Gender and Color Specific Differences in Event Related Potentials

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Gender and Color Specific Differences in
Event-related Potentials

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A thesis submitted to the faculty of
Brigham Young University
In partial fulfillment of the requirements for the degree of

Master of Science
in Neuroscience

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ABSTRACT

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Master of Science
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This project analyzed gender and color-specific differences in event-related potentials (ERPs). Previous studies have shown that males process color differently than females. In a recent study, sex differences were found in ERPs during a visual object recognition task. There were higher EEG amplitudes in females (especially P300) than males. Significant sex and color-specific differences have been found in diseases involving altered dopamine (DA) machinery. Thus, we analyzed differences between ERPs in males vs females during a color task. We also compared the color-specific differences in ERPs between males and females. Males and females participated in EEG recording sessions for 2 color studies during a color-go-no-go task, where two studies examined the gender and color-specific differences in ERPs, respectively. Data from 32 males and 24 females and 21 females and 31 males, respectively, in two color studies demonstrated significant sex-specific differences in ERPs during a color-go-no-go task. Males consistently showed higher EEG amplitudes (particularly P300) than females, which is contradictory to what we demonstrated previously in the object recognition task, indicating different color processing systems in males and females. Regarding color-specific differences, no significant differences were found in P300s between the three colors red, green and blue in males and females when each color was the relevant stimulus, suggesting that color is not a marker for inducing ERPs in normal subjects. These studies will provide the impetus to compare patients having altered DA mechanisms such as in attention-deficit hyperactivity disorder (ADHD), Parkinson’s, or chemical addiction.
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Introduction

Visual Information processing

Visual information processing is how visual information from the eyes is interpreted and processed by the brain. It involves visual attention which examines how cognitive and neural components interact to select certain information and inhibit other information for further internal analysis (Geng & Behrmann, 2003). Within this broad area many theories have been developed regarding how meaningful visual information is discriminated from distracting stimuli. The Feature Integration Theory (FIT) was originally developed by Treisman to account for how visual processing of information occurs. It proposes that information must initially meet certain target criteria before it is selected for further evaluation (Geng & Behrmann, 2003). Treisman expanded her original explanation of FIT to account for separate attention parallel coding procedures (1994). For example, when participants were given advanced location information, they use an “attention window” to narrow their visual field by selectively searching a specific location; when given advanced information regarding relevant stimuli, participants use inhibition to disregard irrelevant stimuli and make their selection; and when participants are not given any advanced information, they choose an area within their visual field to serially scan until the target stimulus is found.

An interesting phenomenon that occurs in visual attention mechanisms is the “pop-out effect”. This automatic response takes place when an object within the visual field has characteristics which make it unique from surrounding objects, often called “distracters”. This contrast results in the object “popping-out” from the distractors and immediate attention is focused on the unique item (Krummenacher & Müller, 2005). Wolfe (2003) has argued that
preattentive processes (such as those which result in the pop-out effect) rely on categorical information and enable quick identification of potential objects in a visual scene for more comprehensive analyses. In other words, preattention does not occur independently of normal selective attention processes, but works to enhance the overall search mechanism.

A recent study (S. C. Steffensen et al., 2008) examined event-related potential gender differences of the pop-out effect using a visual object recognition task. Subjects were asked to distinguish between relevant (diamond shaped), standard (right-facing arrows), and irrelevant (a diamond with a line through it) stimuli presented in a matrix fashion. Results supported previous studies indicating that P300 amplitudes are greater in females than males, but indicated that N400 amplitudes associated with a distracting stimulus were a more sensitive index of gender differences. Another similar study (Nash 2009) found similar sex specific differences in event related potentials as previous studies having higher EEG amplitudes for females than males in object recognition task.

