Spring 2018

# Gender Differences in Task Switching: An Event-Related Potential Study

Briana M. Bratcher
*Central Washington University*, briana.bratcher@cwu.edu

# GENDER DIFFERENCES IN TASK SWITCHING:

# AN EVENT-RELATED POTENTIAL STUDY

---

A Thesis

Presented to

The Graduate Faculty

Central Washington University

---

In Partial Fulfillment

of the Requirements for the Degree

Master of Science

Experimental Psychology

---

by

Briana Bratcher

May 2018

CENTRAL WASHINGTON UNIVERSITY

Graduate Studies

We hereby approve the thesis of

Briana Bratcher

Candidate for the degree of Master of Science

APPROVED FOR THE GRADUATE FACULTY

| | |
|---|---|
| _____ | _____ |
| | Dr. Ralf Greenwald, Committee Chair |
| _____ | _____ |
| | Dr. Heath Marrs |
| _____ | _____ |
| | Dr. Mary Radeke |
| _____ | _____ |
| | Dean of Graduate Studies |

ABSTRACT

GENDER DIFFERENCES IN TASK SWITCHING:

AN EVENT RELATED POTENTIAL STUDY

by

Briana Bratcher

May 2018

The current study examined the possible differences in several brainwaves and behavioral reaction times between males and females in relation to task switching. Previous research has shown gender differences in various aspects of cognition including task switching. Task switching refers to the ability to cognitively switch from processing one task to processing another, completely different task. The current study utilized a color-shape target switching paradigm and event-related potentials to analyze possible gender differences. The results of the study showed no gender differences in relation to reaction times, P2 and P3b brainwave latencies or amplitudes. However, the study found a difference in the N2 component between genders. Moreover, the study found differences in the topographic distribution of ERP components which may indicate that gender differences in cognition are not necessarily in strength of neural activation but rather in spatial patterns of activation.

ACKNOWLEDGMENTS

I would like to thank my lab assistants, Viktoriya Broyan and Cheryl Drummond for their assistance in participant collection. I would also like to thank the constant support of the Central Washington University Psychology Department for supplying professors and mentors that were receptive and accessible throughout the thesis process. Finally, I would like to thank my committee, Dr. Mary Radeke and Dr. Heath Marrs, and my chair, Dr. Ralf Greenwald, for their efforts in advising.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Figure Page

# Chapter I.

## INTRODUCTION

Executive functions enable humans to rapidly make decisions and adaptions to the environment. Located primarily in the prefrontal cortex, executive functions encompass several cognitive functions like problem solving, sequencing, attention, inhibition, task switching and cognitive flexibility (Chan, Shum, Toulopoulou, & Chen 2008; Diamond 2013). There is a substantial body of literature examining these various cognitive processes in relation to brain function, brain anatomy, and behavior (Chan et. al., 2008; Diamond 2013). In addition, several studies examine cognitive differences in relation to gender. For instance, research on executive functions show that "females perform better on speech production, episodic memory, and face-recognition tasks, while men perform better on spatial cognitive tasks, such as visual spatial tasks," (Feng et. al., 2011). Despite some of the research on executive function and gender, not all aspects of executive function have been investigated in relation to potential gender differences. Specifically, not many studies have investigated task switching in terms of gender. Task switching is defined as the ability to flexibly switch between tasks and is considered a hallmark of cognitive control and flexibility.

In developing a full understanding of executive functions and human behavior, it is important to investigate potential cognitive differences relative to gender. The following sections will outline some of the key aspects involved in gender differences and executive function. Specially, these sections will focus on research dealing with gender and executive function, task switching, and brain wave studies dealing with task

switching.

**Gender and Executive Function**

Executive functions are a set of neural processes that deal with managing mental resources in order to achieve a desired goal. Key aspects of executive functioning include attentional control, cognitive inhibition, inhibitory control, working memory, task switching and cognitive flexibility (Chan et.al., 2008; Diamond 2013). Collectively, these processes allow for greater optimization of thought, decision making, multitasking, attention, and adaptation to the environment. While it is unclear whether the ability to effectively manage executive functions is due to personality, educational, or social factors, it is also important to consider gender in relation to human cognition (Halpern, 2012; Taleb & Awamleh, 2012). In alignment with previous studies, gender in this study is defined as either of the two sexes (male and female) as defined by biological factors.

Previous research dealing with cognition has shown that there are gender differences in relation to brain processing involved in cognition (Halpern, 2012). For example, Christakou, Halari, Smith, Ifkovits, Brammer and Rubia (2009) found that in tasks of working memory, mental rotation, cognitive switching, and interference inhibition, males had stronger parietal activation while females had stronger frontal activation. Similarly, Yuan, He, Qinglin, Chen, and Li (2008) found that males are less able to control inappropriate behavior, are more impulse seeking, and less able to detect deviant stimuli than females. Moreover, when looking at brain wave data, the same study showed that females have larger amplitudes and shorter latencies in their brainwaves with more attention to deviant stimuli. Differences have also been found in other executive functions tasks. For example, judgement of line orientation tasks and visuospatial stimuli

tasks, show that males perform better on behavioral measures (i.e., scores) than females (Cherney & Collaer, 2005). In addition, Johnson and Bouchard (2007) also found brain activation differences between the genders. Specifically, males showed signs of bilateral brain activation while females showed primarily left hemisphere activation. Further studies have shown that females find it less difficult than males to switch between tasks and that they are better in certain multi-tasking situations (Stoet, O'Connor, Conner, & Laws, 2013).

Given these findings in relation to differences in executive functions and cognitive processing, it is possible that gender differences in brain processing may also exist for other executive functions like task switching. In fact, a recent functional brain imaging study showed that male brains show greater brain metabolism when shifting attention than females. Moreover, males also show greater activity in the dorsolateral prefrontal cortex of the brain compared to females during task switching (Kuptsova, Ivanova, Petrushevskiy, Fedina, & Zhavoronkova, 2016).

**Task Switching**

Task switching (TS) refers to the ability to cognitively switch from processing one task to processing another, completely different task. This cognitive ability makes humans highly adaptable to their constantly changing environment and is one of the major factors of cognitive control and flexibility. Previous research has shown that task switching requires several regions of the brain to coordinate and execute successfully. For example, according to Braver, Reynolds, and Donaldson (2003), task switching occurs in the dorsolateral prefrontal cortex and left superior parietal cortex. In addition, research conducted by Dove, Pollmann, Schubert, Wiggins, and Yves von Cramon

(2000) also implicated the left frontal lobe, anterior cingulate gyrus, and premotor cortex as primary regions of activation for task switching. In considering the brain processes that correspond to task switching, it is important to consider the various task switching paradigms utilized in research studies.

For instance, when defining a task for an experiment, researchers have utilized a variety of simple tasks such as word reading, color and object naming, categorizing digits regarding magnitude or parity, categorizing letters as vowel or consonant, categorizing words as living/ nonliving, and report of stimulus location (Kiesel et.al., 2010). It has been well established, that these tasks coupled with appropriate task switching cues, are able to generate the brain processes required to engage task switching (e.g., Monsell, 2003; Salthouse, Fristoe, McGuthry, & Hambrick, 1998).

Finally, many studies investigating task switching have also focused on participant reaction times. Reaction time (RT) is a measure of the response by a participant to a stimulus and is an important factor in task switching. For example, Dove et.al. (2000) found that while task switching, participants experienced differences in reaction time and accuracy in the task switch condition compared to the repetition trials. These differences in speed and accuracy may reflect the various demands placed on executive control during task switching (Dove et.al. 2000). It is interesting to note, that many factors can affect human reaction time. These include, age, gender, handedness, visual fields, practice, fatigue, personality types, and exercise (Karia, Ghuntla, Mehta, Gokhale, & Shah, 2012).

**Evoked Response Potential and Task Switching**

In contrast to the poor temporal resolution associated with functional brain

imaging that focuses on spatial resolution, researchers can record electrical brain activity averages in real time using Evoked Response Potentials (ERPs). ERPs represent peaks in brain activity that are time locked to a specific stimulus (Luck, 2014). For example, a task involving various modes of presentation (e.g., visual) referred to as the oddball paradigm has most commonly been used to elicit a positive brain waveform around 300 milliseconds after the onset of a novel stimulus. The waveforms that appear in relation to particular stimuli are labeled as individual *components*, such as the P3 component in relation to the oddball paradigm. Moreover, these components have been examined in terms of specific cognitive behaviors that may be related to differences between experimental and control conditions.

In relation to ERPs and task switching, researchers have focused on several components (waveforms) of the ERP. Specifically, when evaluating waveforms in task switching, three components are the main focus. These components are labeled the N2, P2, and P3b waveforms. The N2 waveform, occurring at 100-200ms after stimulus onset, reflects cognitive control such as response inhibition, response conflict, and error monitoring. In addition, the N2 waveform also reflects response selection (Gaál & Czigler, 2015). Next, the P2 waveform which occurs at approximately 200ms after stimulus onset picks up on target stimuli features, particularly infrequent target stimuli (Luck, 2014). Finally, the P3b waveform occurs at about 350-500ms post stimulus onset is sensitive to attentional resources engaged during dual task performance and target probability (Hillyard & Kutas, 2002; Luck, 2014; Polich, 2007). Overall, ERPs have the fine grain temporal resolution that may be required in order to detect possible brain processing differences in gender with regards to task switching.

The aim of this study was to identify possible gender differences in the executive function of task switching. Specifically, the current study sought to investigate the possible gender differences in task switching in relation to brain processing (ERPs) and behavioral responses (reaction time). Based on previous studies, there has been some evidence for gender differences in cognition. However, to date there have been few studies investigating the possible gender differences in task switching. Utilizing Event Related Potentials, the proposed study used a color-shape target switching (TS) paradigm adapted from Gaál and Czigler (2015). It was hypothesized that there would be gender differences in brain waveforms and reaction times in relation to task switching. In more detail, it is hypothesized:

H (1): Female participants will record smaller mean amplitude and shorter latency of the early positivity (P2 component) and the late positivity (P3b component) waveforms for cue-locked ERPs than male participants.

H (2): Female participants will record a smaller mean amplitude and shorter latency of the N2 and P3 waveform components for target-locked ERPs than male participants.

H (3): Female participants will record shorter RTs than male participants.

# Chapter II.

# METHOD

## Participants

A total of twenty participants were recruited for the study. The sample consisted of ten males, with an average age of 24±, and ten females, with an average age of 20±. Recruitment of participants was achieved through the Central Washington University Department of Psychology's Sona system website (Appendix A) and email outreach to students not in the Department of Psychology (Appendix B). Research participation credit was granted to participants based on their attendance to the date and time submitted by the participant on the Sona website. Additionally, participants who successfully completed the study were eligible for a raffle of one $100 Amazon gift card. The gift card raffle was completed after analysis. The study was open to anyone willing to participate between the ages of 18 to 30 who were free of any persistent medication, drug use, and/or neurological disorders.

