2007-2008 John Wesley Powell Research Conference

4-2008

Motor and Cognitive Tasks Effects on Frontal Theta

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Abstract

Previous studies in our laboratory have examined the effect of social rejection on frontal theta, showing frontal theta decrease. Confounds of the study included decreased motor and cognitive skills during the period of social rejection. This experiment looked at the effects of motor and cognitive activities on frontal theta with regard to both type of task and length of task. Eleven males and nine females from the Illinois Wesleyan University general psychology classes completed a set of short and long, motor and cognitive tasks. Participants were asked to type a series of 14 and 24 lines on a computer during motor tasks to echo the amount of lines typed during the previous study's social rejection phase. During the cognitive tasks, participants were asked to read and comprehend online chats of 14 and 24 lines long. Cognitive quizzes were assigned to determine how well the participants had comprehended the cognitive tasks. There was a significant difference in correct scores between the short and long task. No significant differences of theta power or frequency were found for motor or cognitive tasks, as well as length of task. Gender did not affect the task, as there was no significant between task type or length and gender.

Motor and Cognitive Tasks Effects on Frontal Theta

People who experience social rejection report mood changes and lowered self-esteem and mood as evidenced in a study examining rejection using a ball-tossing experiment in which participants were ignored during a cyber ball-toss game (Ladro, Williams, & Richardson, 2004). Social rejection has been linked to the right ventral prefrontal cortex and anterior cingulated cortex frontal lobes through fMRI studies (Eisenberger & Lieberman, 2004; Panksepp, 2003). Recent studies in our laboratory have explored social rejection in a chat room environment and its effects on frontal theta. Although these studies found a decrease in frontal theta power during social rejection, two possible confounds arose: decreased motor and cognitive activity. During the social rejection phase of the experiment, the participants typed less and read less text on the computer screen, averaging 14 less lines between the rejection phase and normal phases. The current study will address these confounds by examining whether frontal theta power significantly changes during motor and cognitive task performances.

Electroencephalogram

Since the electroencephalogram (EEG) was discovered in 1929, it has been used extensively to look at the structures of the brain (Rosler, 2005). This type of break-through has allowed research to expand tremendously and to examine questions psychologists never thought imaginable (Cutmore & James, 2007). Electroencephalograms allow researchers to study relationships between different brain waves and mental states or differences in personality (Rosler, 2005). EEG recording has been used to non-invasively measure changes in electrical potential during tasks performed by a human participant (Cutmore & James, 2007). These electrical potential changes are recorded as waves (Cutmore & James, 2007) that are generated by electrical impulses of the nerve cells, which fire in distinct patterns (Givens, 1996). The EEG measures basic rhythms such as: alpha, beta, delta, and theta activity, with alpha measured mostly during rest and beta measured during mental activity (Rosler, 2005). The alpha band has been found to increase when there is a higher memory load during working memory (Herrman, Senkowski, & Rottger, 2004).

These waves also differ in terms of amplitude and frequency. Amplitude is also referred to as power, and it measures the amount of cells firing at one point in time, in a specific area of the brain (Levtin, Nuzzo, Vines, & Ramsay, 2007). The more cells firing at the same time, the higher the power. If the power is lower, not as many cells are firing at once, or are firing at different times. Beta wave activity has the lowest degree of synchronization, while delta waves show the heist degree of synchronization (Rosler, 2005). Frequency can be defined as the amount of cycles in one-second periods of the EEG data (Levtin et. al, 2007). Changes in amplitude and frequency of frontal theta have been linked to various changes in brain activity, such as differences in motor, cognitive, and emotional experiences.

Motor Activities

During motor tasks, activity in the medial prefrontal cortex receives input from limbic system structures (Freeman, Jr., Cuppernell, Flannery, & Gabriel, 1996). Vanderwolf (1987) studied rhythmical slow activity (RSA, i.e. theta waves) in the hippocampus while rats and cats were changing postures, moving their heads, walking, etc. He discovered hippocampal RSA to be at least partially correlated with motor activity (Vanderwolf, 1987). These results were similar to those from an earlier study completed with Wishaw, when the two researchers studied RSA near the hippocampus while rats and cats were moving without an outside force (Wishaw & Vanderwolf, 1973). Wishaw and Vanderwolf (1973) found during large movements, the RSA amplitude was as much as six times greater than small movements. Frequencies of theta between 7-9 Hz were also recorded during prolonged large movements resulting in increased theta power (Wishaw & Vanderwolf, 1973). In rats, Bland et. al (2006) found theta power and frequency are positively correlated with motor activity; as the rats performed more motor tasks, such as jumping, the frequency and power of theta both increased. These results suggest theta is intricately linked to voluntary motor movements.

However, actual movement is not necessary for theta power or frequency to increase. While the rats and cats slept, increased theta amplitude and power were related to involuntary muscle twitches, supporting the idea that increased theta waves might relate to higher levels of controlled voluntary movement (Wishaw & Vanderwolf, 1973). Thinking about motor activity can affect theta as well. Sinnamon (2005) found that theta activity was continuous during the entire motor activity phase with rats, not just during the actual movement, indicating that even the idea of moving will increase theta power and frequency. Thinking, about movement or otherwise, can cause theta power and frequency to increase or decrease.

Cognitive Activities

Although there are some exceptions, most previous research regarding frontal theta and cognitive tasks has shown an increase in theta power and frequency when participants are engaged in cognitive tasks (Osipova, Takashima, Oostenveld, Fernández, Maris, & Jensen, 2006). Increases of theta power are usually associated with alpha wave power (Klimesch et al., 2005). However, other studies of cognitive activities have revealed conflicting results. Although, De Araújo et. al (2002) found that theta power was greater when subjects were exploring a virtual environment compared to periods of no activity, they found no consistent increase in theta power during any of the specific tasks (De Araújo et al., 2002). Theta increases in other functions, such as working memory.

Working memory, also referred to as declarative memory, is a type of memory used for facts, and events, and has been studied by comparing brain activity while participants encoded memories which were retrieved and memories which could not be retrieved (Osipova, Takashima, Oostenveld, Fernández, Maris, & Jensen, 2006). Working memory allows us to store incoming information for a few seconds while performing a cognitive activity (Deiber et al., 2007). Increases in frontal theta have been shown during working memory. Osipova et al. (2006) studied working memory using pictoral stimuli to determine remembered and forgotten pictures. They found increased power in gamma and theta waves associated with working memory encoding and retrieval. This increased power in gamma and theta waves “enhances neural synchronization,” which occurs during working memory encoding and retrieval (Osipova et al., 2006, p. 7528). An increase in theta frequency range (about 4-8 Hz) is observable only under certain conditions, such as when subjects are focused and concentrating on a task for an extended period of time (Klimesch, Schack, & Sauseng, 2005). An increase in theta power is seen in tasks of short-term memory, for example when encoding words to be remembered for recall (Klimesch et al., 2005). Givens (1996) examined working memory in rats tested for their sensory discrimination. Rats using working memory showed a resetting of rhythmic activity, or relevant stimuli increase, unlike their reference memory counterparts (Givens, 1996).