**Dopamine & Visual Processing**

Dopamine (DA) plays an important role in visual processing, as suggested by various past studies. It has been found in amacrine cells in the mammalian retina and serves as an inhibitory neurotransmitter (Kramer, 1971; Roman, Rohde, & Hutz, 2004). Dopamine plays an important role in visual attention by virtue of its innervation of the basal ganglia and helps in formation of visual working memory (Vitay et al. 2008). A role for DA in visual attention has been demonstrated where lesioning of midbrain DA neurons reduces the attentive component of behavior (Ljungberg & Ungerstedt, 1976). It has been shown that discrimination along the blue-yellow axis (compared to the red-green axis) is particularly impaired in various disorders.
involving altered DA mechanisms. Thus, specific blue-yellow color vision disturbances are found in Tourette syndrome (Melun, Morin, Muise, & DesRosiers, 2001), Parkinson's disease (Buttner, Kuhn, Muller, Patzold, Heidbrink et al., 1995; Haug, Kolle, Trenkwalder, Oertel, & Paulus, 1995; Pieri, Diederich, Raman, & Goetz, 2000; Sartucci et al., 2003), and Huntington's disease (Paulus et al., 1993). Changes of retinal DA levels arising from cocaine-withdrawal (Desai, Roy, Roy, Brown, & Smelson, 1997; A. Roy, Roy, Berman, & Gonzalez, 2003; M. Roy, Roy, Smelson, Brown, & Weinberger, 1997) and normal aging (Bannon et al., 1992; Djamgoz, Hankins, Hirano, & Archer, 1997) have been associated with blue-yellow color vision losses.

**Dopamine & Behavioral Disorders**

The neurotransmitter dopamine has been implicated in many ADHD pathophysiologies. Researchers believe that a large majority of ADHD arises from a combination of various genes, many of which affect the DA transporter (Roman et al., 2004). In ADHD subjects, significant impairments have been found in speeded naming of color stimuli especially blue-yellow color discrimination (Banaschewski et al., 2006). One hypothesis states that there may be a CNS deficiency of retinal DA, which causes the low performance of ADHD subjects in processing of short wavelength (blue) color. Normalization of central DA functioning via pharmacological intervention with psychostimulant medication normalizes retinal DA, which in turn normalizes blue-yellow color perception and performance on tasks requiring speeded color naming (Tannock, Banaschewski, & Gold, 2006).
Gender and Color Differences

Profound differences have been found in visual processing systems in males and females. The rods and cones within the retina are structurally different in the male and female eyes (Cowey & Stoerig, 2001; Sumner, Anderson, Sylvester, Haynes, & Rees, 2008). The rods are more numerous and are more sensitive than the cones. However, they are not sensitive to color. They are responsible for our dark-adapted vision. There are approximately 18 times more rods than cones in the human eye (see Kolb, Fernandez, & Nelson, 2009 for information on the retina and visual processing). Cones provide the eye's color sensitivity and they are responsible for all high resolution vision. Both rods and cones send their signals to bipolar cells and then to ganglion cells in the direct retinal pathway. Some ganglion cells are large while others are small. However, they have different functions. The large cells are wired to rods and are sensitive to motion (Fried & Masland, 2007). The male retina has mostly these larger, thicker M (magnocellular) ganglion cells, and can track objects anywhere in the field of vision (see Vaegan & Hollows, 2006). The smaller cells (cones) answer the questions, "What is it, and what are the colors and textures?" The female retina has predominantly the smaller, thinner P (parvocellular) ganglion cells which are concentrated in and around the fovea, the center of the field of vision (Vanni, Henriksson, Viikari, & James, 2006). The male eye structure is geared to motion, therefore looking out the window or out the classroom door, watching the classroom action, and anything moving will catch boys’ attention (see Cowan et al., 2000; Okun & Lampl, 2008; Roussos, Giakoumaki, & Bitsios, 2009; Wager, Phan, Liberzon, & Taylor, 2003). Kovalik (2008) thought this may be a key element in understanding why males have the high rate of being diagnosed with ADHD.
There are significant gender-specific differences in the prevalence of disorders involving altered DA mechanisms and color vision disturbances along the blue-yellow axis. ADHD diagnosis is found approximately 2.5 times more frequently in males than females ("Mental health in the United States. Prevalence of diagnosis and medication treatment for attention-deficit/hyperactivity disorder--United States, 2003," 2005). Several studies have found male preponderance of Parkinson’s disease in European countries and in the United States (G F Wooten et al. 2004), (Kuopio, Marttila, Helenius, & Rinne, 1999), (Mayeux et al., 1995). Studies have found sex-specific variations in DA receptor density (Andersen & Teicher, 2000) and DA turnover. (Walker, Rooney, Wightman, & Kuhn, 2000).