## Design and Procedure

After participants provided consent to participate in the study (Appendix C), demographic data were collected by way of the participant completing a Handedness Preference Questionnaire (Appendix D) and Participant History Questionnaire (Appendix E). Following completion of the demographic data, participants were instructed about the ERP phase of the study. During this phase, participants were fitted with the Neuroscan EEG Quickcap and asked to participate in the color-shape classification task presented via a computer monitor and the Neuroscan STIM program. Adapted from Gaál and

Czigler (2015), the color-shape classification task was an informatively cued task switching (TS) paradigm in which participants classify stimuli based on color and shape. The participants were required to make fast and accurate choice button presses via a computer mouse, using a right or left mouse click using the index or middle finger. according to the instructions appropriate to one of two tasks (color-shape task).

As seen in Figure 1, the stimuli were pairs of orange and light blue triangles, squares and circles. Cue colors green and yellow indexed the shape task (identical or different), while cue colors purple and red were used for the color task (identical or different). Each trial started with a colored cue for 1000 msec, followed by a target stimulus presented for 2000 msec during which each participant was required to make a response. Cue colors were not repeated on successive trials to separate TS from cue switching. Stimuli were presented in pseudorandom order with 50% switch probability and with the restriction that the same target cannot be repeated on successive trials and that no more than three TS or three task repetition (TR) trials can follow in succession. All tasks were “Go” trials (trials that use only paradigm stimuli of shape or color) and no “No-Go” trials (trials that do not use paradigm stimuli of shape or color) were included. Overall, single tasks were presented in one block each for shape and color tasks with 48 stimuli. Mixed color and shape tasks were presented in five blocks with 240 stimuli total. Finally, prior to starting the experiment, all participants were given a practice block familiarizing them with the experimental procedures.

**Figure 1.** Color-Shape Classification Task

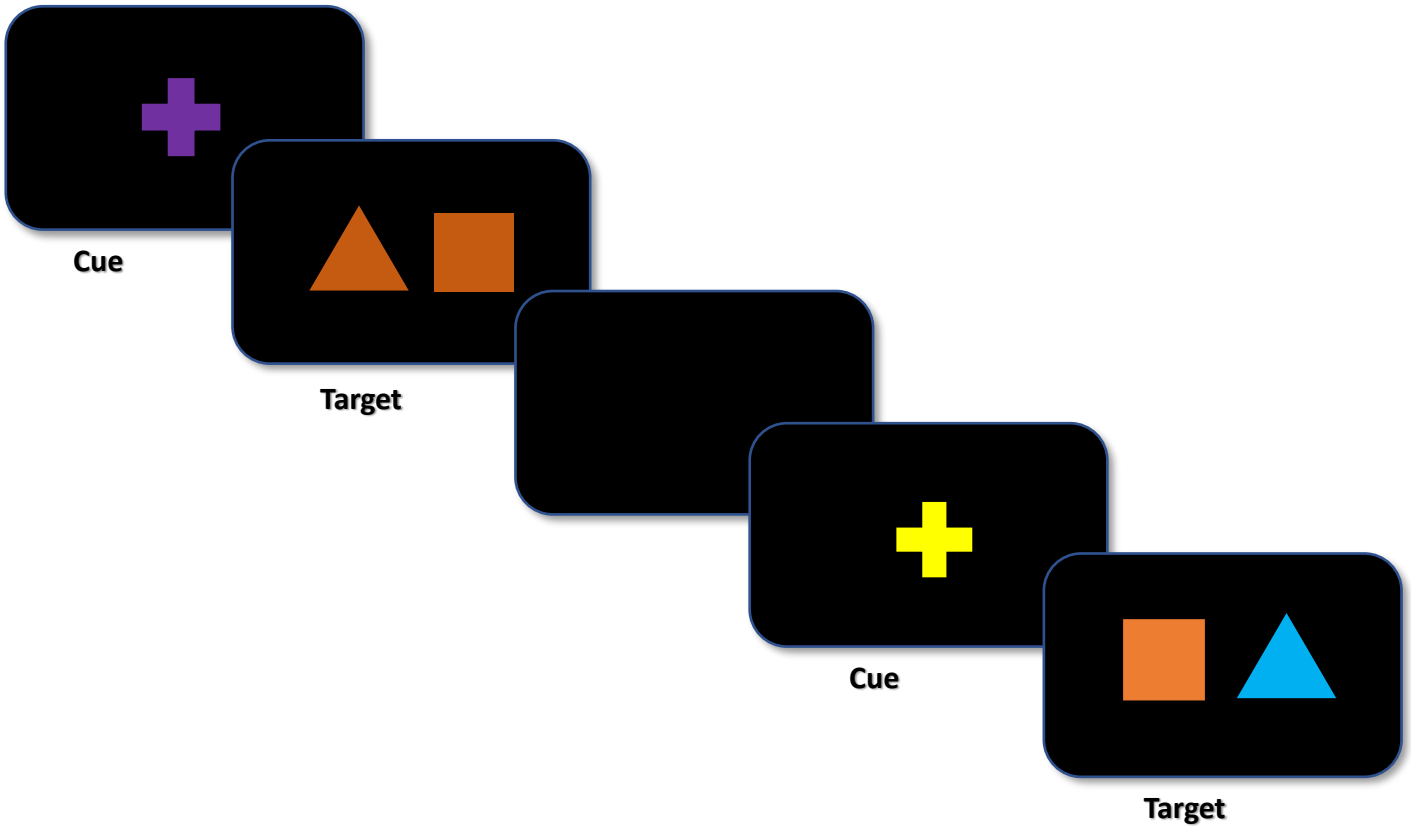



*Figure 1.* Color shape classification task presented to participants. Each participant was shown an informative cue cross for 1000ms. The color of the cross determined if the next task would be a shape task (colors yellow or green) or a color task (colors red or purple). The target screen was shown for 2000ms. The target stimuli were pairs of triangles, circles, or squares in either orange or blue or a combination of the two. Participants had to identify if the target stimuli were the same or different based on the previous cue indicating the task.

Upon completion of the experiment, the EEG Quickcap was removed from the participants and participants were debriefed (Appendix F). During the debriefing, the participant answered questions about their experience and were provided with a description of the hypotheses and purpose of the study (Appendix G).

## Measures

**EEG Acquisition.** Participants were guided into the EEG stimulus viewing room and fitted with the Neuroscan 32 channel quick cap. Electrical impedance of each electrode was minimized to under 15mΩs, and the system was referenced on the nasion of the participant. Eye blinks were monitored via two electrodes positioned at the outer canthus of the left eye and just above the left eyebrow. Electrodes were aligned in a 10-20 system, meaning the distances between adjacent electrodes were either 10 or 20% of the total front-back, left-right distance of the skull. Actual electrophysiological data were recorded from 32 electrode sites distributed evenly across the scalp using silver/silver-chloride (Ag/AgCl) electrodes attached to an elastic cap (Neuromedical Supplies Inc.) and a Neuroscan amplifier/stimulator (SynAmps) with the SCAN Neuroimaging Suite software. Data were recorded continually and epoched to the onset of the visually presented experimental stimuli. The stored epoch encompassed 1100 msec (including a 100 msec prestimulus baseline) relative to stimulus onset. ERPs were averaged across -100 msec to 700 msec relative to cue onset and for target-locked ERPs from -100 msec to 1000 msec relative to target onset.

**EEG Analysis.** Amplification of the continuous EEG recording was from .15 to 70 Hz (1 to 100 Hz for the EOG channel), and digitized through the Neuroscan

acquisition interface system. Continuous analog-to-digital conversion of the EEG and stimulus trigger codes was performed on-line by the Neuroscan acquisition interface system. Signal averaging was conducted after offline artifact rejection and baseline correction.

Individual epochs were examined and rejected whenever electrical activity in either EOG (Blink) channels exceeded ±75μV. Successfully averaged ERP waveforms were digitally lowpass-filtered with .1 phase-shift at 30Hz with a filter slope of -12 dB per octave in order to remove ambient electrical noise and muscle artifact. Averaged waves were separated into their respective gender categories as well as averaged for target locked and cue locked target ERPs.

**Behavioral Data.** Reaction time (RT) and accuracy of the responses were recorded via the Neuroscan STIM software program. Specifically, RTs were collected after each participant's response (using a standard computer mouse) to the experimental stimulus on the screen. Participants were instructed to respond quickly and accurately.

**Coding Procedures.** To ensure participant anonymity, all participants in the study were labeled with an alpha-numeric code. This code was used in the storage of the participant's EEG data. Participant's data from the averaged waveforms from the EEG, and demographic data were analyzed and compared between gender.

## Hypotheses

H (1): Female participants will record smaller mean amplitude and shorter latency of the early positivity (P2 component) and the late positivity (P3b component) waveforms for cue-locked ERPs than male participants.

H (2): Female participants will record a smaller mean amplitude and shorter latency of the N2 and P3 waveform components for target-locked ERPs than male participants.

H (3): Female participants will record shorter RTs than male participants.

**ERP Analysis**

Analysis of the TS paradigm ERP components was based on the following parameters. Cue locked ERPs were analyzed for (1) early positivity waveform P2 in the 150-250ms interval/range and (2) late positivity waveform P3b in the 300-500ms interval/range. Next, Target locked ERPs were analyzed for the N2 waveform in the 100-200ms range and P3b waveform in the 300-500ms range. The timeframe of the waveforms was determined through previous literature.

**Statistical Analysis**

Multivariate analysis of variance (MANOVA) was performed using SPSS statistical program with independent variables of Gender (two levels: male and female) and dependent variables cue locked (CL), with subcategories task switching (TS) and task repetition (TR), target locked (TL) and reaction time (RT). Averaged data from the PZ electrode for each participant were used to compare the ERP and behavioral data for cue locked ERPs and target locked ERPs. A *t*test was performed to compare gender differences in reaction time. Finally, based on previous studies, task accuracy was not expected to differ and therefore was not subject to analysis.

# Chapter III.

# RESULTS

## ERP Waveforms

A multivariate analysis of variance (MANOVA) was conducted on gender responses to cue locked ERPs and target locked ERPs at the CPZ electrode site. Tables 1 through 3 show the means and standard deviations of each MANOVA conducted. Figures 2 through 5 show the comparisons of the grand averaged wave forms across all conditions for the N2, P2 and P3b components.