Ekstrom, Caplan, Ho, Shattuck, Fried, and Kahana (2005) examined theta while participants explored a virtual taxi cab setting, discovering an increase in during attention. The amplitude of the frontal theta was found to depend on the level of attention needed to complete the cognitive task (Deiber et al., 2007). Theta plays a significant role in attention and working memory (Ekstrom et al., 2005). Other types of cognition, such as emotional experiences, can also cause a change in theta.

Emotional Experiences

Emotional expression has been linked with changes in frontal theta power and frequency. Emotion is categorized by the type of emotion expressed (anger vs. joy) and with the intensity it is expressed (Dawson, 1994). Researchers have found a relationship between emotion expression and the frontal theta activity (Dawson, 1994; Lane, Reiman, Axelrod, Yun, Holmes, & Schwartz, 1998). Dawson (1994) found that the theta waves were better predictors of the intensity of emotional distress than hemispheric differences, although hemispheric differences were found to be better predictors of the type of emotion the infant would display. Infants were exposed to several conditions that would cause them to feel different emotions. Multiple studies briefly separated infants from their mother while facial expression was taped and brain electrical activity was recorded (Dawson, 1994; Fox & Davidson, 1988). Hemispheric differences are variable. Dawson (1994) found increases in brain waves from both the right and left hemisphere when the infants were separated from their mothers, with the highest times of distress related to the most intense peaks on the EEG. Fox and Davidson (1988) found greater activity in the left frontal lobe during smiling, more power in the left frontal lobe during sadness, and greater power in the right frontal lobe during the expression of anger. Emotion creates a difference in wave activity between hemispheres.

Differences in EEG measured brain waves have been attributed to the differences in the right and left-brain hemispheres (Aftanas, Pavlov, Reva, & Varlamov, 2003). Research may be threatened according to new hemispheric changes in theta (Aftanas et al., 2003), since handedness might change the way one's theta waves record onto an EEG. Aftanas et al. (2003) found left hemispheric activity to favor lower theta than the right hemisphere. Such biases need to be taken into account when determining the results of one's study. Because people with different dominant hands process information with an emphasis on different parts of their brains, these hemispheric differences must also be related to the participant's handedness, as handedness changes the hemispheric activity, and hence theta.

Current Study

Changed in theta are linked to motor, cognitive, and emotional activity. A previous study on our lab has found decreased motor and cognitive activity to be potential confounds of their social rejection study. Therefore, it is essential to examine the effect of motor and cognitive tasks on frontal theta. Our current study examined the potential confounds of Williams previous study (2006-Present) of decreased motor and cognitive activity during social rejection. Our current study determined whether the decreased motor and cognitive activity had an effect on the decreased theta. Subjects in the current study were given two different motor tasks: one long and one short, to echo the difference in lines typed during the previous experiment. To counteract the possible cognitive confound, subjects were given two different cognitive tasks: a longer and a shorter chat room conversation to read and comprehend. After each cognitive task, the participant was given a short quiz to determine comprehension of the cognitive task. This study helped to determine whether the motor and cognitive aspects of the social rejection study affected the increase in theta.

Hypotheses

There are two potential outcomes of the study, and both are equally likely. One hypothesis is the frontal theta frequency and power will increase or decreased equally during the motor and cognitive tasks. Therefore, the change in theta power or frequency will not be significant. Without significant change of theta power or frequency, the decrease in theta power and frequency from the previous study can be attributed solely to the social rejection and the confounds dismissed.

Frontal theta frequency and power might significantly increase or decrease during the motor and cognitive tasks, creating significant main effects. This hypothesis will support the confounds from the previous study. Therefore, concluding social rejection alone may not cause a decrease in theta power and frequency, but could be caused by decreased motor and cognitive activities.

Method

Participants

Males and females, ranging in age from 18-22, from General Psychology classes at Illinois Wesleyan University were recruited as participants (N = 38). Participants were credited two General Psychology research credits for the two hours they spent participating in this experiment.

Apparatus

To collect the EEG data, each participant was hooked to an EEG cap obtained from Electro-Cap International, Inc. (Eaton, OH). The cap was connected to EEG *STP100 Optical Interface to UIM100* amplifiers from BioPac (Goleta, CA). The amplifiers were in turn connected to an Intel Pentium III processor computer, 698 MHz, which acquired and stored the data through the program AcqKnowledge 3.9.0.

Tests

Motor Task. Participants performed two typing tasks to examine the effects of motor activity on frontal theta EEG activity. The participant was asked to complete a short motor task by retyping fourteen sentences onto the computer after they appeared on the screen (see Appendix A), as well as a long motor task by retyping twenty-four sentences (See Appendix B). During the short motor task, each sentence appeared approximately every 34 seconds, during which time the participant had time to retype the sentence exactly as it appeared on the screen. During the long motor task, the participant was given 20 seconds to retype the sentence that appeared on the screen. The number of lines typed and read were chosen to mirror the motor demands of the previous social rejection study.

Cognitive Task. Participants were given two cognitive tasks to complete: a long and a short cognitive task. The participant was asked to read a short chat room conversation between three students discussing favorite television shows (see Appendix C). The time each sentence appeared on the computer screen was taken from the actual times sentences appeared on a computer screen during preliminary chats in a study by Williams and French (2006-Present). These times can also be found in Appendix C. The entire activity lasted about eight minutes. After reading the conversation, the participant was asked to complete a short three-question quiz (see Appendix C) to ensure the participants were cognitively engaged in the task. The answers to the quiz were recorded.

To complete the other cognitive activity, participants read a longer discussion between the same three students discussing their favorite television shows (see Appendix D). The time each sentence appeared on the computer screen can also be found in Appendix D. The entire activity length varied in regards to the number of sentences read and no motor activity occurred during this time. After the participant read the conversation, he or she was asked to complete a short three-question quiz (see Appendix D) to ensure the participants were cognitively engaged in the task. The answers to the quiz were recorded.