We have previously demonstrated that females have larger event-related potentials (ERPs), in particular the P300 component of the event-related potential, than males, in an object recognition task. (S. C. Steffensen et al., 2008). Another study on event-related potentials suggest a gender-related differential processing during the performance of a visual-spatial attention task (Vaquero, Cardoso, Vazquez, & Gomez, 2004). Research focusing on color-specificity of retinal abnormalities in cocaine-withdrawn subjects have revealed that the blue cone electroretinogram (M. Roy et al., 1997), and blue-yellow color perception (Desai et al., 1997), are reduced compared to measures observed during red-green stimulation. Further significant sex differences has been found in visual cortical response to blue light, but not red light, and are correlated with sex-specific differences in DA function, suggesting blue/yellow light response may have utility as a non-invasive marker for DA function (Cowan et al., 2000).
Rationale for the study

As there are marked differences in visual processing in males and females, we have previously demonstrated notable sex-specific differences in ERPs on a visual object recognition task, and since males appears to process color differently than females, we evaluated sex-specific differences in ERPs on a color go-no-go task. Also, since significant differences were found in specific-color processing in males and females, we evaluated the role of specific colors (e.g., Red/Green/Blue) as relevant stimuli in modulating ERPs.
Methods

Participants

45 female and 63 male participants were recruited from Brigham Young University undergraduate psychology and neuroscience classes for two color studies. Both female and male participants were asked to participate in a single EEG recording session presented with the same tasks. Participants were screened to ensure they were in good overall health with no personal history of physiological or psychological disorders, as well as drug use or color blindness. Color blindness was determined by using the modified L’Anthony 15 Hue Test. Each participant was compensated with a $5.00 BYU bookstore gift certificate and a food treat. Behavioral (i.e., psychometric tests, visual processing responses, reaction time) and physiological responses (i.e., EEG) were recorded during a color go-no-go task (see below). All members of the research team complied with BYU-IRB regulations and all data collected were handled with confidentiality, as per IRB approval.

Procedure

We extended the results of the visual object recognition tasks used by Steffensen et al., (2008) and by Nash (2009) to determine if there are significant gender differences in a color recognition task. Participants completed a similar visual attention “pop-out” paradigm to the one described by Steffensen et al., (2008) and Nash (2009) except instead of objects, colors were presented. The visual stimuli consisted of three randomly-presented screens of one solid-color each. For the first study, a blue screen served as the target “Relevant” (Roman et al., 2004) stimulus, while red and green screens served as “Irrelevant” stimuli. The first study was
performed on a 64 channel EGI Geodesic EEG system (Fig. 1). For the second study, the behavioral paradigm was identical but was performed on a 128 channel EGI Geodesic EEG system. The second study also consisted of a comparison between colors as Relevant stimuli. The Relevant and Irrelevant stimuli appeared randomly, and at 2-4 sec randomized intervals during each of the EEG sessions. Subjects were instructed to press a key pad button when the Relevant stimulus was randomly presented, but to not respond when the Irrelevant stimuli were presented. The averaged VEP waves in both male and female participants consisted of multiple components which were identified by their respective positions on the waveform, relative to the time of stimulus presentation (the dashed vertical line in Fig. 3 represents the time of presentation of the visual stimulus). Seven distinctive alternating positive/negative peaks on the VEP waveform were identified, which occurred at characteristic latencies from the time of stimulus presentation. Early and late peaks of the VEP were identified according to established convention and were labeled P100, N100, P200, N200, P300, late negative (LN), and late positive (LP). The parietal and occipital electrode sites evinced the most well-defined combination of early (i.e., task-independent) and late (task-dependent) components of the VEP. Positive voltage was plotted above baseline; negative was plotted downward. Regarding the individual electrode position on the head: F = frontal; C = central; T = temporal; P = parietal; and O = occipital. Reaction time (RT) was measured from the time of visual stimulus presentation to the time the participant pressed the key to respond to the Relevant stimulus. Participants were shown their RT (measured with 1 msec precision) when they responded to the Relevant stimulus and an ‘Incorrect’ when they responded to the Irrelevant or Standard stimuli. E-Prime software (Pittsburgh, PA) was used to run the visual attention task and the stimuli were presented on a PC-type computer screen. Net Station software was used to acquire and analyze the EEG data.
Visual evoked potentials (VEPs) were acquired in 1-sec epochs during each visual stimulus presentation; beginning 100 msec prior to and ending 900 msec after each stimulus presentation. Each participant’s EEG session data was filtered using a 0.3-45 Hz band pass filter and sampled at 250 Hz on-line. NetStation software was used off-line to segment the data, reject artifacts, mark bad channels and remove ocular movements. Averaged data was obtained using an adaptive mean method and the reference electrode was adjusted during the off-line analysis. Finally, baseline correction was used beginning at 100 msec before stimulus presentation. The latency and amplitude were measured for each of the peaks of the within-subject averaged VEP components N50, P100, N100, P200, N200, P300, LN, and LP. **Figure 1** shows the 64 channel EGI sensor net configuration and **Figure 2** shows the electrodes of the 10-20 system taken from the 64 channel sensor net and the grouping of electrodes for statistical analysis.