Table 1

*Means and Standard Deviations for Cue Locked ERPs.*

| | Gender | *N* | *M* | *SD* |
|---|---|---|---|---|
| P2 Amplitude | Male | 10 | 4.76 | 2.39 |
| | Female | 10 | 5.24 | 2.77 |
| P2 Latency | Male | 10 | 220.90 | 17.94 |
| | Female | 10 | 201.50 | 28.238 |
| P3b Amplitude | Male | 10 | 4.35 | 2.80 |
| | Female | 10 | 5.27 | 2.65 |
| P3b Latency | Male | 10 | 391.50 | 40.80 |
| | Female | 10 | 382.50 | 29.24 |

M = mean, SD = standard deviation

Table 2

*Means and Standard Deviations for Target Locked ERPs*

| | Gender | *N* | *M* | *SD* |
|---|---|---|---|---|
| N2 Amplitude | Male | 10 | -9.62 | 5.81 |
| | Female | 10 | -4.21 | 4.75 |
| N2 Latency | Male | 10 | 150.70 | 17.55 |
| | Female | 10 | 143.10 | 26.13 |
| P3b Amplitude | Male | 10 | 5.49 | 3.83 |
| | Female | 10 | 5.24 | 3.08 |
| P3b Latency | Male | 10 | 400.40 | 21.84 |
| | Female | 10 | 386.10 | 20.48 |

M = mean, SD = standard deviation

Table 3

*Means and Standard Deviations for Task Switch and Task Repetition comparison in Cue Locked ERPs*

| Condition | | Gender | *N* | *M* | *SD* |
|---|---|---|---|---|---|
| Task Switching | P2 Amplitude | Male | 10 | 5.20 | 2.73 |
| | | Female | 10 | 4.53 | 2.76 |
| | P2 Latency | Male | 10 | 218.50 | 25.93 |
| | | Female | 10 | 203.40 | 21.61 |
| | P3b Amplitude | Male | 10 | 4.70 | 2.70 |
| | | Female | 10 | 5.68 | 2.57 |
| | P3b Latency | Male | 10 | 383.00 | 39.12 |
| | | Female | 10 | 391.90 | 35.69 |
| Task Repetition | P2 Amplitude | Male | 10 | 5.15 | 2.67 |
| | | Female | 10 | 6.90 | 5.00 |
| | P2 Latency | Male | 10 | 215.60 | 22.65 |
| | | Female | 10 | 202.90 | 23.84 |
| | P3b Amplitude | Male | 10 | 6.05 | 2.16 |
| | | Female | 10 | 6.39 | 2.91 |
| | P3b Latency | Male | 10 | 368.10 | 38.28 |
| | | Female | 10 | 375.70 | 41.02 |

