AN ANALYSIS OF EVOKED POTENTIALS DEMONSTRATED IN THE WISCONSIN CARD SORT TASK

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Abstract

INTRODUCTION & BACKGROUND: The Wisconsin Card Sort Test is a classic measure of cognitive function. It tests a subject's ability to perform rule maintenance, response suppression, and rule switching as he or she tries to discover the criterion for matching a set of cards, and then adapts when the rule switches with no warning. Previous studies have found that all three of these tasks largely involve the lateral prefrontal cortex.

SPECIFIC EXPERIMENTAL AIMS: The aim of this study is to investigate the evoked potentials generated by the task, using a newly developed Wisconsin card sort tool.

METHODS AND DESIGN: This study is an evaluation of the evoked potentials generated by the rule breaking component of the task, using a high-density electroencephalographic study on a set of ten subjects. For this study, a customized Wisconsin Card Sort program was developed in java in order to allow for each phase of the card selection to be separated into distinct epochs.

RESULTS: Performing a coherence analysis of the data collected allows for the discovery not only the brain regions involved but also the temporal sequence of involvement.

CONCLUSIONS & FUTURE DIRECTIONS: Reproducible evoked potentials are generated during the status presentation portion of the Wisconsin Card Sort task, which are not statistically insignificantly different from the evoked potentials generated by the continuous performance portion of the task. Future studies will include an investigation into the neural networks involved in the task.

Introduction

The Wisconsin Card Sort is test of cognitive function that has been utilized since its discovery by Berg in 1948. It was found that subjects with frontal lobe deficits could not adapt to the rule-changing requirements of the task. fMRI studies have localized the brain regions activated during the task to the lateral prefrontal cortex. (Monchi et al, 2001).

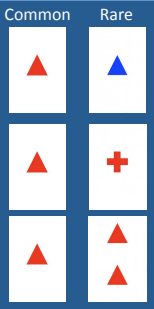
The p300 is a reproducible signal that occurs when an oddball stimulus is presented within a series of expected stimuli. The underlying neurocircuitry is thought to involve connections between the parietal and frontal lobes, as the portions of the brain required in updating working memory and the portions of the brain required to maintain attention are tasked during presentation of the oddball stimulus (Polich 2003).

In this experiment, we seek to evaluate whether an evoked potential occurs when a rule is broken, and whether this evoked potential is similar to targeted p300 evoked potentials. We would expect that subjects learning the rule would become accustomed to the "Correct" status received when applying that rule, and that this would produce a diminished response, as occurs during p300 continuous performance tasks on presentation on common stimuli. Likewise, when a rule is shifted unexpectedly, this should mirror the rare presentation of stimuli during the p300 continuous performance task. We expect to see a p300 signal when the rule is first broken.

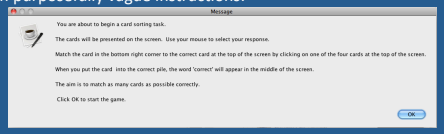
A customized Wisconsin Card Sort Program was developed for this task. The program was written in the Java programming language, and allows for triggers to be sent from the testing machine to the machine collecting electroencephalographic data. In this way, events can be isolated and data collected so that it is clear which events the subject is responding to. Data was collected on nine subjects and was analyzed to look at the rule-breaking portion of this task. Future analysis will allow for investigation into the neural networks involved, using source localization and a coherence analysis.

Methods

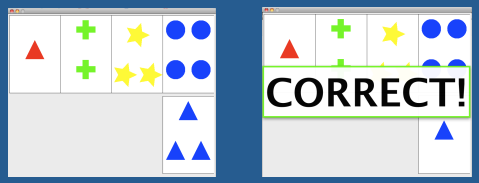
Nine healthy adult subjects were given a series of four continuous performance tasks, followed by the Wisconsin card sort task. They had a 40 lead electroencephalographic cap placed on their head, and data was continuously recorded using NeuroScan Scan 4.3. The first continuous performance task was an auditory p300 experiment, where subjects were instructed to count the rare, higher tone. Next, they were shown a series of images of cards that will be seen during the Wisconsin Card sort, and were instructed to count the rarely presented cards. There were 100 images presented with 200 ms presentation, with a 1500 ms interstimulus interval.