*Figure 1. Electrode configuration for 64-channel EEG sensor net.* The 128 channel net is similar but with electrodes distributed in a more dense configuration.
Figure 2. Electrode position array for a 10-20 montage. The 10-20 system electrodes were extracted from the 64 (Study 1) or 128 (Study 2) channel sensor net. For statistical analysis, we combined electrodes into natural configurations based on our observations of potential distributions (see Figures below). Cz was the reference electrode (shown in white). Electrodes in pink, brown and yellow were combined to represent front, middle, and back of the head, respectively.
Results

Differential Modulation of Event-related Potentials to Relevant Color

As we have demonstrated previously in an object recognition task, the late components of VEPs were differentially modulated by response selection in the color recognition task. **Figure 3** shows a representative example of averaged ERP’s recorded from a male subject associated with the presentation of color stimuli in this go-no-go task. The insets above the montage in **Figure 3** show the 3 color screens that were randomly presented at 2-4 sec intervals during the 12 min recording session (i.e., Relevant, Irrelevant, and Standard stimuli). Note that a P300 wave is produced in association with the Relevant (Blue screen) stimulus and not the Irrelevant (red or green), while P100s and N100s were produced by all visual stimuli. The P100, N100, P300 and LN components are labeled in **Figure 3**. Subjects were instructed to press a key pad button when the relevant stimulus was randomly presented, but to not respond when either the Irrelevant or Standard stimuli were presented. VEPs elicited by Relevant, Irrelevant, and Standard stimuli are superimposed at each electrode site of the 10-20 system. The VEPs at electrodes in the back of the head were characterized by conventional waveform components including the N50, P100, N100, P200, N200, and P300. We also characterized and analyzed two less-known potentials including the Late Negative (LN) and Late Positive (LP). The LN is evident in the back of the head while the LP is negligible on the back of the head but prominent in the front. The parietal and occipital electrode sites evinced the most well-defined combination of early (i.e., task-independent) and late (task-dependent) components of the VEP. While the early components (i.e., N50, P100, N100, P200 and N200) of the averaged VEP waveforms were relatively unaffected by type of visual stimulus presented, the late components of the averaged VEP waveforms (P300 and LP) evinced significant amplitude differences across stimulus
The amplitude of the P300 component of the waveform appeared to be much greater in association with the Relevant stimulus than with Irrelevant and Standard stimuli, in particular at occipital and parietal locations.

Figure 3. Visual Evoked Potentials in 10/20 International System Montage during a color go-no-go task in a male subject. (A) Blue Square corresponds to relevant stimulus and a montage of visual evoked potentials (VEPs) from electrodes in the 10-20 System extracted from the 64 channels of the EEG sensor net. (B) Enlarged and scaled representation of overlaid waveform data obtained at electrode P4 for red, green, and blue stimuli. The reaction time for this subject to respond to the relevant stimulus (Blue color) is also shown.
**Gender-specific Differences in Event-related Potentials in a Color Task**

Figure 4 shows grand-averaged VEPs obtained in male and female subjects in the color go-no-go task. Grand averaged VEPs are shown for Pz and Fz in males (Fig. 4A; n=31) and females (Fig. 4C; n=21). The colored plots in each graph correspond to their respective Red, Green and Blue stimuli. The subject was asked to respond to the Blue stimulus and to not respond to the Red or Green stimuli. Thus, the Blue stimulus was the Relevant stimulus. Note that at each recording site that responding for Red, Green or Blue produced nearly identical early components of the VEP. However, the later components (beyond 150 msec) were differentially modulated by the Subject’s response to the Blue stimulus. In particular, around 300 msec (i.e., P300) the VEP shows a response that is markedly different from that produced by either Red or Green stimuli. Even closer inspection reveals subtle differences between male and female P300 responses in association with responding for the Blue stimulus. Indeed, the P300 at the Pz site is significantly larger in males than females which are evident in the topomaps for males (Fig. 4C) and females (Fig. 4D). The topomaps show color weightings of potentials recorded at all 64 electrode sites for first color study (Fig. 4) and at 128 electrodes for the 2nd color study (Fig. 5). Note that the topomaps for the Relevant stimulus differs considerably from Irrelevant stimuli, evincing strong signals across parietal and occipital regions. Red color in topomaps corresponds to positive waves (P100, P300) and Blue color in topomaps corresponds to negative waves (N100). In both color studies there are significant differences in male and female ERPs, especially in the P300 component. These results are opposite to that reported previously using an object recognition task. In addition, in the second color study we found consistent Frontal Late Positives (LP) around 600 msec which shown different modulations to relevant stimuli as it
has been shown in various previous studies that they are elicited by deviant stimuli. There were no significant differences between males and females in eliciting LP. Figure 5 shows grand-averaged VEPs obtained in male and female subjects in the second color go-no-go task, results were similar to those from the first color task.
Figure 4. Visual Evoked Potentials in males and females during a first color go-no-go task
Figure 5. Visual Evoked Potentials in males and females during a second color go-no-go task
**Statistical analysis**