M = mean, SD = standard deviation

**Figure 2. Gender comparison for cue locked (CL) ERPs at the PZ electrode**

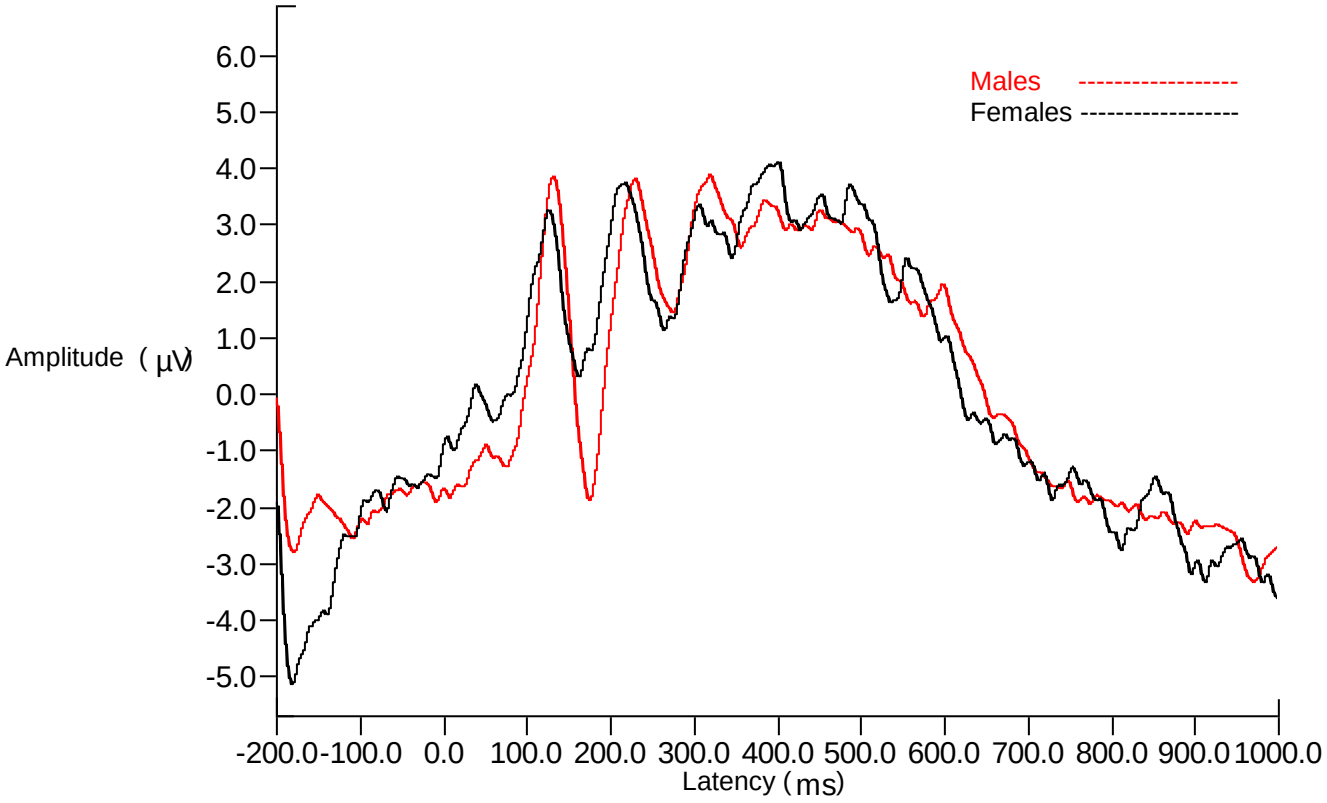


**Figure 3.** Gender comparison for target locked (TL) ERPs on the PZ electrode

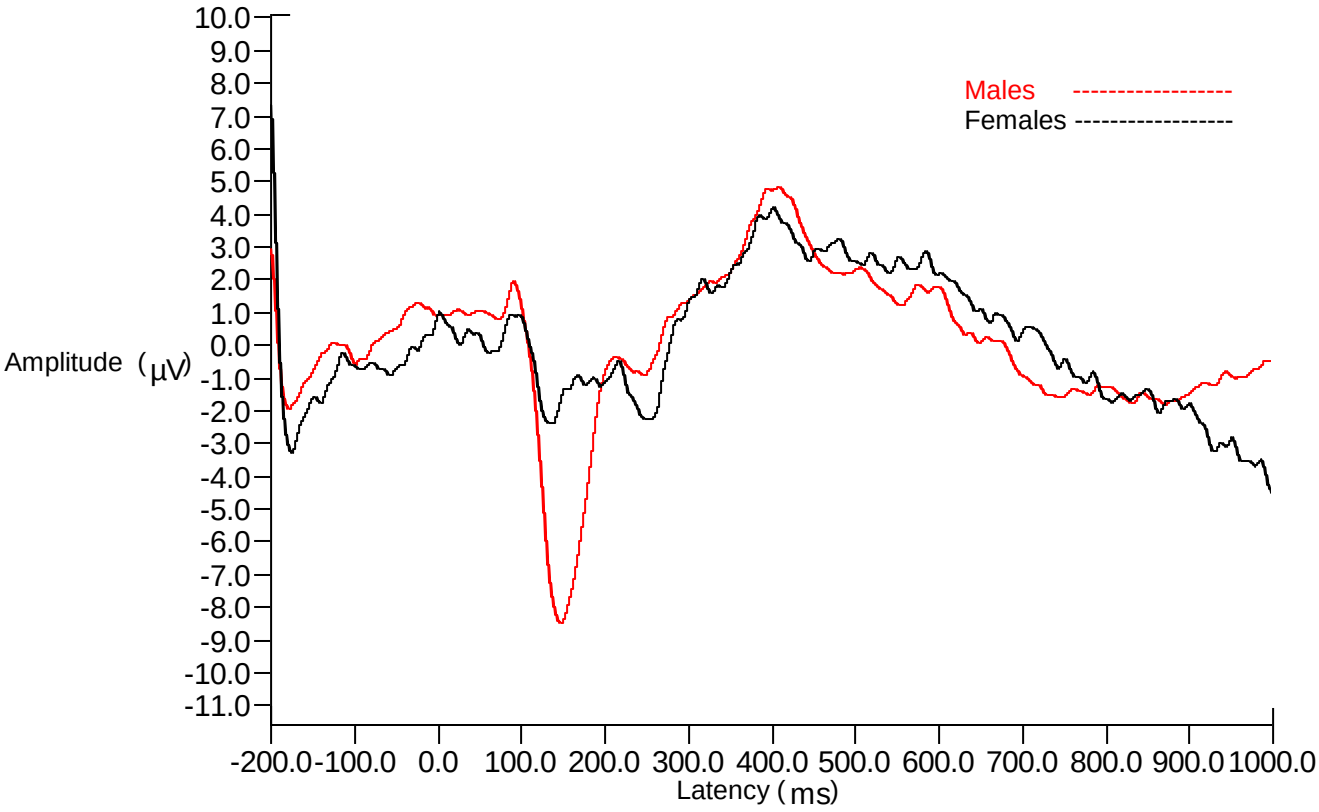


**Figure 4.** Gender comparison on task repetition (TR) on cue locked stimuli

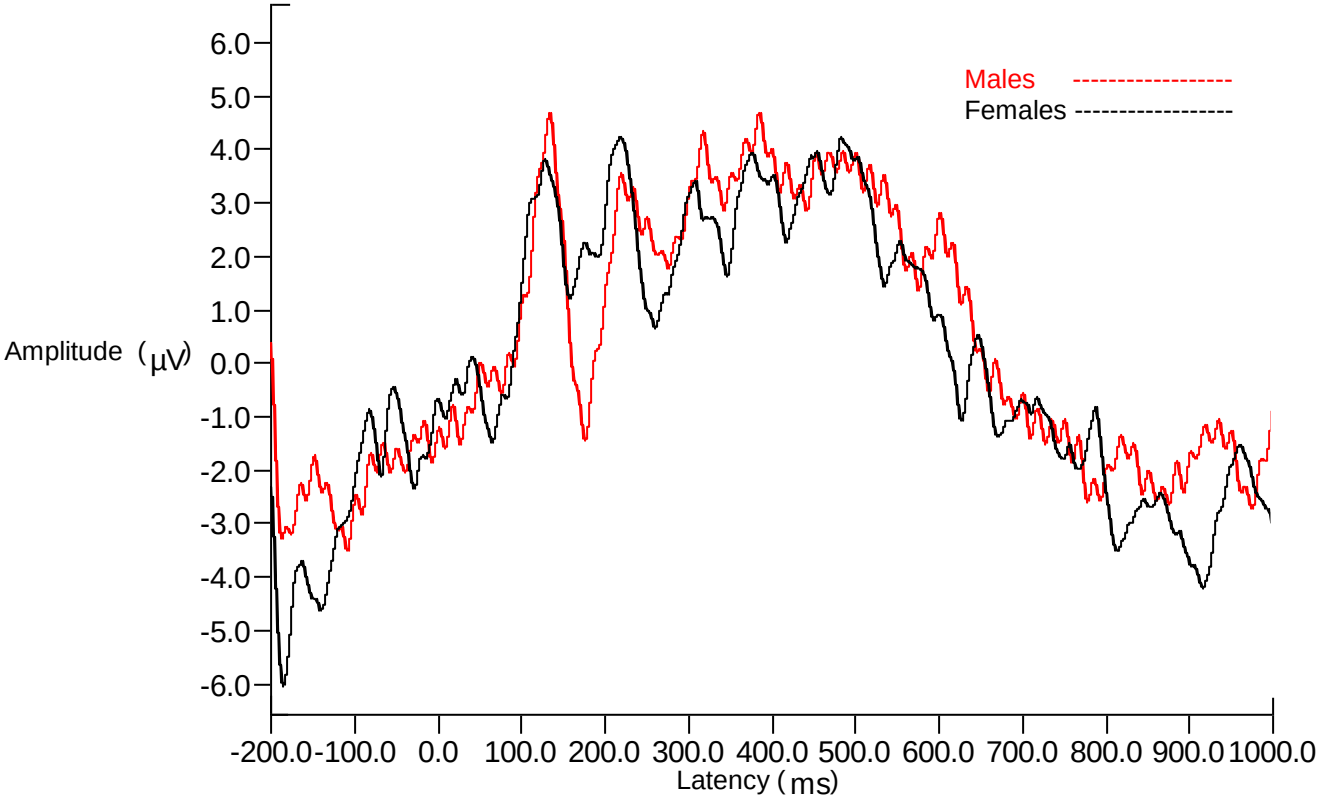
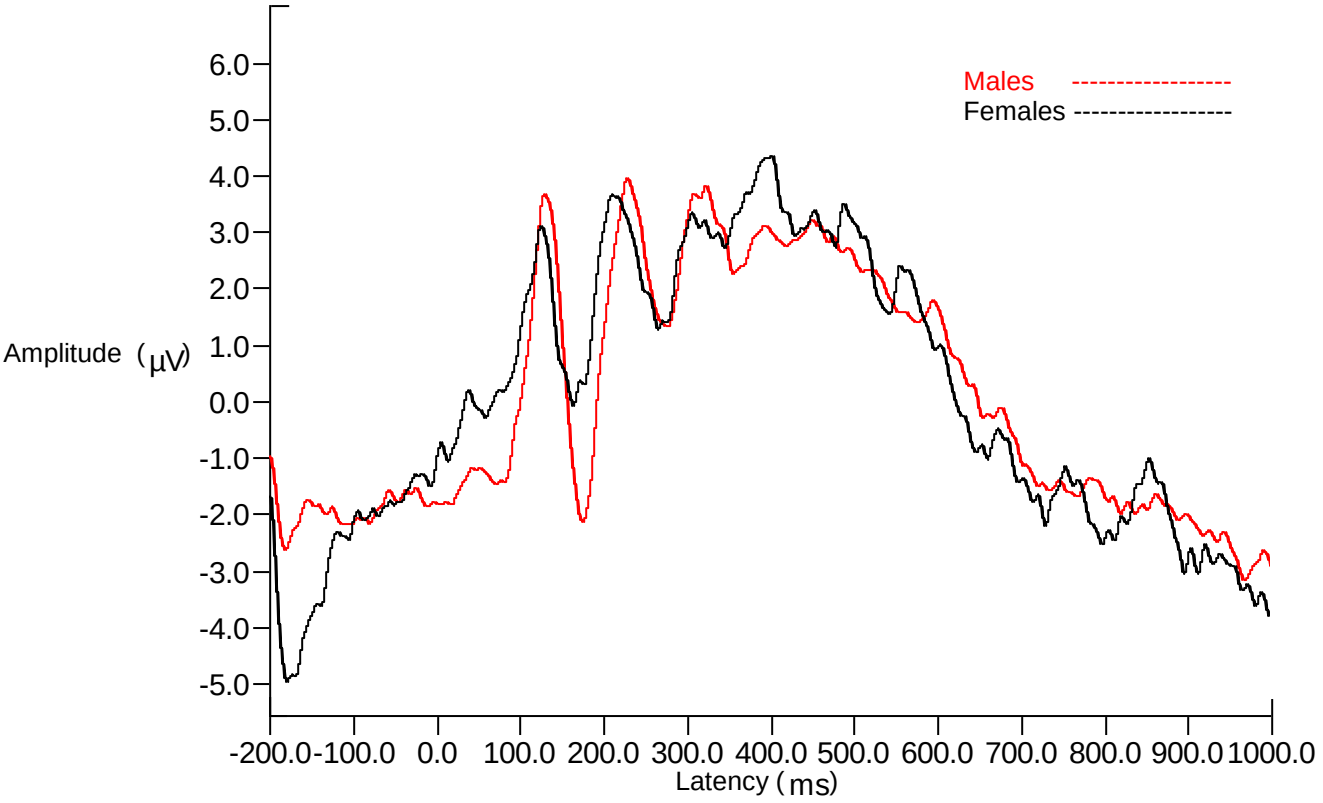


**Figure 5.** Gender comparison for task switching (TS) in cue locked stimuli



Both analyses were not significant for cue locked ERPs, $F$ (4,15) = 1.079, $p$ = 0.40, $\lambda = 0.78$, $\eta^2 = 0.22$ (Table 4), and target locked ERPs (P2, P3b) $F(4,15) = 1.780$, $p$ = 0.19, $\lambda = 0.68$, $\eta^2 = 0.32$ (Table 5). However, N2 amplitude was significant for Gender, $F(4,15) = 5.20$, $p = 0.03$, $\eta^2 = 0.22$. Further analysis of cue locked ERPs separated task switching responses and task repetition responses of participants. The MANOVA for the comparison of task switching versus task repetition conditions was not significant $F(8,11) = 0.3$, $p = 0.94$, $\lambda = 0.81$, $\eta^2 = 0.19$ (Table 6).

Table 4

*Multiple Analysis of Variance for Cue Locked stimuli.*

| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | *F* | *Sig.* |
|---|---|---|---|---|---|---|
| Corrected Model | P2 Amplitude | 1.77 | 1 | 1.17 | .17 | .68 |
| | P2 Latency | 1881.80 | 1 | 1881.80 | 3.36 | .08 |
| | P3b Amplitude | 4.18 | 1 | 4.18 | .55 | .46 |
| | P3b Latency | 405.00 | 1 | 405 | .32 | .57 |
| Intercept | P2 Amplitude | 500.71 | 1 | 500.71 | 74.31 | .00 |
| | P2 Latency | 892108.80 | 1 | 892108.80 | 1593.77 | .00 |
| | P3b Amplitude | 463.92 | 1 | 463.92 | 61.98 | .00 |
| | P3b Latency | 2995380.00 | 1 | 2995380.00 | 2376.55 | .00 |
| Gender | P2 Amplitude | 1.17 | 1 | 1.17 | .17 | .68 |
| | P2 Latency | 1881.80 | 1 | 1881.80 | 3.36 | .08 |
| | P3b Amplitude | 4.18 | 1 | 4.185 | .55 | .46 |
| | P3b Latency | 405.00 | 1 | 405.00 | .32 | .57 |
| Error | P2 Amplitude | 121.27 | 18 | 6.73 | | |
| | P2 Latency | 10075.40 | 18 | 559.74 | | |
| | P3b Amplitude | 134.72 | 18 | 7.48 | | |
| | P3b Latency | 22687.00 | 18 | 1260.38 | | |
| Total | P2 Amplitude | 623.16 | 20 | | | |
| | P2 Latency | 904066.00 | 20 | | | |
| | P3b Amplitude | 602.83 | 20 | | | |
| | P3b Latency | 3018472.00 | 20 | | | |

| | | | |
|---|---|---|---|
| Corrected Total | P2 Amplitude | 122.45 | 19 |
| | P2 Latency | 11957.20 | 19 |
| | P3b Amplitude | 138.91 | 19 |
| | P3b Latency | 23092.00 | 19 |

Table 5

*Multiple Analysis of Variance for Target Locked stimuli.*

| Source | Dependent Variable | Type III Sum of Squares | df | Mean Square | *F* | *Sig.* |
|---|---|---|---|---|---|---|
| Corrected Model | N2 Amplitude | 146.74 | 1 | 146.74 | 5.20 | .03 |
| | N2 Latency | 288.80 | 1 | 288.80 | .58 | .45 |
| | P3b Amplitude | .325 | 1 | .325 | .02 | .87 |
| | P3b Latency | 1022.45 | 1 | 1022.45 | 2.28 | .14 |
| Intercept | N2 Amplitude | 957.64 | 1 | 957.64 | 33.94 | .00 |
| | N2 Latency | 431592.20 | 1 | 431592.20 | 871.02 | .00 |
| | P3b Amplitude | 576.73 | 1 | 576.73 | 47.52 | .00 |
| | P3b Latency | 3092911.25 | 1 | 3092911.25 | 6897.57 | .00 |
| Gender | N2 Amplitude | 146.74 | 1 | 146.74 | 5.20 | **.03**** |
| | N2 Latency | 288.80 | 1 | 288.80 | .58 | .45 |
| | P3b Amplitude | .32 | 1 | .32 | .02 | .87 |
| | P3b Latency | 1022.45 | 1 | 1022.45 | 2.28 | .14 |
| Error | N2 Amplitude | 507.81 | 18 | 28.21 | | |
| | N2 Latency | 8919.00 | 18 | 495.50 | | |
| | P3b Amplitude | 218.42 | 18 | 12.13 | | |
| | P3b Latency | 8071.30 | 18 | 448.40 | | |
| Total | N2 Amplitude | 1612.19 | 20 | | | |
| | N2 Latency | 440800.00 | 20 | | | |
| | P3b Amplitude | 795.48 | 20 | | | |
| | P3b Latency | 312005.00 | 20 | | | |
| Corrected Total | N2 Amplitude | 654.55 | 19 | | | |
| | N2 Latency | 9207.80 | 19 | | | |
| | P3b Amplitude | 218.74 | 19 | | | |
| | P3b Latency | 9093.75 | 19 | | | |