Procedure

The Illinois Wesleyan University Institutional Review Board approved all tasks used in our study. Each participant met in the basement of the Center for Natural Sciences and was taken upstairs to the experiment room. As the researcher guided the participant to the room, she quickly briefed the participant on the types of tasks he or she would be completing (see Appendix E). Once in the experiment room, the participant sat in a stationary chair in front of the computer and was asked to sign the informed consent form (see Appendix F). Also, at this time, the participant filled out an information sheet with their age, gender, and handedness. Once the participant had consented, he or she was fitted with an EEG cap.

The EEG preparation was conducted according to the manual provided by the Electro-Cap International, Inc. (Eaton, OH). To determine which cap the participant should wear, the circumference of his or her head was measured approximately one inch above the nasion (bridge of the nose) around to the inion (the protrusion on the back of the head directly across from the eyebrow). If the circumference was between 58-64 cm, a large cap was used, and a medium cap was used if the circumference was between 54-58 cm.

A reference electrode was attached to the left earlobe with a small amount of Electro-Gel to assist in conductance. The participant was measured once more to find the distance of the nasion and inion. This length in centimeters was divided by ten to discover the best placement distance between the frontal electrode mounts of the cap. Two frontal electrode mounts (Fp1 and Fp2) were attached to the middle two electrodes on the cap. The cap was pulled onto the participant's head, the strap was Velcro-ed beneath the chin, and the frontal mounts were attached to the participant's forehead on corresponding points previously marked, to prevent electrode gel from spreading to the forehead of the participant.

In this study, we were interested in theta EEG activity within the frontal lobe. The Fz recording site recorded the midline theta, while the F3 and F4 sites recorded the areas adjacent to Fz, in the left and right hemispheres respectively. After the cap was secured onto the participant's head, the cap connector was connected to the electrode board adapter connecter. Using a blunt needle, the three corresponding electrode cavities to the research, F3, Fz, and F4, were filled with ECI electro-gel until a small amount of gel protruded from the cavity. The gel was worked into the scalp to create a secure connection.

The EEG cap was connected to a computer in the adjoining room separated by a two-way mirror. A Biopac Systems interface was used to collect the EEG data. The EEG activity was recorded in waveform outputs and analyzed separately for each site. Once the participant was properly fitted with the EEG cap, the researcher left the participant in the room alone and walked to the adjacent room with the EEG machine and administrator computer.

The researcher began the first task, either the motor or cognitive task, through the administrator computer. Once the participant completed this task, the researcher began the second task, either the cognitive or motor task. This gave the researcher an opportunity to remind the participant of the directions for each type of task, as well as to ask them not to move during the cognitive task. The tasks were counterbalanced in terms of task order between motor and cognitive tasks, as well as conditions within each task, i.e. long or short activity. Counterbalancing reduced practice effects, as the participant could not increase their performance due to the order of tasks. Results are not due to the order of the task type or length, as both were randomized. The entire experiment took about one hour.

The researcher turned off the EEG machine and walked back into the room with the participant. The researcher reminded the participant of the goals of the experiment and gave them an opportunity to ask any questions. Then the researcher removed the EEG cap and escorted the participant back downstairs. The experiments helped to determine whether motor or cognitive tasks affected theta activity, so this information could be applied to the previous social rejection study.

Results

After data was collected from the three frontal lobe sites, the Fz recording site recorded the midline theta, while the F3 and F4 sites recorded the areas adjacent to Fz, in the left and right hemispheres respectively, each set of data was examined for excess noise before performing analyses. Although data was collected from 38 participants, only eighteen participants had useable data. Data with more than 50% noise was removed from results. Noise was removed because of participant movement, extraneous background noise recorded by the machine, and incorrect attachment of the EEG cap by research assistants. The remaining data from 18 participants included 9 males and 9 females. The data was analyzed using a repeated measures ANOVA, with cognitive or motor task length as a within subject variables, gender as a between subject variable, and theta power, theta frequency, and percent correct as dependent variables.

Cognitive Tasks

The participants answered 98.3% of the short cognitive quiz questions correctly and 73.3% of the long cognitive quiz questions correctly. A repeated measures ANOVA, using cognitive quiz task length as a within subject variable, gender as a between subject variable, and percent correct as a dependent variable, revealed no significant main effect of task length. (See Figure 1). Participants scored significantly higher on the short cognitive quiz compared to the long cognitive quiz, F (1, 18) = 17.17, $p = 0.00$. There was no significant interaction effect between task length and gender, F (1, 18) = 1.00, $p = .33$.

A repeated measures ANOVA revealed no significant main effect of cognitive task length in regard to theta frequency: F_z recording site [F (1, 16) = 1.21, $p = .29$], F_3 recording site [F (1, 16) = .86, $p = .37$], and F_4 recording site [F (1, 16) = 1.50, $p = .24$]

(See Figure 2) or theta power: F_z recording site [F (1, 16) = .02, p = .89], F_3 recording site [F (1, 16) = .26, p = .62], and F_4 recording site [F (1, 16) = .98, p = .34]. (See Figure 3). There was also no significant cognitive task length and gender interactions for theta frequency: F_z recording site [F (1, 16) = .35, p = .5], F_3 recording site [F (1, 16) = 3.13, p = .10], and F_4 recording site [F (1, 16) = .19, p = .67] or theta power: F_z recording site [F (1, 16) = .74, p = .40], F_3 recording site [F (1, 16) = .39, p = .54], and F_4 recording site [F (1, 16) = .92, p = .35]. These results suggest theta power and frequency did not differ regardless of the length of cognitive task or gender.

Motor Tasks

A repeated measures ANOVA revealed no significant main effect of motor task length in regard to theta frequency: F_z recording site [F (1, 16) = .36, p = .56], F_3 recording site [F (1, 16) = .94, p = .35], and F_4 recording site [F (1, 16) = 1.91, p = .19] (See Figure 4) or theta power: F_z recording site [F (1, 16) = .80, p = .38], F_3 recording site [F (1, 16) = .07, p = .80], and F_4 recording site [F (1, 16) = 1.05, p = .33]. (See Figure 5). There was also no significant motor task length and gender interactions for theta frequency: F_z recording site [F (1, 16) = .34, p = .57], F_3 recording site [F (1, 16) = 1.20, p = .29], and F_4 recording site [F (1, 16) = .27, p = .61] or theta power: F_z recording site [F (1, 16) = 3.72, p = .07], F_3 recording site [F (1, 16) = 2.66, p = .12], and F_4 recording site [F (1, 16) = .99, p = .34]. These results suggest theta power and frequency did not differ regardless of the length of motor task or gender.