The subjects then began the Wisconsin Card Sort task. Subjects were given purposefully vague instructions:



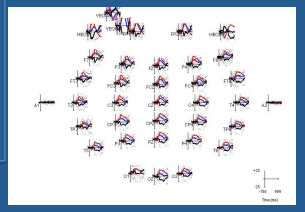
They were then required to learn the rule to correctly match the cards. The status was displayed for 1000 ms post match before the card was flipped, to enable recording the sbuject's response to the status.

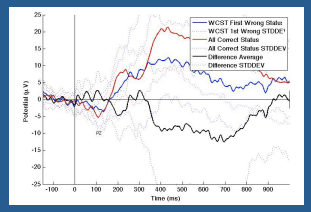


The card was subsequently flipped and a new trigger was sent. Subjects were required to correctly match ten cards consecutively, at which point the rule would change. They were required to match six rounds of ten consecutive cards before the activity terminated.

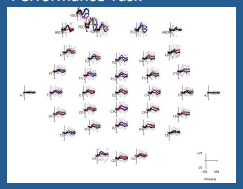
Results

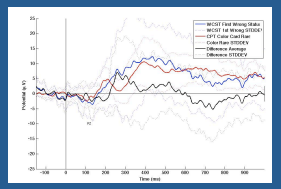
Using NeuroScan EDIT 4.3 to filter the continuous files and Matlab with the EEGLab package to analyze and plot the data, the following is a look at the first wrong status epochs compared with all correct status epochs.



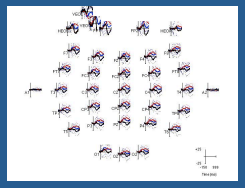


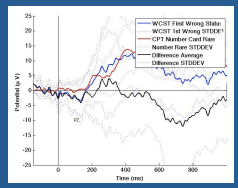
Comparison of first card wrong to Color Card Rare Presentation during the Continuous Performance Task





Comparison of first card wrong to Number Card Rare Presentation during the Continuous Performance Task





Conclusions

The potentials generated by the change in rule and first notification of an incorrect status were not statistically significantly different than the potentials generated by receiving a correct status. However, it is interesting to note that these potentials are also not statistically significantly different than those generated by the targeted p300 continuous performance experiment. Visual inspection demonstrates that there are changes in the shape of the waveforms, suggesting different processes occuring throughout the cerebral cortex. This does suggest reproducible evoked potential activity for all status presentation in the p300 time scale (200-400 ms) (Polich 2003). However, a more thorough analysis will be necessary in order to determine the different sources of activity in the cerebral cortex. A coherence analysis will allow for discovery of the different neural networks involved in each activity.

These results demonstrate that as a tool, the newly developed Wisconsin Card Sort program coupled with electroencephalographic data allows for more specific analysis of each of the events of the task. The evoked potentials generated by the status presentation are new measurements and further analysis will provide insight into how rule switching is performed in the human cerebral cortex.

Acknowledgements

References

Delorme, A & S Makeig (2004) *EEGLAB: an open source toolbox for analysis of single-trial EEG dynamics*. Journal of Neuroscience Methods 134:9-21

Monchi, O., Petrides, M. Petre, V., Worsley, K., & Dagher, A. (2001). *Wisconsin card sorting revisited: Distinct neural circuits participating in different stages of the task identified by event-related functional magnetic resonance imaging*. The Journal of Neuroscience, 21(19), 7733-7741.

Polich, J. (2003). Overview of P3a and P3b. In J. Polich (Ed.), *Detection of Change: Event-Related Potential and fMRI Findings* (pp. 83-98). Kluwer Academic Press: Boston.