Table 6

*Multiple Analysis of Variance for the comparison of Task Switch and Task Repetition Cue Locked stimuli*

| Source | Condition | Dependent Variable | Type III Sum of Squares | df | Mean Square | *F* | *Sig.* |
|---|---|---|---|---|---|---|---|
| Corrected Model | Task Switch | P2 Amplitude | 2.26 | 1 | 2.26 | .29 | .59 |
| | | P2 Latency | 1140.05 | 1 | 1140.05 | 2.00 | .17 |
| | | P3b Amplitude | 4.82 | 1 | 4.82 | .69 | .41 |
| | | P3b Latency | 396.05 | 1 | 396.05 | .28 | .60 |
| | Task Repetition | P2 Amplitude | 15.41 | 1 | 15.41 | .95 | .34 |
| | | P2 Latency | 806.45 | 1 | 806.45 | 1.49 | .23 |
| | | P3b Amplitude | 0.58 | 1 | 0.58 | .08 | .76 |
| | | P3b Latency | 288.80 | 1 | 288.80 | .18 | .67 |
| Intercept | Task Switch | P2 Amplitude | 473.87 | 1 | 473.87 | 62.60 | .00 |
| | | P2 Latency | 889998.05 | 1 | 889998.05 | 1562.17 | .00 |
| | | P3b Amplitude | 539.22 | 1 | 539.22 | 77.38 | .00 |
| | | P3b Latency | 3002350.05 | 1 | 3002350.05 | 2141.06 | .00 |
| | Task Repetition | P2 Amplitude | 727.41 | 1 | 727.41 | 45.17 | .00 |
| | | P2 Latency | 875711.25 | 1 | 875711.25 | 1619.13 | .00 |
| | | P3b Amplitude | 775.03 | 1 | 775.03 | 117.78 | .00 |
| | | P3b Latency | 2766192.20 | 1 | 2766192.20 | 1756.74 | .00 |
| Gender | Task Switch | P2 Amplitude | 2.26 | 1 | 2.26 | .29 | .59 |
| | | P2 Latency | 1140.05 | 1 | 1140.05 | 2.00 | .17 |
| | | P3b Amplitude | 4.82 | 1 | 4.82 | .69 | .41 |
| | | P3b Latency | 396.05 | 1 | 396.05 | .28 | .60 |
| | Task Repetition | P2 Amplitude | 15.41 | 1 | 15.41 | .95 | .34 |
| | | P2 Latency | 806.45 | 1 | 806.45 | 1.49 | .23 |
| | | P3b Amplitude | 0.58 | 1 | 0.58 | .08 | .76 |
| | | P3b Latency | 288.80 | 1 | 288.80 | .18 | .67 |

| | | | | | |
|---|---|---|---|---|---|
| Error | Task Switch | P2 Amplitude | 136.25 | 18 | 7.75 |
| | | P2 Latency | 10254.90 | 18 | 569.71 |
| | | P3b Amplitude | 25.42 | 18 | 6.96 |
| | | P3b Latency | 25240.90 | 18 | 1402.27 |
| | Task Repetition | P2 Amplitude | 289.86 | 18 | 16.20 |
| | | P2 Latency | 9735.30 | 18 | 540.85 |
| | | P3b Amplitude | 118.44 | 18 | 6.58 |
| | | P3b Latency | 28343.00 | 18 | 1574.61 |
| Total | Task Switch | P2 Amplitude | 612.39 | 20 | |
| | | P2 Latency | 901393.00 | 20 | |
| | | P3b Amplitude | 669.47 | 20 | |
| | | P3b Latency | 3027987.00 | 20 | |
| | Task Repetition | P2 Amplitude | 1032.68 | 20 | |
| | | P2 Latency | 886253.00 | 20 | |
| | | P3b Amplitude | 894.06 | 20 | |
| | | P3b Latency | 2794824.00 | 20 | |
| Corrected Total | Task Switch | P2 Amplitude | 138.52 | 19 | |
| | | P2 Latency | 11394.95 | 19 | |
| | | P3b Amplitude | 130.25 | 19 | |
| | | P3b Latency | 25636.95 | 19 | |
| | Task Repetition | P2 Amplitude | 305.27 | 19 | |
| | | P2 Latency | 10541.75 | 19 | |
| | | P3b Amplitude | 119.03 | 19 | |
| | | P3b Latency | 28631.80 | 19 | |

**Topographic Brain Maps**

The topographic brain maps were derived from the grand-averaged ERP data for all conditions at peak responses for each main ERP component. Figure 6 shows the topographic maps comparing male vs female P2 and P3b components in the cue locked condition. For the P2 component, males showed a more central distribution while females showed a more occipital mapping. A similar mapping was found for the P3b component with females displaying a more occipital mapping than males. For the target locked condition (Figure 7), the N2 component showed a more central distribution for both males and females but with males showing greater activation. Similarly, the P3b component showed slightly greater activation in males while both genders showed a centro-frontal distribution of activation. Next, figure 8 shows the comparison of topographic maps for the task switching condition. For the P2 component, males showed a more central distribution while females showed a more occipital mapping, while the P3b component was more distributed towards the left hemispheres in females. Finally, in the task repetition condition (see Figure 9), the P2 component, showed a more central distribution in males while females showed a more occipital mapping. For the P3b component, females showed a more left hemisphere distribution than males.

**Figure 6.** Topographic maps for male vs. female P2 (200-250ms) and P3b (300-400) components in the cue locked condition.

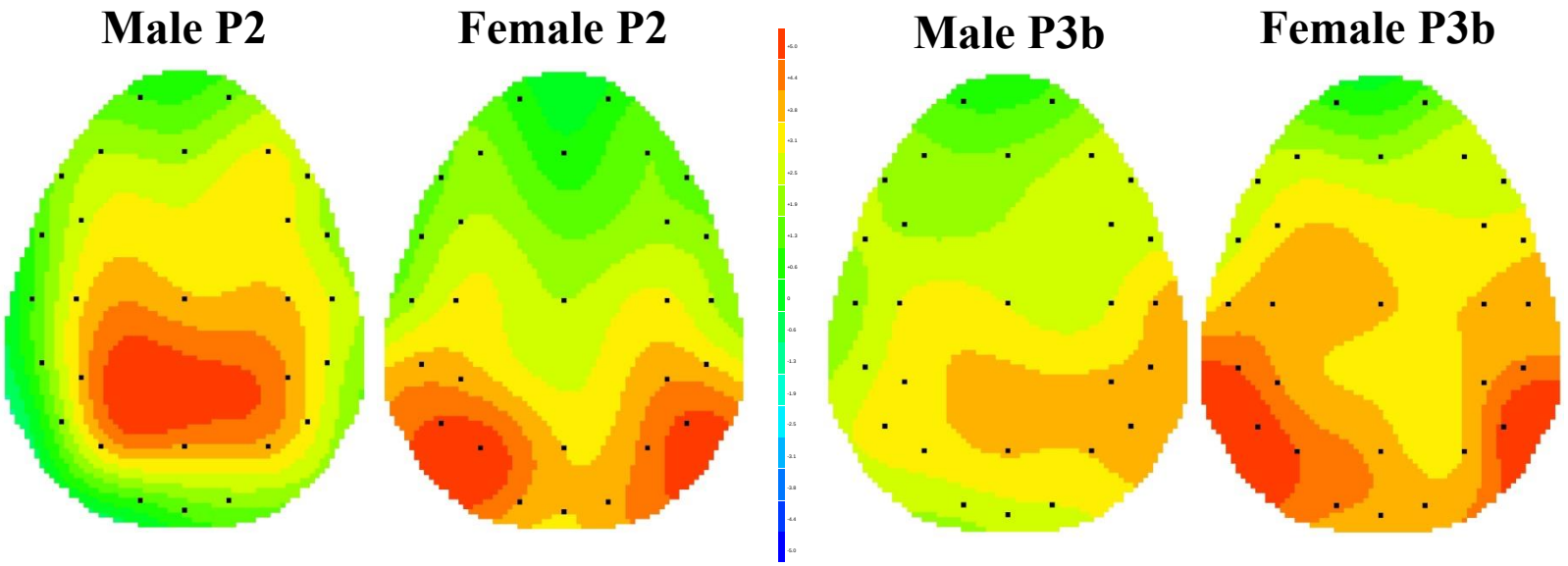


**Figure 7.** Topographic maps for male vs. female N2 (100-150ms) and P3b (350-400) components in the target locked condition.

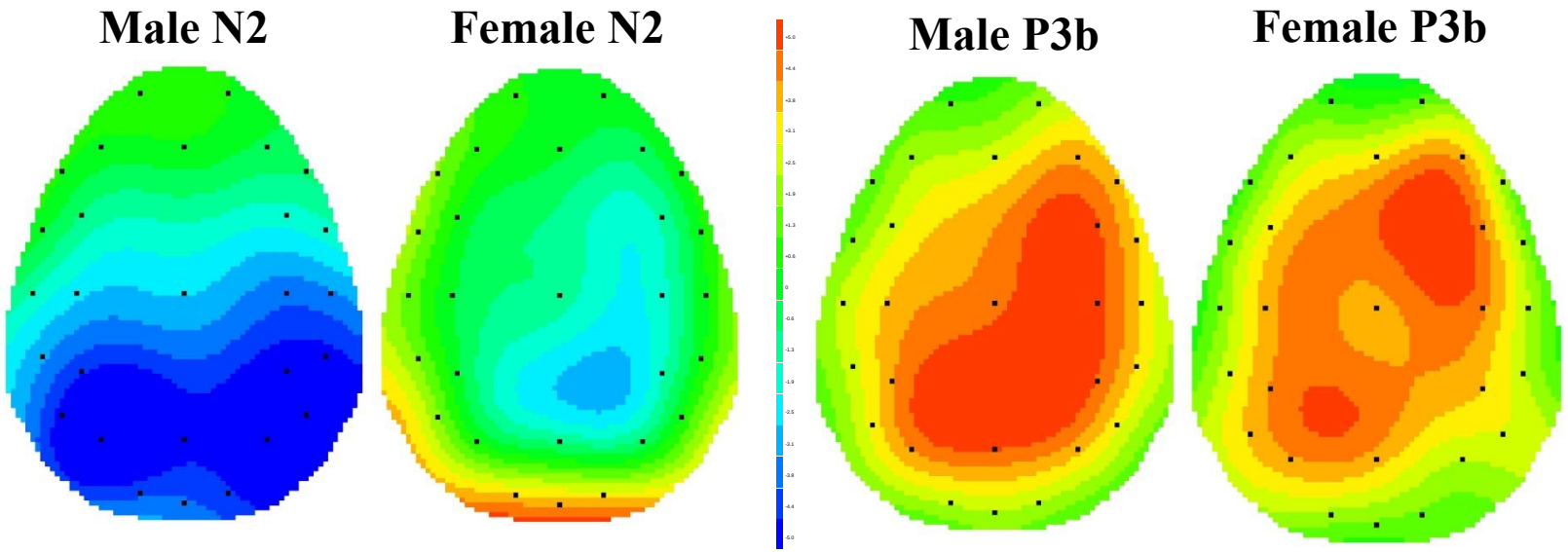


**Figure 8.** Topographic maps for the male vs. female P2 (200 – 250ms) and P3b (300 - 400ms) components in the task switching condition.