Results indicate males and females did not differ in the increase of frontal theta power or frequency regardless of the task length or type. Males and females performed equally well on the cognitive quizzes. This concludes the results are applicable to both males and females regardless of the type or length of task.

Discussion

An ongoing study in our lab has found a decrease in frontal theta during the phase of social ostracism in their chat room study. Possible confounds include decreased reading or typing, as seen by the average number of lines typed during this exclusion phase as compared to the other phases. Our results show no significant difference between motor and cognitive tasks, regardless of the length, therefore supporting the conclusion of the previous study: the decrease in frontal theta observed during periods of exclusion are due to social rejection rather than motor and cognitive processes.

Cognitive and Motor

While an increase in theta power and frequency has been correlated, in some studies, to cognitive tasks (Osipova, Takashima, Oostenveld, Fernández, Maris, & Jensen, 2006) and motor tasks (Bland et. al, 2006), other studies have revealed no such increases in theta (De Araújo et al., 2002). Our results found no significant increase or decrease regardless of the length of the task; one possible explanation is that other studies have focused on different complexities and lengths in tasks (Bland et. al, 2006; Osipova et. al, 2006; Ekstrom et. al, 2005), whereas our study has a difference of ten sentences between tasks. Our results may not be significant due to the small difference between task length or complexity. Future analyses could focus on larger differences between task length or task complexity to determine changes in theta frequency or power.

A second possible explanation is the level of analysis. Although, theta power was greater when subjects were exploring their environment compared to periods of no activity, they found no consistent increase in theta power during any of the specific tasks (De Araújo et al., 2002). Although previous research has shown both increases (Herrman et. al, 2004) and decreases (Araújo et. al, 2002) in frontal theta when performing a motor or cognitive task, these studies compare the task to a period of inactivity, or a baseline. In the present study, the cognitive and motor tasks were compared to each other, differing only in length of each task. Frontal theta frequency and power did not significantly increase, as other research suggests, because the tasks were compared to each other, not a period of inactivity. Theta is naturally higher during a task compared to resting potential. Future research might measure a baseline during the experiment, to use as a comparison for frontal theta power and frequency to task type and length.

It is also possible that species differences might account for some dissimilarities. Theta frequencies of animals are measured at 7-9 Hz, where as theta frequencies in humans at measured at 4-8 Hz. Because of the range differences, motor changes seen at 7-9 Hz in animals, may not be seen at 4-8 Hz. Therefore, our study may not have seen a significant increase in theta frequency, as opposed to previous animal studies (Bland et. al, 2006) because of the difference in human versus animal Hz.

Because the cognitive quiz scores were high, we conclude the participants comprehended the cognitive tasks. There was a significant difference between the results of the short cognitive quiz and the long cognitive quiz. Participants scored 98.3% of the short cognitive quiz questions correctly and 73.3% of the long cognitive quiz questions correctly. Two possible explanations for this are working memory and problems with the wording of question three on the long cognitive quiz. The long cognitive quiz had a lower percentage of correctly answered questions due to a 35% correct response rate for question three. This can be accounted for the by the ambiguity or misunderstanding of the third question in the cognitive long quiz. Different wording of question three might produce a higher outcome. Humans average storage of approximately seven short-term memories, with individual memories occurring at beta/gamma frequency (Lisman & Idiart, 1995). Because there was more time between the beginning of the long cognitive task and the quiz, as compared to the amount of time between the short cognitive task and quiz, the participants may have forgotten some information read at the beginning of the task. The long cognitive quiz may have been too demanding. Delays in time decrease memory, as demonstrated by the percentage correct on the long cognitive quiz. If the third question on the long cognitive quiz had been discarded, the total percentage correct on the long cognitive quiz would have been 92.5%. However, it should be noted that despite differences between the long and short cognitive quizzes, there was no significant differences in theta power or frequency between the short and long cognitive tasks.

Gender

Our results showed no significant interactions in regards to task length with regards to gender. Thus our results are applicable to both males and females. Our participants were 50% males and 50% females, thus the genders were both represented equally. Previous studies related to memory processing found females perform better than males on cognitive tasks (Guillem & Mograss, 2005). This study looked at event-related potentials instead of theta. Thus, increases in event-related potentials differ from increases in theta.

Limitations

Two limitations in the study were the low number of participants and excessive noise. Thirty-eight participants were tested, but only eighteen participants were analyzed because of various errors. The amount of noise recorded during the experiment resulted in a lower number of participants. While accounting for noise by removing any excess data from out theta range, multiple data sets lost more than fifty percent of usable data. Such data sets were considered unusable in this study. EEG noise can result from a variety of sources. The most prominent source in our study was subject movement. Although every participant was reminded at various times throughout the experiment to avoid movement, many still moved. Research assistants mislabeled a few data sets, so these data sets were also discarded. Many data sets were recorded on the wrong channel, resulting in either only noise or no recorded data. Because of these errors, only twenty of the thirty-eight participant's data sets were analyzed once noise was removed.

Future Research

This study should continue in the future with a larger sample size. As the sample size increases validity increases. Future studies should also look at brain regions in the cortical areas. The EEG machine used in our study only recorded three channels at a time. A more advanced machine would have allowed us to measure a variety of brain waves, resulting in more analyses and results. This would allow researchers, for instance, to assess the parietal or temporal lobe to determine whether these structures are activated during motor and cognitive tasks. Future research should repeat our study with multiple recording sites. Other areas in the study could be examined to increase validity.

In addition, the length of task could be exaggerated. For example, our study only used a difference of ten sentences between tasks to echo differences from a previous study. A contrast of ten sentences may not have been a large enough change to create a qualitative difference. Using a difference in tasks between fifty or one hundred sentences could change our results. By exaggerating the differences in the task length, the results might better exhibit the effect of task length on theta, therefore applying to a better variety of real-world tasks.

Complexities of the motor and cognitive tasks could also be extended. Because our study was modeled from a previous study, many aspects of the experiment were rigid. By examining differences between more complex motor and cognitive tasks the applicability to theta research could increase. For example our motor task involved typing sentences at a computer. If one measured frontal theta when the participant was moving a joystick through spatial navigation, as opposed to typing at a computer, frontal theta might differ. Wishaw and Vanderwolf (1973) found during large movements with rats, the RSA amplitude was as much as six times greater than small movements. Perhaps the same idea holds true for humans. The ability to measure motor task performance in humans with an EEG is more problematic, since electrodes are implanted directly into animal brains to record their motor task performances. Complexity of cognitive tasks can also be increased. In our study, participants read a chat between three girls. If participants were asked to complete a crossword puzzle as compared to reading a passage, results might differ. Such an experiment could provide important information about frontal theta and the complexity of tasks to the psychology field. Confounds may arise with increasing task complexity, such as anxiety levels. The small difference in task length caused little, if any, anxiety in participants. Anxiety, and other confounds could decrease the validity of a future study if not accounted for.

