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Honors Thesis Proposal

Running Title

The Effects of Atmospheric Pollutant Levels on Cognitive Processes from Memory Search Tasks: A Comparison of Two EEG Analytical Methods, Standard ERP Component Analysis and the Whole-Wave Cognitive Spectral Bands Approach to Analysis.

Project Purpose

The purpose for this Thesis is to take the EEG data from the infectious disease study done by Dr. Bruce Brown of BYU, and combine it with the measured levels of each of the six main pollutants for each of the specific test days done in the study. The project will be to compare levels of air pollutants with levels of cognition on participant data and whether poor air quality significantly affects cognition for the worse. There will then be two sets of analyses using Multivariate Multiple Regression; the first will use the standard event-related potential (ERP) component measures (P300, N200, etc.) from the analyses done on the Sternberg memory load test, gathered in the EEG data recorded by myself and my colleagues (both faculty and student) in the infectious disease research. The second will use the cognitive spectral bands (CSB) method to determine if, by measuring the levels of cognition in the participants, it can be determined which days were poor air days, and which days were good air days.

Project Importance

Any potentially significant findings in this study may lead to opportunities to present findings in concordance with Dr. Brown's EEG infectious diseases study, and may further create

some urgency if the toxin levels in the air are shown to significantly impair cognition. Everyday matters such as driving, education, and working all depend on our ability to perform cognitive tasks. If air quality is significantly impairing the ability for people at large to perform well cognitively, then this project could help lead to further efforts to reduce toxicity in our air. For example, if poor driving was found to be strongly correlated with poor air quality, then perhaps fewer automobile accidents would occur if air quality improved significantly. Presenting such findings at conferences would both help create awareness for such a need for change, while also allowing for incredibly valuable experience to an undergraduate student aspiring for graduate studies.

Project Overview

There are countless maladies in the world today, yet our ability to diagnose them all with precise accuracy is a work in progress. Mental illnesses such as schizophrenia, autism, ADHD, ADD, and anxiety (Kim, 2018, Matheweson, 2012, Van Dongen-Boomsma, 2010) have been shown to alter the mental states of those who suffer from them on a neurological level. Due to the blurry lines of defining these conditions and their symptoms, exact measurement or diagnosis is difficult due to the variability of such conditions. In 2007, Drs. Bruce Brown, Dawson Hedges, Donovan Fleming and Scott Steffensen pioneered a new eigenvector method to plot data via the event-related potential (ERP) method in order to create a more effective method of diagnosing mental disorders (Brown et. al 2007). The ERP method works by using a time lock over the course of several repetitious activities in order to pinpoint exactly where the activity is taking place in the brain. Over the repetition of many tasks, the waves are averaged out to create one smooth pattern that is measure-friendly.

Upon discovering this new method in 2007, Dr. Brown and his associates found that more information could be taken from these waves by using "whole-wave analysis". By analyzing the

"cognitive spectral bands" (CSB) the brain waves proved to be both unique to each person like a fingerprint, but more importantly also had diagnostic capability. The measures were shown to be even more accurate than the ERP method at determining individual aspects of cognition unique to the individual. This technique showed significant and consistent differences between those with healthy brains compared to persons with mild Alzheimer's disease (Brown, 2017). The excitement of such this discovery led to the development of this technique, and could prove to be a more accurate means of diagnosing mental conditions such as anxiety, depression, as well as other conditions. If mental conditions could be mapped precisely on a graph, then diagnoses could be given in a far less subjective manner than a clinician's personal speculation. Implications for a measure like this could be vast in regards to treating mental illness today.

When these findings were presented in 2017, professionals commented on how the results appeared to be impressive, yet the data might only be significant due to chance, that the data happened to be ideal for this model of measurement. In order for the model to be considered more valid, one would have to apply the method to a different set of data in another experiment. An attempt was made to do just this with smaller samples, and the results showed that the model indeed did not transfer over to other samples. However this did not necessarily discredit the model. The advocates for CSB believed that this was due to shaky criteria for diagnosis already existing in the DSM5 (Diagnostic and Statistical Manual-5), as well as the small sample sizes that were gathered. As mentioned before, the diagnoses of mental health disorders is notorious for being having overly-generic definitions, that there are rarely clearly defined lines for what is, and for what is not a disorder. The need for more substantial data to back this new method resulted in the research in which I base my Honors Thesis.