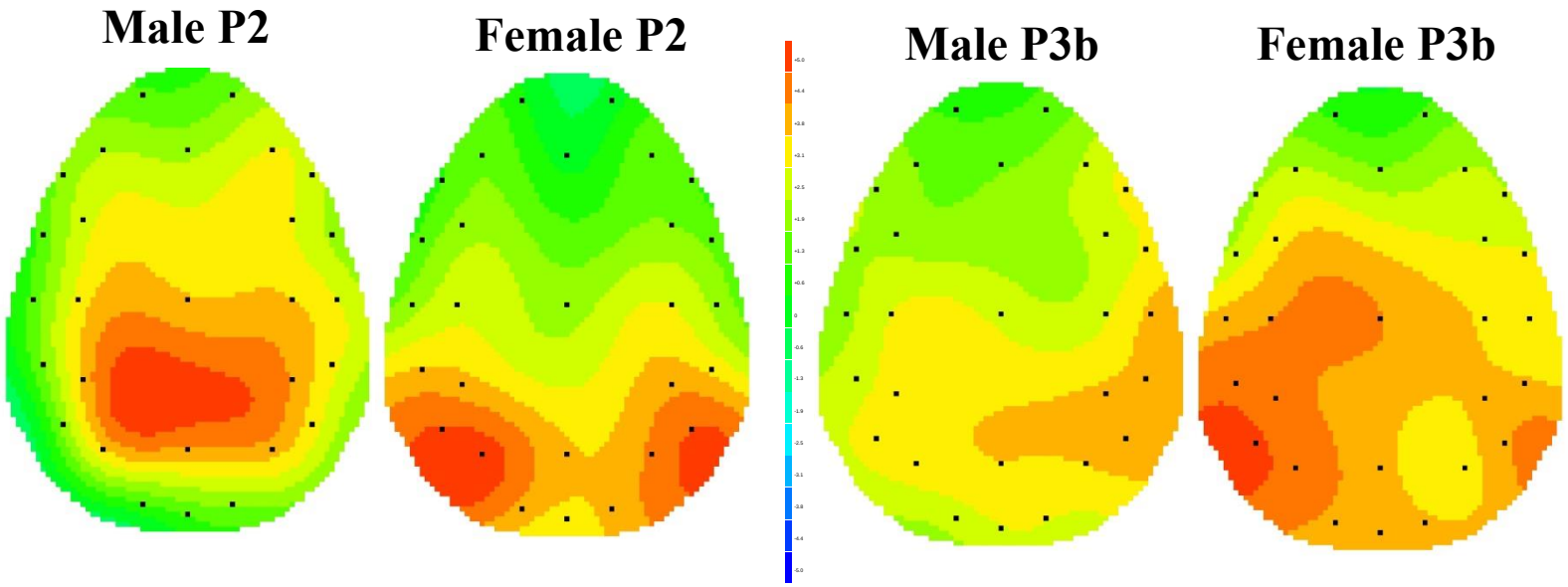
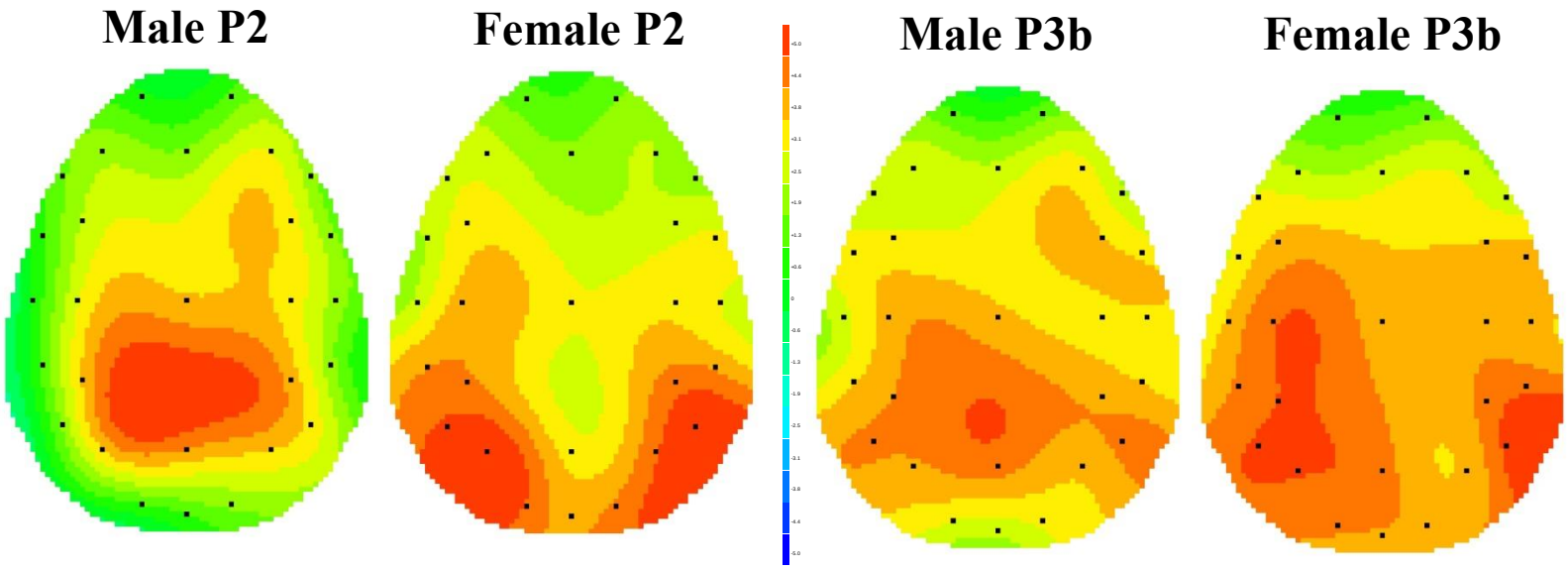


**Figure 9.** Topographic Maps for the male vs female P2 (200 – 250ms) and P3b (300 - 400ms) components in the task repetition condition.



**Behavioral Data**

An independent samples *t*test for reaction time between genders was conducted. Table 7 shows the means and standard deviations of participants. Results show there was no significance for reaction time between genders $t(18) = -1.32$, $p = 0.20$.

Table 7

*Means and Standard Deviations for Reaction Time (milliseconds).*

| Gender | N | *M (ms)* | *SD (ms)* |
|---|---|---|---|
| Male | 10 | 730.73 | 243.82 |
| Female | 10 | 872.30 | 234.30 |

M = mean, SD = standard deviation, ms = milliseconds

# Chapter IV.

# DISCUSSION

## Current Study

The purpose of the current study was to investigate possible behavioral and neural gender differences in task switching. Using a color-shape classification task, it was predicted that there would be differences in ERP measures between genders as well as reaction time differences. In agreement with previous studies (Gaál & Czigler, 2015; Hillyard & Kutas, 2002; Luck, 2014; Polich, 2007), the current study found ERP activation of the N2, P2 and P3b components in response to task switching. Specifically, analysis of both behavioral data and the P2, P3b components showed no significant differences in gender for all conditions related to task switching. However, there was a significant difference in the N2 component amplitude in the target locked condition. In addition, the current study added to the literature by evaluating the topographic distribution of the ERP components and found some differences in gender across conditions. Overall, the findings of the current study provide further evidence for the role of the N2, P2 and P3b components in relation to the neural underpinnings of task switching and executive functioning. Similarly, the current study's findings of no reaction time differences match other studies that have shown some potential differences in psychomotor speed but not necessarily in cognitive processing speed in relation to gender (Karia et. al., 2012; Munro et. al., 2000; Taleb, & Awamleh, 2012).

Although some previous research dealing with cognition has shown that there are gender differences in relation to brain processing involved in cognition (Halpern, 2012),

the current findings of no gender differences in the P2 and P3b components and a difference in the N2 component specific to task switching are in line with other studies. For example, Kray and Lindenberger (2000), only found task switching gender differences in relation to aging and not among young adults. Similarly, Munro et al. (2012) found no gender differences on tests of auditory divided attention, category fluency and executive functioning. Moreover, in their study, some patterns of gender differences were linked to changes in cognition due to age. Given the results of these and the current study, it may well be the case that some brain wave gender differences in relation to task switching are not present during adulthood and may only become apparent in elderly individuals. In turn, this provides further support for the notion that several factors thought to underlie gender differences in cognition (e.g., neural function) may be more affected by the aging process (i.e., Bracco, Bessi, Alari, Sforza, Barilaro, & Marinoni., 2010; Gaál & Czigler, 2015).

The current study did find a gender difference in N2 component amplitude in the target locked condition. This finding is similar to Gaál & Czigler (2015) who found a change in the N2 component in relation to aging and gender. The N2 component is thought to represent stimulus evaluation and selective attention (Gaál & Czigler, 2015; Luck, 2014; Monsell, 2003), and so the current study's finding could point to potential gender differences among young adults in the cognitive processes of selective attention and stimulus identification/distinction.

Next, the topographic findings of the current study are in line with previous studies on gender differences in patterns of brain activation in relation to executive

functions (Christakou et al., 2009; Dove et. al., 2000; Halpern, 2012; Yuan et al., 2008; Johnson & Bouchard, 2007; Kuptsova et al., 2016). Specifically, the topographic distribution differences found in the current study may indicate that males and females utilize different brain regions in order to select stimuli and engage in task switching. Moreover, the current findings may provide further evidence that some potential gender differences in cognition are not necessarily in strength of neural activation but rather in spatial patterns of activation. Again, this matches functional brain imaging studies that have indicated potential spatial activation differences between genders engaged in task switching (Dove et al., 2000; Kuptsova et al., 2016).

**Limitations**

Given the patterns of ERP data, the lack of statistical significance could have been related to the low sample size. Generally, when investigating possible gender differences in cognition, it is important to have a reasonable sample size. For example, Munro et al. (2012) had a total sample of fourteen-hundred and twenty-five to investigate gender differences in various cognitive functions. Given the complexity of ERP studies, it is not feasible for a sample size of this magnitude; however, the addition of more participants (e.g., Gaál & Czigler, 2015, who had seventy-nine participants) may have increased the likelihood of teasing out possible gender differences across all ERP components. In addition, although the color-shape classification task has been established to elicit specific brain wave patterns that represent task switching (Gaál & Czigler, 2015), it may not be the best task switching paradigm to elicit gender differences. Finally, as discussed above, some cognitive gender differences may only emerge in late adulthood (Kray & Lindenberger, 2000; Munro et al., 2012). Given the fact that the current study focused on

only young adults, it was not able to evaluate whether some gender differences on task switching emerge later in life.

**Recommendations of Future Research**

Further research evaluating gender differences related to task switching should pursue a larger participant pool as well as a broader age range. If as research suggests, some gender differences in task switching occur later in life (i.e., Bracco, Bessi, Alari, Sforza, Barilaro, & Marinoni., 2010; Gaál & Czigler, 2015), then a subsequent study may wish to compare possible gender differences in task switching between younger and older adults. In turn, this could also provide a more useful approach to investigating mental decline in executive functions due to gender and aging.

Next, it has also been reported that gender differences across various tasks tend to appear when tasks become more difficult and disappear when tasks are easy (Coluccia & Iosue, 2004). Consequently, utilizing a more complex task-switching paradigm may provide a more accurate picture of gender and task switching. For example, Taleb and Awamleh (2012) added mixing colors and letters to the task switching paradigm which potentially makes task switching more challenging.

**Conclusion**

In conclusion, the current study provides further evidence that there may not be neural differences in task switching due to gender in young adults across all ERP components but only in the N2 component. Further, the results show that there are however potential differences in brain activation patterns. In addition, the specific ERP waveforms elicited in the current study (i.e., N2, P2 and P3b) denote the neural

mechanisms of task switching thus providing further evidence to support the theory that young adults develop an explicit cognitive representation of the task structure which helps them engage in task switching (Gaál & Czigler, 2015). Consequently, the current findings along with findings cited in the literature, allow us to speculate that some of the neural processes in task switching may only change in relation to gender as part of the aging process. Moreover, the topographic distribution differences found in the current study could indicate that brain activation patterns (i.e. spatially) and not necessarily brain activation strength differ across gender in relation to task switching. Finally, the gender difference in N2 amplitude may indicate that males and females utilize separate stimulus evaluation techniques and that there are potential differences in selective attention between genders (Kuptsova et al., 2016).