Finally, one might explore the correlation between motor and cognitive tasks. Since there was no significant difference between the motor and cognitive tasks, one may assume theta increases or decreases do not differ regardless of the task performed. Perhaps improvement in one area increases improvement in the other area. Does a daily cognitive task, such as a crossword puzzle, increase one's motor abilities, such as fine motor skills? Do people who perform more motor tasks, perform better on cognitive tasks? Our study cannot provide support for this hypothesis, as we did not examine the effects of motor skills on cognitive skills or vice versa. Future research in this area could provide answers about correlations between tasks. Improvement in cognition may create improvement in motor skills or vice versa. A correlation between tasks could provide researchers with information to improve the aging brain. Training on a cognitive task might increase performance on a novel motor task, which could be measured with theta power and frequency. The applications could be extremely beneficial to both the scientific community as well as the general public.

Conclusion

Participants in our study performed a variety of cognitive and motor tasks differing in length. There was no significant difference of task length or task type and frontal theta. Males and females performed equally well on cognitive and motor tasks, and both genders tended to perform better on the short cognitive quiz as opposed to the long cognitive quiz. Our results allowed a previous study in our lab to dismiss confounds from a social rejection study in a chat room environment, in which decreased motor and cognitive activities were thought responsible for a decrease in frontal theta. Our results show typing less and reading less during do not significantly change frontal theta. Motor and cognitive tasks, regardless of gender, do not cause a significant change in frontal theta.

Author's Notes

I would like to thank Dr. Joseph Williams without whom I could not have completed my thesis. Thank you to Dr. Doran French and Dr. Jason Themanson for composing my oral defense committee. I would also like to thank my research assistants who spent countless hours running subjects: Allison Heim, Steph Ross, Isabella Rossi, Kim Voelker, Michelle Meehan, Joey Schmitt and Anne Marquette. To my parents, thank you for the countless hours of listening to my complaints and tears. It is through your encouragement and advice I finished this project. Thank you to Nicholas, for waking up just in time to hear my oral presentation at the John Wesley Powell Research Conference. And of course to Grace, for complaining with me about her own major senior projects, for giving me encouragement, and keeping me on task. Words cannot describe how much I appreciate all of you.

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Appendix A

Motor Task Short

1. I wish I had more time to watch tv.
2. I really liked the show "American Dreams" that was on NBC like two years ago. I was sad when they cancelled it.
3. My mom always makes fun of me for watching it.
4. I have all ten seasons and my roommate and I watch it all the time.
5. My boyfriend and his roommates love “Girls Next Door.”
6. At home, my whole family loves survivor.
7. I can never find time to sit down to schedule programming.
8. I like that show too it is interesting to watch and funny at the same time.
9. I think I prefer “Project Runway.”
10. I saw it last night.
11. Are you referring to American Dreams?
12. Everyone is passionate about something.
13. That is a good show.
14. One show I like on mtv is “Dancelife.”

Appendix B

Motor Task Long

1. I'm a theatre design major- what about you guys?
2. All I remember about geology came from the 6th grade.
3. I didn't catch what city you all were from.
4. Well I am from Joliet which is about 45 minutes south of Chicago.
5. I go to Illinois Wesleyan and I am a freshman.
6. It is about 5 blocks away from ISU in Bloomington.
7. I like it a lot.
8. Oh- I'm a senior- and ready to graduate.
9. I want to work either in a hospital or a physical therapy clinic.
10. Haha
11. I'll go back to grad school in a couple of years- now I just want to work professionally.
12. Sometimes I perform.
13. We perform and write personal stuff too.
14. Yea, I know.
15. I love shopping too.
16. What types of movies do you like?
17. The ending will blow you away.
18. Ah. not as boring as I thought ;)
19. I read all but the very last book that came out of Harry Potter.
20. I have to catch up.
21. wow
22. Yeah I am loving the weather; it is perfect for running.
23. yep
24. I was supposed to be on the cross team here but over the summer I got mono and didn't get over it until the end of October.

Appendix C

Cognitive Task Short

13:01:08 Administrator Please take the next eight minutes to talk about your favorite TV shows.
13:05:26 Steph reality tv is scarily addicting
13:05:37 Christy definitely!
13:05:38 Steph i feel like i just get so wrapped up in it, even if i know it's stupid
13:05:55 Jen yea i know, its definitely a love-hate relationship
13:06:03 Steph exactly
13:06:13 Jen yeah me too
13:06:25 Steph there was a show on mtv last weekend that i got hooked on....i don't know the name
13:06:33 Christy What was it about?
13:06:36 Steph but the parents picked out 2 people for their kid to go on dates with
13:06:45 Jen oh i know that one steph!
13:06:46 Christy Oooh, I forgot the name
13:06:53 Jen i can't remember the name either
13:06:51 Christy but I've watched it before!

<u>How well were you paying attention?</u>

1. Which type of show was discussed during this conversation?
    a. Cooking shows
    b. Cartoons
    c. Reality shows
    d. Musicales

2.Which was NOT a name of a girl participating in the conversation?
    a. Jen
    b. Sara
    c. Christy
    d. Steph

3.The girls could not remember the name of a show. Do you remember which channel they saw it on?
    a. MTV
    b. BET
    c. ABC
    d. VH1

Appendix D

Cognitive Task Long

13:01:08 Administrator Please take the next eight minutes to talk about your favorite TV shows.
13:01:23 Christy Well, I'll always love Sex & the City.
13:01:28 Christy Does anyone else like that show?
13:01:31 Jen ok, well this is a hard one for me, i don't really watch tv shows regularly
13:01:40 Steph hmmm, I don't watch that much tv either
13:01:41 Christy Me neither, but I have a few..
13:01:52 Christy I tend to wait until they come out on DVD
13:01:58 Jen although i am obsessed with practically everything on the food network and the travel channel
13:02:06 Steph when i was younger it used to be friends
13:02:14 Christy Oh yes! I love the travel channel
13:02:15 Steph haha the food network just makes me hungry
13:02:22 Christy and Animal Planet!
13:02:28 Jen see i never even got into friends
13:02:34 Christy I would watch the food network more often if I could cook..
13:02:42 Steph it was hard not to when that's all my friends ever talked about
13:02:58 Jen yeah i know what you mean steph!
13:03:07 Steph I think last semester we watched seasons 1-6 in the first 3 weeks of school
13:03:19 Jen wow, that's impressive
13:03:22 Christy Aw! Sounds fun.
13:03:25 Steph Jen have you ever seen America's next top model?
13:03:30 Steph that's a fun one I sometimes catch
13:03:38 Jen yes, that is a fun one
13:03:41 Christy The new season starts next week!
13:03:46 Jen before i came here i was watching the girls next door
13:03:51 Steph I don't think i know that one

How well were you paying attention?