This past year, I have participated in a research group that grew out of this work. We have been carrying out a substantially more definitive test in order to determine the strength of the CSB analytical method on a much larger sample. This research group is conducting a major study two years in the making, which has gone through a number of iterations, IRB amendments, etc. The research team now includes nine faculty colleagues with a strong and diverse set of capabilities. Besides Drs. Brown, Hedges, and Steffensen who began this research line over 12 years ago, the team now includes Drs. David McPherson and Daniel Kay who provide support and training in electrophysiological measurement area and guidance in the interpretation of results; Dr. Eric Wilson who provides support in the hematological testing and interpretation area of participants who give blood for analysis in addition to the EEG; and Drs. Shawn Gale, Joseph Olsen, and Lance Erickson who provide support in the areas of neuropsychological testing, psychometrics, and statistical analysis. Needless to say, the group does not lack in ability as they are employed by BYU, a university with high standards in employing competent faculty.

The performance of the actual testing, and much of the statistical/mathematical analysis is being carried out by about a dozen student research assistants, including myself, with both graduate and undergraduate students. We students in this group been trained in relevant skillsets such as quantitative analysis, electroencephalographic (EEG) testing, and in hematological testing for blood samples taken from participants. It has been a wonderful opportunity for being mentored, and an invaluable learning experience for me as well as my student colleagues. The study will soon have over 200 participants in order to gain enough of a confidence interval in order to withstand intense inspection for the model's validity. My Honors Thesis Project will build off the data already gathered from this study. My personal aim for this project is to take the existing data from Dr. Brown's EEG analysis, and to use it to measure the levels of cognitive performance of participants in this study, only with the caveat of a new direction of testing.

I intend to measure, using the existing data from Dr. Brown's EEG study, on how strongly air quality in Utah County correlates levels of mental cognition. The primary focus of the study is to perform preliminary analyses based off of the hypothesis that bad-air days will be shown to have a significant effect upon memory-search performance tasks, such as the Sternberg, a memory load test shown to be valid in measuring the brain's ability to remember certain items. My personal role will be to take a subset of the Sternberg task recordings from the infectious disease study, and combine selected parts of that dataset with a set of data from Dr. Pope regarding the concentrations of five primary polluting agents (O3, CO, SO2, NO2, PM10, and PM2.5) found in Utah Valley air. Levels of pollution on each of the testing days of the EEG study will be measured, and compared with the levels of cognition of the participants. I will then be tutored by these professors in how to use Multivariate Multiple Regression to test several hypotheses as a pilot study to prepare for and guide their planned future endeavors of investigating the matter.

The air quality in the state of Utah valley is notorious for being poor, what with the presence of air pollutants on a consistent basis. Dr. Arden Pope of BYU in previous years led studies that clearly showed the clearly negative effects of bad air quality on cardiovascular health (Pope et. al. 2004, Pope et. al 2006, Pope et. al. 2015). Efforts are being made in this branch-off study to see if any correlations exist between physical health as well as with cognition.

The process for my project will be to take the first 80 participants from the study on certain days of testing, and will measure the Sternberg task performances on days varying in levels of air-pollutants. Days with both poor and fair air quality will be measured, as well as the corresponding data recorded in the EEG study. I will first use both the well-established event-related potential (ERP) method to observe the correlation of cognition with pollution. Then I will also test how well the Cognitive Spectral Bands (CSB) method can differentiate good air days compared to bad air days

by the levels of cognition in the participants. The data will be analyzed by the Multivariate Multiple Regression, and I will compare the results and record them accordingly.

My hypotheses in this study are as follows:

1: It is hypothesized that one particular pollutant, PM2.5, will have a greater effect upon performance on the memory search task that the other five pollutant independent variables.

2. In the standard ERP component method of analysis, the effects of pollution on the P300 dependent variable will be stronger than the effects on the other ERP dependent variable components (N200, LP, and LN).

3. In the whole-wave approach to neurocognitive measurement, the effects of pollution on the "memory load" CSB dependent variable will be stronger than the effects on the other whole-wave CSB dependent variables ("presence vs. absence," and "replications").

4. The effects of pollution on cognition will be much stronger when calculated with the CSB approach than when tested with the standard ERP component approach.