## Chapter V.

## REFERENCES

Bracco, L., Bessi, V., Alari, F., Sforza, A., Barilaro, A., and Marinoni, M. (2011). Cerebral hemodynamic lateralization during memory tasks as assessed by functional transcranial Doppler (fTCD) sonography: Effects of gender and healthy aging. *Cortex, 47*(6), 750-758. doi.org/10.1016/j.cortex.2010.03.007

Braver, T. S., Reynolds, J.R., and Donaldson, D. I. (2003). Neural mechanisms of transient and sustained cognitive control during task switching. *Neuron, 39*, 713-726.

Chan, R., Shum, D., Toulopoulou, T., and Chen, E. (2008). Assessment of executive functions: Review of instruments and identification of critical issues. *Archives of Clinical Neuropsychology, 23*, 201-216. doi:10.1016/j.acn.2007.08.010.

Cherney, I.D. and Collaer, M.L. (2005). Sex differences in line judgment: Relation to mathematics preparation and strategy use. *Perceptual and Motor Skills, 100*(3), 615-627.

Christakou, A., Halari, R., Smith, A.B., Ifkovits, E., Brammer, and M., Rubia, K. (2009). Sex dependent age modulation of frontostriatal and temporo-parietal activation during cognitive control. *Neuroimage 48*, 223–234.

Coluccia, E., and Louse, G. (2004). Gender differences in spatial orientation: A review. *Journal of Environmental Psychology, 24*(3), 329-340.

Diamond, A. (2013). Executive functions. *Annual Review of Psychology, 64,* 135-168.

doi: 10.1146/annurev-psych-113011-143750.

Dove, A., Pollmann, S., Schubert, T., Wiggins, C.J., and Yves von Cramon, D. (2000). Prefrontal cortex activation in task switching: An event-related fMRI study. *Cognitive Brain Research, 9,* 103-109.

Feng, Q., Zheng, Y., Zhang, X., Song, Y., Luo, Y., Li, Y., and Talhelm, T. (2011). Gender differences in visual reflexive attention shifting: Evidence from an ERP study. *Brain Research, 1401,* 59-65. doi: 10.1016/j.brainres.2011.05.041.

Gaál, Z. A., and Czigler, I. (2015). Age-related processing strategies and go–nogo effects in task-switching: an ERP study. *Frontiers in Human Neuroscience, 9*, 177. http://doi.org/10.3389/fnhum.2015.00177.

Halpern, D.F. (2012) *Sex differences in cognitive abilities* (4th ed.). New York, NY: Taylor & Francis.

Hillyard, S.A., and Kutas, M. (2002). Event-related potentials and magnetic fields in the human brain. In *Neuropsychopharmacology: The Fifth Generation of Progress* (pp. 427-439). Philadelphia, PA: Lippincott, Williams, & Wilkins.

Johnson, W. and Bouchard, T. J. (2007). Sex differences in mental abilities: G masks the dimensions on which they lie. *Intelligence, 35,* 23-39. doi:10.1016/j.intell.2006.03.012.

Karia, R. M., Ghuntla, T. P., Mehta, H. B., Gokhale, P. A., and Shah, C. J. (2012). Effect of gender difference on visual reaction time: A study on medical students of Bhavnagar region. *IOSR Journal of Pharmacy*, *2*(3), 452-454.

Kiesel, A., Steinhauser, M., Wendt, M., Falkenstein, M., Jost, K., Philipp, A. M., and Koch, I. (2010). Control and interference in task switching—A review.

*Psychological Bulletin, 136*(5), 849-874. doi:10.1037/a0019842.

Kray, J., and Lindenberger, U. (2000). Adult age differences in task switching. *Psychology and Aging, 15*(1), 126.

Kuptsova, S.V., Ivanova, M.V., Petrushevskiy, A.G., Fedina, O.N., and Zhavoronkova, L.A. (2016). Sex- and age-related characteristics of brain functioning during task switching (fMRI study). *Hum Physiol 42*(4). 361-370. https://doi.org/10.1134/S0362119716040101.

Luck, S. J. (2014). *An introduction to the event-related potential technique* (2nd ed.). Cambridge, MA: Massachusetts Institute of Technology.

Monsell, S. (2003). Task switching. *Trends in Cognitive Sciences, 7*(3), 134-140. doi:10.1016/S1364-6613(03)00028-7.

Munro, C. A., Winicki, J. M., Schretlen, D. J., Gower, E. W., Turano, K. A., Muñoz, B., ... and West, S. K. (2012). Sex differences in cognition in healthy elderly individuals. *Aging, Neuropsychology, and Cognition, 19*(6), 759-768.

Polich, J. (2007). Updating P300: An integrative theory of P3a and P3b. *Clinical Neurophysiology, 118*(10). 2128-2148. doi: 10.1016/j.clinph.2007.04.019.

Salthouse, T. A., Fristoe, N., McGuthry, K. E., and Hambrick, D. Z. (1998). Relation of task switching to speed, age, and fluid intelligence. *Psychology and Aging*, 13(3), 445-461.

Stoet, G., O'Connor, D.B., Conner, M., and Laws, K.R. (2013). Are women better than men at multi-tasking? *BMC Psychology 1*(18), 1-10. https://doi.org/10.1186/2050-7283-1-18.

Taleb, A., and Awamleh, A. (2012). Gender differences in cognitive abilities. *Current*

*Research in Psychology, 3(1),* 33-39. doi: 10.3844/crpsp.2012.33.39.

Yuan, J., He, Y., Qinglin, Z., Chen, A., and Li, H. (2008). Gender differences in behavioral inhibitory control: ERP evidence from a two-choice oddball task. *Psychophysiology, 45,* 986-993. doi: 10.1111/j.1469-8986.2008.00693.x.

# Chapter VI.

## APPENDICES

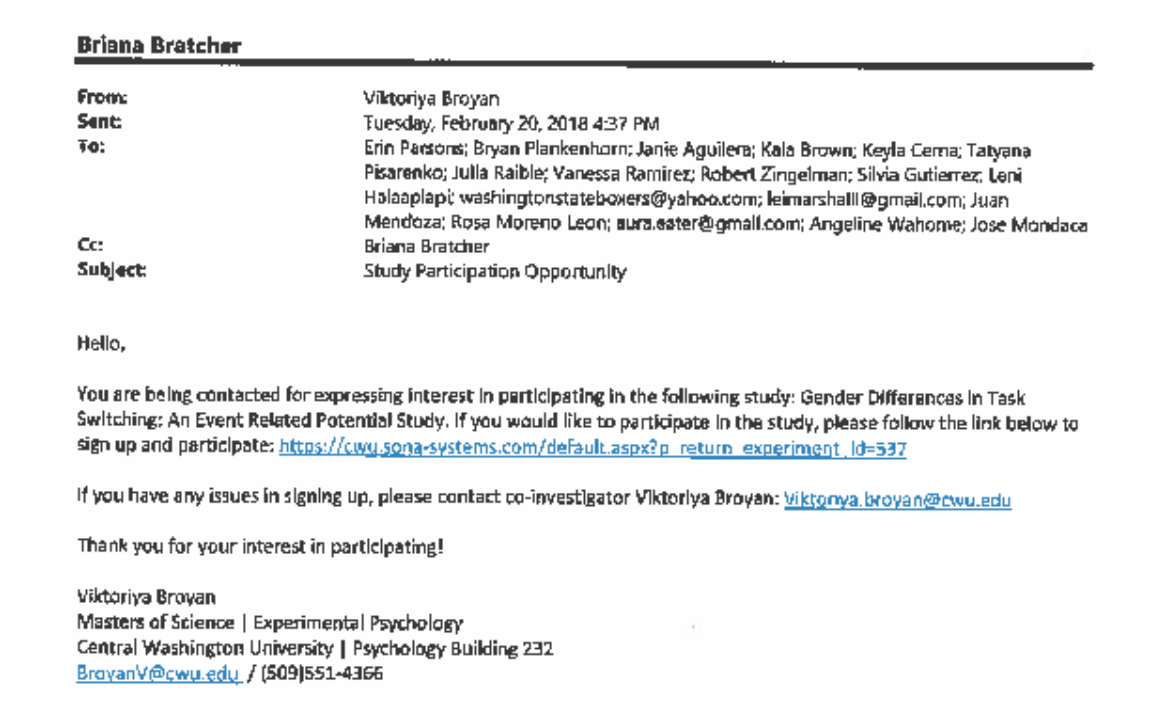
**Appendix A:** Sona Recruitment Description

## Sona Description

**Study Name:** Gender Differences in Task Switching: An Event Related Potential Study
**Description:** This study is designed to gather information about possible differences between male and females in task switching. You must be 18 to 30 years old in order to participate. You will be asked to respond to two visually presented shape and color tasks while wearing an elasticized electrode cap that will record your brainwave activity. A salt-based water solution will be applied to each electrode on the cap (32 in all) in order to insure a proper brain wave recording. You will also be asked to provide information regarding basic demographic information and hand preference. This study should take about 100 minutes to complete.
**Note:** Prior to your participation in our study, your hair should be clean, dry, and without gel, conditioner or hair products. It's also a good idea to bring a hat to wear after the experiment, since there may be some salt-based solution residue in your hair (this will wash out easily with normal shampoo).
Participation is voluntary, and you may withdraw at any time during the study.
**Duration:** 100 minutes
**Points:** 4 Points
**Principal Investigator:**
Briana Bratcher
Email: briana.bratcher@cwu.edu

**Appendix B:** Non-Psychology student recruitment email

STEM Recruitment Email



**Briana Bratcher**

**From:** Viktoriya Broyan
**Sent:** Tuesday, February 20, 2018 4:37 PM
**To:** Erin Parsons; Bryan Plankenhorn; Janie Aguilera; Kala Brown; Keyla Cerna; Tatyana Pisarenko; Julia Raible; Vanessa Ramirez; Robert Zingelman; Silvia Gutierrez; Leni Holaaplapi; washingtonstateboxers@yahoo.com; leimarshall@gmail.com; Juan Mendoza; Rosa Moreno Leon; aura.eater@gmail.com; Angeline Wahome; Jose Mondaca
**Cc:** Briana Bratcher
**Subject:** Study Participation Opportunity

Hello,

You are being contacted for expressing interest in participating in the following study: Gender Differences in Task Switching: An Event Related Potential Study. If you would like to participate in the study, please follow the link below to sign up and participate: https://cwu.sona-systems.com/default.aspx?p_return_experiment_id=537

If you have any issues in signing up, please contact co-investigator Viktoriya Broyan: Viktoriya.broyan@cwu.edu

Thank you for your interest in participating!