1. Which of the following tv shows was mentioned in the conversation?
    - **a. America’s Next Top Model**
    - b. Simpsons
    - c. Family Guy
    - d. Rachael Ray’s cooking show

2. What show had Jen and her friends watched six seasons in the first three weeks of school?
    - a. Full House
    - b. Parental Control
    - **c. Friends**
    - d. Girls Next Door

3. Who, despite adding to the conversation, said she does not watch tv shows regularly?
    - a. Steph
    - b. Jen
    - c. Christy
    - **d. All of the above**

Appendix E

Script for Introduction

Hi, I'm ______(Insert your name here) , and we are upstairs today, so let's head on up. So, just to give you a little back ground on what we're doing today, we're looking at the effect of motor and cognitive tasks on EEG activity to see if there is a relationship between motor activity or cognitive activity and theta rhythms. To test this we've created task in which you will be given a list of sentences, one at a time, you are to copy onto the computer . You will also read a previously recorded chat room session and take a short quiz to see how well you comprehended. You are going to be hooked up to an EEG machine during your task so we can observe what areas of your brain are active when you're completing the tasks vs. the areas that research has shown are activated during motor and cognitive tasks. We're not using any deception for this study, but will actually study your motor and cognitive task EEG thetas. Any questions?

Appendix F

Informed Consent

We are requesting that you participate in a research study being conducted at Illinois Wesleyan University under the supervision of Dr. Joseph Williams and Dr. Doran French. At the end of this form, you will be asked to indicate your willingness or unwillingness to participate and give your signature.

This study is designed to understand how brain activity changes when completing motor and cognitive tasks. You will be seated at a computer and asked to copy sentences onto the computer, as they appear one at a time onto the screen. Also, you will be asked to read a previously recorded chat room session and answer a short quiz to see how well you comprehended the material. We are conducting this study as a response to a previous study explored by Dr. Joseph Williams and Dr. Doran French about social interaction in chat rooms. In our study we are specifically looking at the motor, i.e. typing task, and cognitive, i.e. reading task, aspects of the chat room situation, rather than the social aspects.

To examine how the brain functions during these tasks, you will be hooked up to an EEG monitor designed to assess brain wave activity. This will involve being fitted with an electrode cap which contains small recording electrodes that, when placed over the skull, can record brain activity. This is a non-invasive procedure. The cap is similar in nature to a swim cap or a snug-fitting hat. After the cap is placed onto the head, the recording electrodes will be filled with gel and the gel will be worked into the hair and scalp underneath the electrode site to aid in the ability to detect brain signals. This gel is similar in consistency to hair gel and can easily be washed out after the experiment.

Your data will be classified and stored by participant ID number only and your name will never be attached to the data. The only information about yourself that you will be asked to provide will be your gender and your handedness.

If you have any questions regarding this project, please feel free to contact the supervising faculty member, Dr. Joseph Williams at (309) 556-3006 or Dr. Doran French at (309) 556-3662. If you have any concerns regarding this project, please feel free to contact Dr. Jin Park, the vice chair of IWU's independent review board for ethics in experimentation, at (309) 556-3978.

I have read the above information pertaining to computer-based working memory study described above.

____ I am 18 years or older and agree to participate in this research. I understand that I may stop participation at any time without penalty.

____ I do not agree to participate in this research.

______________________	______________________	__________
Participant Name (print)	Participant Signature	Date
______________________	______________________	__________
Researcher Name (print)	Researcher Signature	Date

