with respect to stimulus onset (blue line in figure below), and averaged to remove randomly generated noise. Finally, sLORETA (standardized low resolution brain electromagnetic tomography) was used to identify potential cranial sources of the surface-measured EEG recordings.

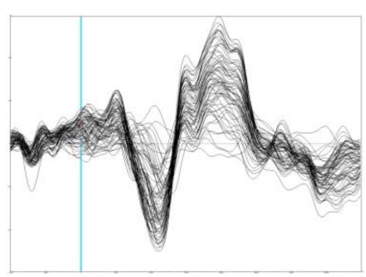

Figure 2. Representative timeseries of 200 trials averaged re: stimulus onset

3. Results

No significant results were found across the eight participants. Because of this lack of significant group results, and acknowledging how recording locations were changed in the middle of this experiment, typical “grand-average” ERP’s are not reported here. Instead, general trends are illustrated in the figures below which show the strongest average activation pattern for one representative participant in each of the three experimental conditions. We are currently improving our data analysis techniques to be able to show collective data in the future.

In the following figures, the anterior portion of the head (i.e. including Ss nose) are at the top of the figure, and the posterior head (i.e. the occipital lobe) at the bottom. The S’s left/right ears appear as semicircles on the left/right of the figure: this is a dorsal view of the S’s cortex, looking down. The color scaling is automatically adjusted in each figure, and range from +/- 50 µV.

As hypothesized, noticeable activity of the primary visual cortex was recorded during the passive visual condition when the participant’s eyes remained open. In the figure below (and in all following), cortical activation is coded in bright orange, and depressed activation, coded in black, is observed in the frontal areas of both hemispheres. Because of the autoscaling of the BioSemi ActiveView software, an activation area appears in front of the triangular shaped nose (upper portion of the figure below) which is artificial.

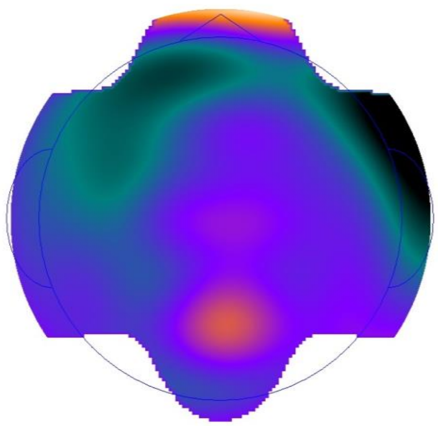

Figure 3. Results of Passive VEP condition

Figure 3 Strong activation was observed in primary visual cortex during the Passive VEP condition

Contralateral motor cortex activation, in addition to primary visual areas was present during the second reaction time presentation of the visual stimuli. Unlike our other participants, this particular person was left-handed, so they pressed the gamepad keys with their left, not right sides. Consequently, their right motor areas in the posterior frontal lobe demonstrate excitation across trials. This excitation is so strong in fact, that primary visual areas appear depressed because of the autoscaling effect as above.

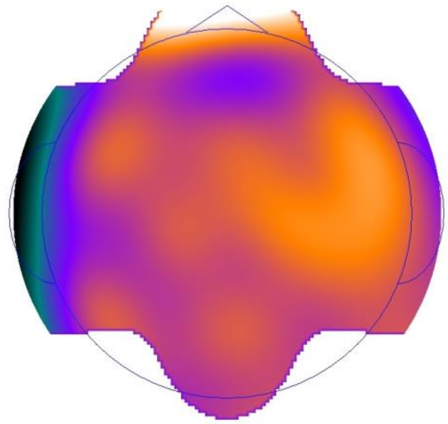

Figure 4. Results of Visual Reaction Time Task

Figure 4 We observe contralateral (R) motor cortex (this participant was left handed)

Finally, as hypothesized, frontal lobe activity was observed during the passive eyes-closed control condition. Further frequency analysis revealed alpha wave activity (operating between nine and fourteen Hz), suggestive of an individual who is awake yet in a relaxed state of mind, during selected transient episodes.

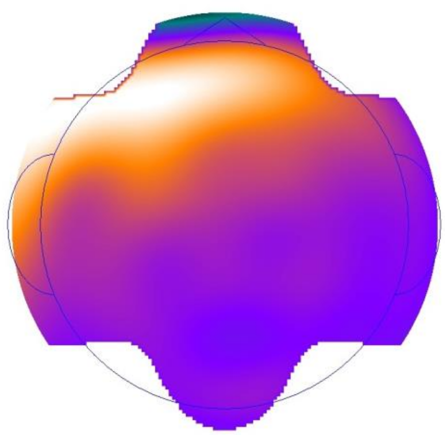

Figure 5. Results of Eyes closed control

Figure 5 We observe activation in frontal lobe including episodes of alpha waves (9-14 Hz)

4. Conclusion

4.1 Discussion Of Results Found

As hypothesized, noticeable activity of the primary visual cortex was recorded during the passive condition with the participant's eyes open. As expected, contralateral motor cortex activation was present during the active condition of the visual task, as was frontal lobe activity during the passive eyes-closed condition. Furthermore alpha wave activity, indicative of an individual who is awake yet in a relaxed state of mind, was also observed during intermittent trials[4,5]. These preliminary data replicate established results, including the seconds-long alpha waves seen in the control condition. It is only a start, but this experiment demonstrates that it is possible that undergraduates at UNCA can feasibly record and analyze EEG data. While cognizant of the impending graduation dates of the student authors, we aim to develop and teach more complicated signal processing and computer programming that will support between-subjects statistical analyses in the near future.

While these results are promising, it is important to note that these are pilot data and continued testing of participants is required to validate results found. As mentioned in the introduction of this paper, this experiment represents a simplified protocol used to troubleshoot our initial electromagnetic noise problems. Initial testing was held in Carmichael Hall (home of the Psychology Department, and the faculty advisor) two years ago. After continuous troubleshooting, including repeat visits from the BioSemi vendor, it was discovered that the aged wiring infrastructure was probably generating an intractable amount of electromagnetic noise. Luckily, this coincided with structural repairs to the building, so our experiment was relocated to a closet in the Wilma M. Sherrill Center during the summer of 2012. These facilities gave us a vastly improved setting to work in with a miniscule amount of electromagnetic noise being produced, so data on the final eight participants was collected. Since the fall semester, the laboratory has been relocated to Carmichael Hall; however, the electromagnetic noise issue persists.

4.2 Future Directions And Collaborations

Creating a rich environment that encourages student undergraduate research is at the heart of UNCA's core missions. The acquisition of neuroimaging technology like the BioSemi EEG System has not only ignited a numerous amount of research interest within the Psychology and Neuroscience programs but has also created a number of opportunities for collaborative projects both on-campus and in the greater Asheville community. Projects within the Psychology Department include the use of EEG to record brainwave response to both visually presented stimuli, as well as auditory stimuli. This equipment is also being used to collaborate with the Health and Wellness, and Mathematics Departments as well.

While this equipment has several applications for promoting research and collaborations at the UNC-Asheville campus, the faculty and student body is also dedicated to finding applications for this technology in the Asheville community. This includes discussions with Dr. Ed Hamlin, of the Pisgah Institute's Center for the Advancement of Human Potential. This local behavioral health practice offers EEG (brainwave) biofeedback training for clients with a variety of conditions including hyperactivity, attention deficit disorder, and specific learning disabilities.

5. Acknowledgements

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6. References

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