Viktoriya Broyan
Masters of Science | Experimental Psychology
Central Washington University | Psychology Building 232
BroyanV@cwu.edu / (509)551-4366

Transcription:
"Hello,

You are being contacted for expressing interest in participating in the following study: Gender Differences in Task Switching: An Event Related Potential Study. If you would like to participate in the study, please follow the link below to sign up and participate: https://cwu.sona-systems.com/default.aspx?p_return_experiment_id=537

If you have any issues in signing up, please contact co-investigator Viktoriya Broyan: Viktoriya.broyan@cwu.edu

Thank you for your interest in participating!

Viktoriya Broyan
Masters of Science | Experimental Psychology
Central Washington University | Psychology Building 232
BroyanV@cwu.edu / (509)551-4366"

## Appendix C: Consent Form



# Central Washington University
# Research Participant Consent Form

**Study Title**: Gender Differences in Task Switching: An Event Related Potential Study
**Principal Investigator:** Briana Bratcher, Graduate Student, Central Washington University, Briana.Bratcher@cwu.edu.
**Faculty Sponsor:** Ralf Greenwald, Ph.D., Associate Professor. Central Washington University Department of Psychology, (509) 963-3630, greenwar@cwu.edu

**1.) What you should know about this study:**

You are being asked to join a research study.
This consent form explains the research study and your part in the study
Please read this carefully and take as much time as you need.
Ask questions about anything you do not understand at any time.
You are a volunteer. If you do join the study and change your mind later, you may quit at any time without fear of penalty or loss of benefits.

**2.) Why is this research being done?**

This research is being done to examine the possible differences between males and females in task switching.

**3.) Who can take part in this study?**

If you are a healthy CWU student, between the ages of 18 and 30, you may qualify to take part in this study. You must be without brain injury or condition, and not be taking medication(s) that might affect responsiveness. To determine eligibility for the study, further screening will be done using questionnaires detailed in item 4 below.

**4.) What will happen if you join this study?**

If you agree to be in this study, you will be asked to do the following:
**Complete two Questionnaires** (approximately 10 minutes)
**a. Participant History Questionnaire**: On this form, you will be asked to provide basic information (age, gender, etc.) and answer questions concerning your brain health and any medications you may currently be taking that could impact the study. If certain medical conditions exist, you may be excluded from participating in this study. In such cases, the principal investigator will notify you immediately.

**b. Hand Preference Questionnaire**: Since handedness has been shown to influence reaction time, the Hand Preference Questionnaire will be used to determine your dominant hand.

**Experimental Tasks:**
**a.) General Overview** (approximately 10 minutes): After completing the questionnaire, verbal instructions will be provided to you about the experimental visual tasks.

**b.) Experimental Visual Tasks** (approximately 70 minutes): You will be escorted to the laboratory where your head circumference will be measured for an electro-cap which measures brainwave activity during the experimental tasks. After the measurement, the cap is placed on your head and adjusted to ensure a good fit. Each electrode site on the outside of the cap will be filled with a water and salt gel. The cap will be adjusted to ensure it is reading brain waves.

After the electrodes are set and responding properly, you will be seated in a chair facing a computer. You will be asked to complete a color-shape classification task on the computer. To familiarize you with the procedure, you will be allowed a practice session for the experimental tasks. The color-shape classification task will have you select stimuli based on color and shape. You will be required to make fast and accurate choices by clicking the computer mouse (using the left or right mouse button). After completion of the experiment, the cap will be removed.
**c.) Debriefing** (approximately 10 minutes):

The principal investigator will ask you a few questions about your experience completing the experimental task.
Total Study Time: 100 minutes
**5.) What are the risks or discomforts of the study?**

There are no known risks to participating in this research. All procedures described in this proposal are considered noninvasive. You may experience mild discomfort or become tired as a result of sitting and staring at the screen; this risk is no more than what you would normally experience in daily life. However, there are several breaks during the experiment and you control the amount of rest time between each trial.
There is a very slight risk of irritation or allergic reaction to the gel used with the cap. However, an allergic reaction is very rare. If you are uncomfortable in any way, we will remove the cap, clean the reaction area, and stop the study. 

**6.) Are there benefits to being in the study?**

There is no direct benefit to you from being in this study. If you take part in this study, you may however help others in the future. Results of this research may enhance our understanding of possible gender difference in brain function.

**7.) What are your options if you do not want to be in the study?**

You do not have to join this study. If you do not join, it will not affect your grade in any class or any of your privileges as a CWU student.

**8.) Can you leave the study early?**

You can agree to be in the study now and change your mind later. If you wish to stop at any time, please let the principal investigator know as soon as possible. Leaving this study early will not affect your standing at CWU in any way. If you leave the study early, the investigator may use information already collected from you.

**9.) Why might you be removed from this study?**

You may be removed from the study if:
a.) You fail to follow instructions.
b.) There may be other reasons to remove you from the study that may come up during the study.

**10.) What information about you will be kept private and what information may be given out.**

Only members of the research team will have access to the original research data collected. The collected data will be locked in the research laboratory. Moreover, research data will be entered into the computer database by a special code. Only the principal investigator and the faculty sponsor have access to the code key which will be kept separately on a password-protected thumb drive. No personal information will be gathered that could link you to your responses. When the study is completed, contact information will be destroyed. Your name will not be used in any written report. Compiled data with all personal identifiers completely removed may be used in future studies, for follow-up analysis, or audited by HSRC or other legally authorized personnel.

**11.) What other information should you be aware of regarding this study?**

This study has been reviewed and approved by the CWU Human Subjects Review Council. You may contact the HSRC if you have questions about your rights as a 

participant, or if you think you have not been treated fairly. The HSRC office phone number is (509) 963-3115.
If you have any questions about this study, contact the principal investigator, Briana Bratcher, at briana.bratcher@cwu.edu, or you can call the faculty sponsor, Dr. Ralf Greenwald, at (509) 963-3630.

**12.) Will you be paid if you join this study?**

You will not be paid. However, if you complete the study, you will be entered into a raffle to win a $100 Amazon gift card. The winner of the gift card will be notified via CWU email. After the gift card is received, all contact information for all participants will be destroyed.

**13.) Will I receive extra credit?**

While extra credit for participation may be offered by some professors if you sign up through SONA, this is up to the professor and is in no way offered or guaranteed by the study.

**14.) What does your signature on this consent form mean?**

By signing this consent form, you are not giving up any legal rights. Your signature means that you understand the study plan, have been able to ask questions about the information given to you in this form, and you are willing to participate under the conditions we have described.

**You have received a copy of this consent form.**

Participant's Name
(print):_____
Participant's Signature: _____ Date _____
Phone Number: _____ Email: _____
Signature of Investigator: _____ Date: _____

**Appendix D: Hand Preference Questionnaire**

Data Code (**lab use only**)

# Brain Dynamics & Cognitive Neuroscience Lab

Central Washington University

## Hand Preference Questionnaire

Please indicate which hand you use for each of the following activities by circling:
**R** for right **L** for left or **E** for either

Which hand orientation would you use:

| | | | |
|---|---|---|---|
| To write a letter clearly? | R | L | E |
| To throw a ball to hit a target? | R | L | E |
| To hold a racket in tennis, squash, or badminton? | R | L | E |
| To hold a match while striking it? | R | L | E |
| To cut with scissors? | R | L | E |
| To guide the thread through the eye of a needle? | R | L | E |
| At the top of the broom while sweeping? | R | L | E |
| At the top of the shovel when moving sand? | R | L | E |
| To deal a deck of cards? | R | L | E |
| To hammer a nail into wood? | R | L | E |
| To hold a toothbrush while cleaning your teeth? | R | L | E |
| To unscrew the lid of a jar? | R | L | E |
| To play your most practiced instrument? | R | L | E |
| To hold a pick while playing guitar (if you play)? | R | L | E |

If you use the RIGHT HAND for all these actions, are there any one-handed actions for which you use the left hand? Please list:

If you use the LEFT HAND for all of these actions, are there any one-handed actions for which you use the right hand? Please list:

Were you born one of TWINS? _____ or TRIPLETS? _____

If yes, please indicate the hand preference of your twin or triplet. _____

If you have children, please indicate the hand preference of your:

First Child _____ This child's other parent _____

Second Child _____ This child's other parent _____

Third Child _____ This child's other parent _____

**Appendix E: Participant History Questionnaire**

_____

Data Code (**lab use only**)

# Brain Dynamics & Cognitive Neuroscience Lab

Central Washington University

## Participant History Questionnaire

What is your age? _____

How do you identify yourself?

- ❑ Male
- ❑ Female

Have you had a concussion, stroke, seizure, or any other traumatic brain injury?

_____

Do you have any conditions, neurological or physiological that could affect reaction time?

(Y/N only) _____

Are you multilingual?

- ❑ Yes
- ❑ No

If yes, please list the languages you are proficient in?

_____

Are you colorblind?

- ❑ Yes
- ❑ No

If yes, what type of color blindness?

_____

Have you taken any pharmaceutical or nonpharmaceutical drugs within the past two weeks?

- ❑ Yes
- ❑ No

If yes, please specify.

_____

Are you currently on any medications that might affect reaction time (ask the researcher if you are uncertain whether or not what you are on might have an effect)? _____

Are you a currently a student?

- ❑ Yes
- ❑ No

If so, please specify your major course of study.

_____

**Appendix F: Debriefing Script**

# Central Washington University
# Research Participant Debriefing Script

**Study Title**: Gender Differences in Task Switching: An Event Related Potential Study

**Principal Investigator:** Briana Bratcher
Graduate Student, Central Washington University,
Briana.bratcher@cwu.edu.

**Faculty Sponsor:** R. Greenwald, Ph.D. Associate Professor. Central Washington University Department of Psychology, greenwar@cwu.edu, (509) 963-3630

---

Thank you for taking the time to participate in our study investigating potential differences in gender regarding task switching. Your data will be kept on a password protected hard drive and names will be coded to protect participant's identity. Your data will contribute to the completion of the principal investigator's master's thesis examining differences in task switching and responsiveness between males and females. Previous research has demonstrated cognitive differences in gender for several areas of executive function, however there is little research involving task switching and responsiveness in males and females.

The tasks completed in the study will be used to measure responsiveness to task switching by looking at event related potential data gathered from the electroencephalograph (EEG). If you have any questions about the methodology, purpose, or research implications please feel free to email: Briana.Bratcher@cwu.edu.

Once again thank you very much for taking the time to participate in my research and be a part of scientific inquisition. Have a great day!

**Appendix G: Participant Debriefing Form**

_____
Data Code (**lab use only**)

# Brain Dynamics & Cognitive Neuroscience Lab
# Central Washington University

## Study Debriefing Form

*This form is to be filled out by the experimenter. Please follow the steps outlined in the debriefing script.*

Date: _____
Study:_____

_____
Experimenter Initials

**Overall, how difficult was the task(s)?**

Easy _____ OK _____ Difficult _____ Very Difficult _____

Explain:

_____

_____

_____

_____

**What (if any) strategies did you use?**

_____

_____

_____

**Was one task easier than the other?**

_____

_____

_____

**Additional Comments:**

_____

_____

_____

_____

_____