Figure 1

Cognitive Quiz Results vs. Gender Effects

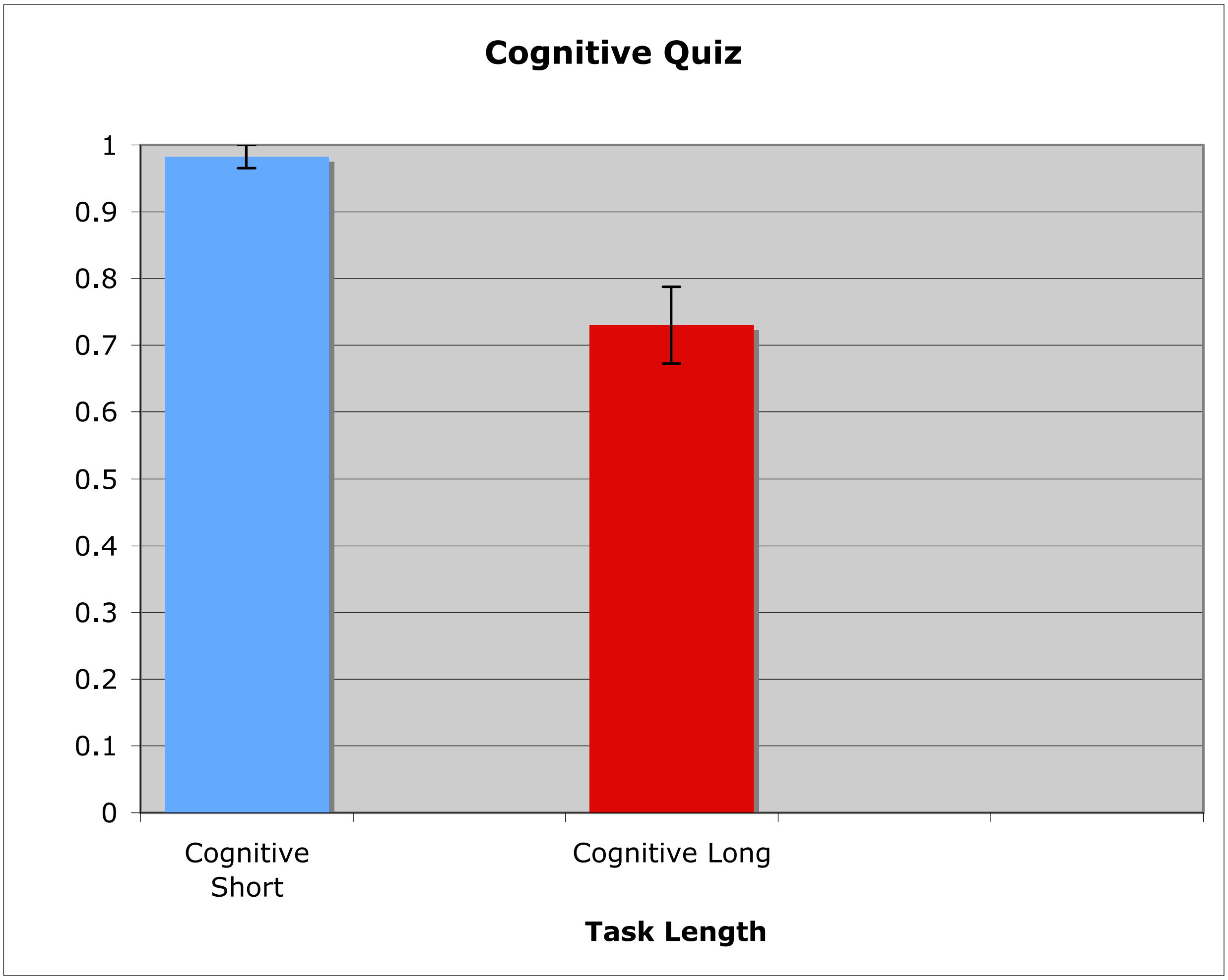

Figure 2

Maximum Theta Frequency: Cognitive Long vs. Cognitive Short

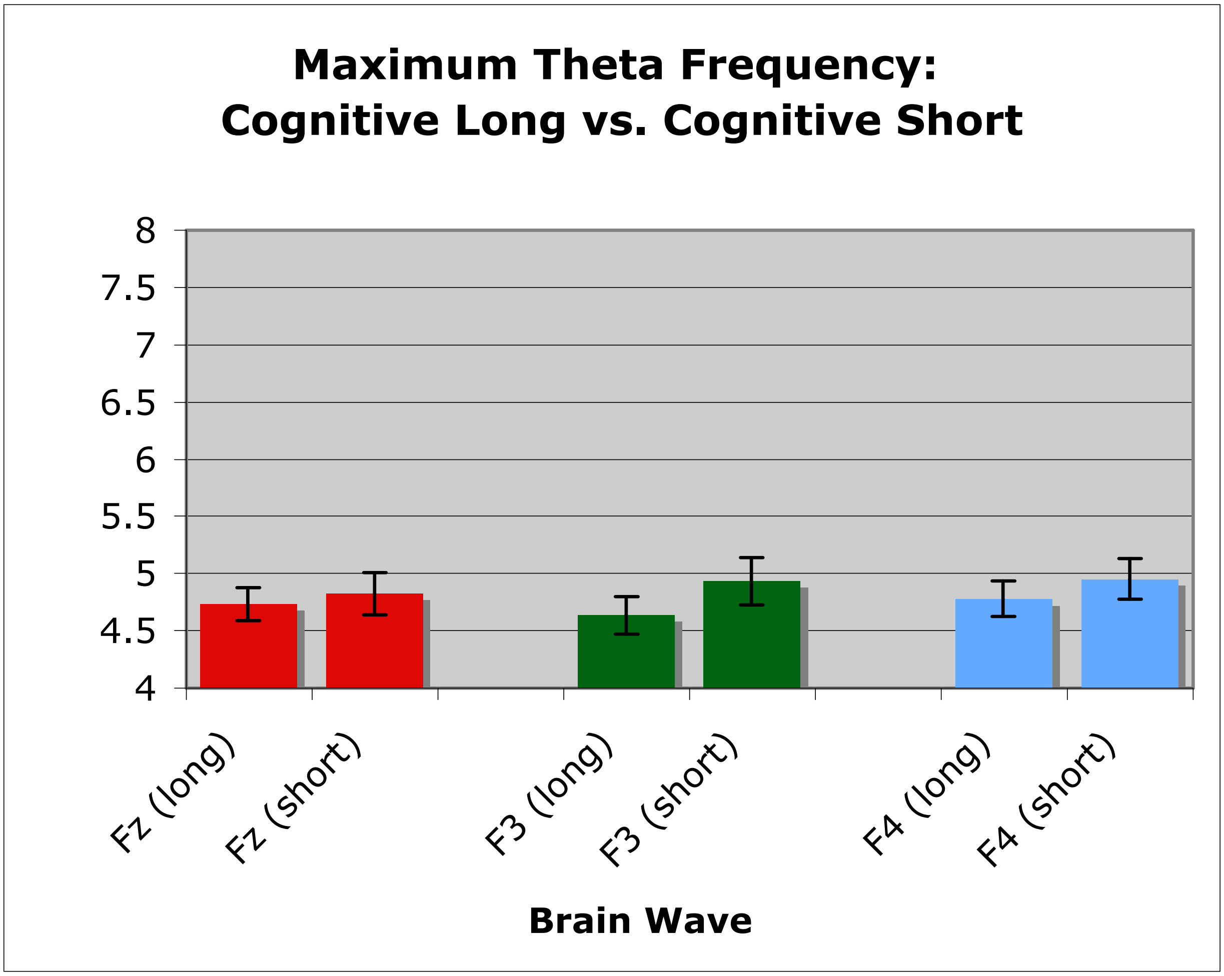

Figure 3