Thesis Committee

Faculty Advisor & Honors Coordinator: Dr. Bruce Brown.

Faculty Readers: Dr. David McPherson & Dr. Daniel Kay

Committee Qualifications

I am thrilled to say in the least about my opportunity to work with these three members of BYU faculty, all three are well established and excel in their individual fields of study. Dr. Bruce Brown is the Honors coordinator for the psychology department and has worked with me for the

past year in supervising the collection of the data for the research in which I currently participate. Dr. Brown was appointed as the coordinator of the psychology department for his incredible ability to effectively mentor students, something he has done for several decades now at BYU. His familiarity with the study allows him to be the most effective mentor for said Thesis, and his in-depth knowledge of the intricacies of psychometrics is almost unparalleled here at BYU. Having taught and researched at BYU with tenure for several decades Dr. Brown is a clear candidate for any Psychology Honors Committee, hence his position as the coordinator and my personal supervisor over the statistical analysis of the data from his research.

Dr. David McPherson also happens to be an Honors Coordinator, though he supervises the Communication Disorders Department at BYU. Dr. McPherson has also played an integral role of gathering the EEG data for the research already done. He was the lab instructor in how to go about using his laboratory to collect the needed data, how to ensure the quality of the data was excellent, and is very experienced in reading brain waves taken from the study and interpreting their meaning. Dr. McPherson has also taught at BYU for a very long time, and has mentored both undergraduate and graduate students for many years and is well equipped in his ability to teach effectively. Dr. McPherson is also a clear candidate for my Honors Committee as he is a co-author on the pending publication that this research will produce; his familiarity with the process, the data, and the research's objectives are well established and I have certainty he will be an excellent source of knowledge to rely on.

Lastly, Dr. Daniel Kay is another professor in the psychology department at BYU. Having recently received tenure at BYU 3 years ago, he provides some alternate perspectives to the data gathered and its implications in regards to not only how the brain waves recorded may indicate conditions for diseases/neurological conditions, but also how the amount of sleep affects them in

their results on the EEG measurements. Dr. Kay's specialization is in sleep disorders and their effects on the psychological well-being of individuals via sleep neuroimaging methods. Dr. Kay provided some of the necessary questionnaires for the study and is also a co-author on the pending publication. Few other professors at BYU have the ability to interpret the neurological effects of sleep deprivation than Dr. Kay. His familiarity with the study as well as with neurological imaging and brain-wave analysis make him another excellent candidate to be part of this committee, and provides an diversity of opinion while bringing a great deal of confidence to the table in regards to academic capability to mentor.

Project Timeline

The project's timeline will be succinct. At the very most the thesis will take until September of this year to complete, however the much more probable time of completion will be by the end of Summer Term. All estimates show that by September 3rd most if not all of analysis will be complete. The writing of the Thesis will be done after the analysis, and the defense of the Thesis will occur in the following November.

IRB Approval

The IRB number for the approved study is X18073.

Funding

It is not expected that funding will be needed for this project.

Culminating Experience

The research currently underway will be in presentable form by the end of the year, and I am excited to say that we will be able to present our findings as well as publish the research in professional articles under the direction of Bruce Brown. The details as to which conferences to

present in as well as which journals the publishing will take place in are still in the process of being determined. I am also excited to take part in this publication process which will enhance my opportunities for post-graduate program applications after my graduation this December.

Conclusion

In conclusion, I happily submit this proposal in the hopes of being part of a highly beneficial project that could sow seeds for progress in several fields, Psychology and Medical Sciences primarily. The findings of this research could be of great value to professionals in many places when caring for patients. This opportunity also will help give invaluable hands-on experience for statistical analysis on an extracurricular and professional level, as well as add value to any graduate school application I will file in the coming year. I submit this proposal in the hopes that it will pass any requirements for a successful Honors Thesis, and eagerly await for the response of the Honors department. Thank you for your consideration.

Sincerely,

Bo McCullough

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Van Dongen-Boomsma, M., Lansbergen, M. M., Bekker, E. M., Kooij, J. S., van der Molen, M., Kenemans, J. L., & Buitelaar, J. K. (2010). Relation between resting EEG to cognitive performance and clinical symptoms in adults with attention-deficit/hyperactivity disorder. *Neuroscience letters*, *469*(1), 102-106.