Maximum Theta Power: Cognitive Long vs. Cognitive Short

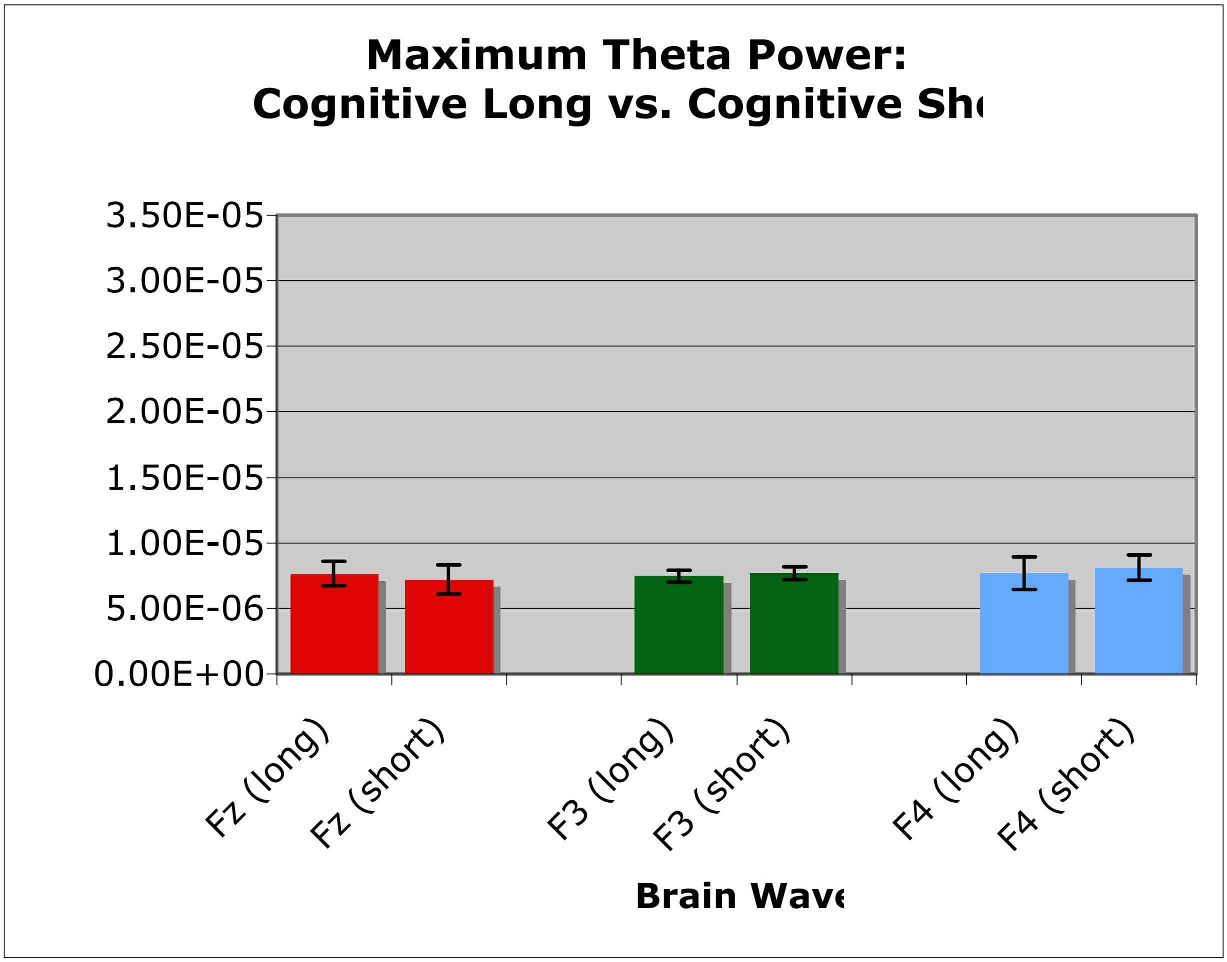

Figure 4

Maximum Theta Frequency: Motor Long vs. Motor Short

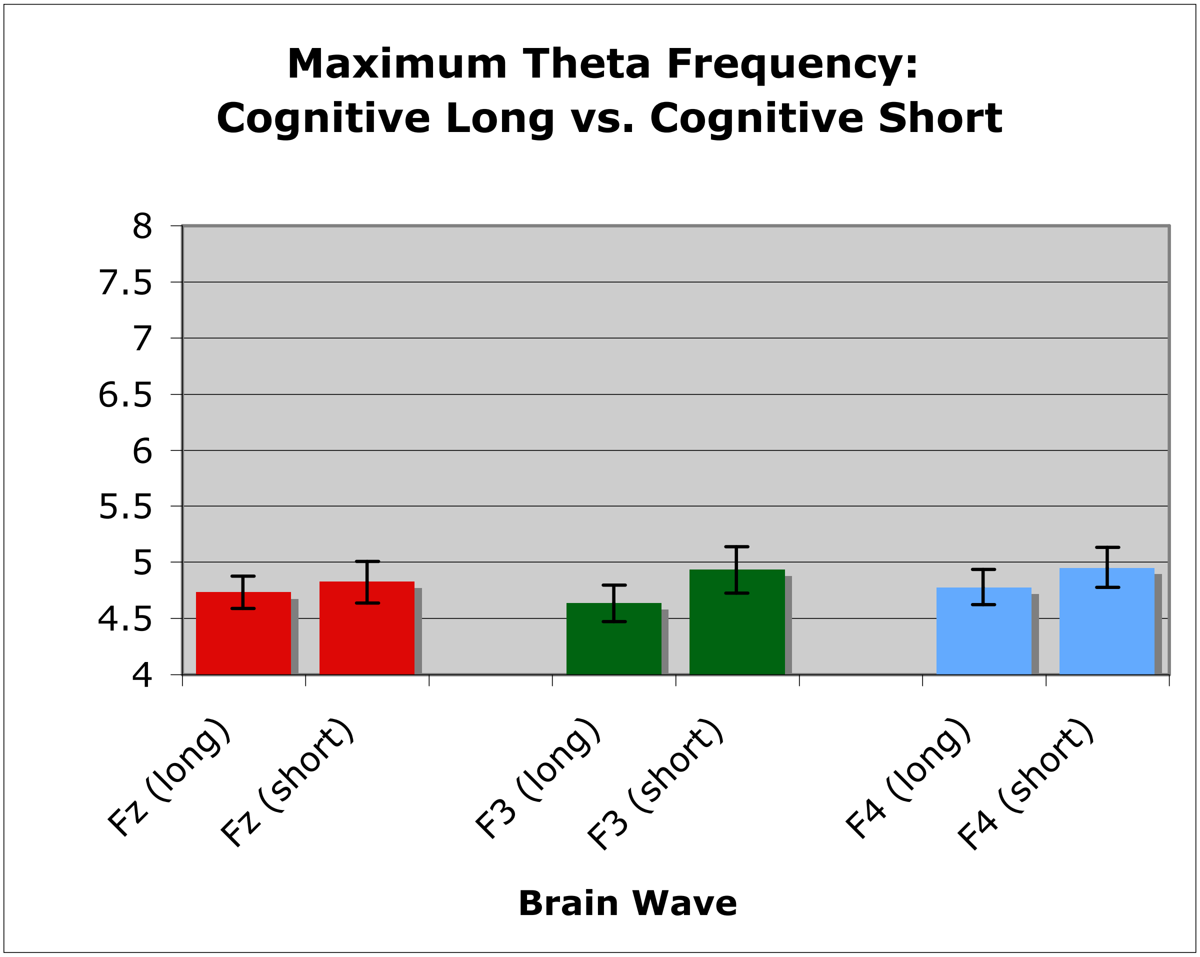

Figure 5

Maximum Theta Power: Motor Long vs. Motor Short