While the grand averaged VEPs and topomaps demonstrated differences between responses obtained with the Relevant stimulus (i.e., Blue color) and the Irrelevant stimuli and also between males and females for the Relevant stimulus, averaging often underestimates the significance of the effects due to temporal dispersion and other vagaries. Thus, we measured each component of the VEP in each subject and obtained individual measurements. These measurements were then submitted to statistical analysis. The independent variables were gender, 18 electrode locations of the 10-20 System and color, while the dependent variables were VEP component. As shown in the methods (Fig. 2), to simplify the analysis, we lumped the 18 electrodes into front, middle and back of the head. The statistical analysis of the first color study (Fig. 6) represents amplitude means of individual ERP components at front, middle and back electrodes for males and females. At frontal electrodes males have significantly higher P200 amplitudes in Relevant stimuli as compared to Irrelevant. Although its functional significance is not well-understood, researchers believe that it seems to represent some higher perceptual processing which is modulated by attention. Studies have shown large anterior P200 amplitudes in response to target stimuli in visual research paradigm (Luck & Hillyard, 1994) which support our findings. The N200 Component has been described as a mismatch detector which is elicited by deviant stimuli (Naatanen, Gaillard, & Mantysalo, 1978). Our studies have shown significantly large N200 amplitudes to the Relevant stimulus in both males and females at frontal electrodes, suggesting their property of detection of mismatch and novelty. Like N200, LPs were found significantly higher in males and females in response to relevant stimuli. There were no significant differences between individual components at electrodes representing the middle of head. As expected, there were higher P300 amplitudes at the back of head in both males and
females in response to Relevant stimuli. Males clearly expressed higher event-related potentials, especially the P300 and P200 components (Fig. 7).
Figure 6. Statistical analyses of first color study (A) These are mean VEP amplitude measurements obtained from 32 males in the front of the head. Note that the P200 and N200 amplitudes were significantly greater in relevant stimuli. (B) These are mean VEP amplitude measurements obtained from 32 males in the middle of the head. (C) These are mean VEP amplitude measurements obtained from male subjects in the back of the head. Note that the P300 amplitudes were significantly greater in relevant stimuli. (D) These are mean VEP amplitude measurements obtained from 24 females in the front of the head. Note that the N200 amplitudes were significantly greater in relevant stimuli like male subjects. (E) These are mean VEP amplitude measurements obtained from 24 females in the middle of the head. (F) These are mean VEP amplitude measurements obtained from females in the back of the head.
Figure 7. Amplitude mean of P200 and P300 ERP components in males and females (blue bars represent males and pink females). Males had significantly higher P200 amplitudes in the front of the head and P300 amplitudes in the back.

Reaction Time

Reaction times were measured for each subject in the color study. It was measured from the start of the Relevant stimulus to the time of responding. The subjects having error rate of responding for the relevant stimuli more than 10% were rejected from analysis. Figure 8 compares the reaction times (RTs) in male and female subjects. Reaction times were approximately 300 msec in male subjects and 340 msec in females. Surprisingly, the RTs for females were significantly longer than males ($P<0.03$, $t_{(2,35)}=2.3$).
Figure 8. Females have longer reaction times than males.

Color specific differences in event-related potentials

Figure 9 shows topographs depicting superimposed VEPs recorded at Fz, and Pz electrode sites for males and females and topomaps showing superimposed VEPs recorded at 128 electrodes on a color task where all three colors red, green and blue served as Relevant stimuli for each subject. Topographs and topomaps clearly show no differences in event-related potentials between three colors as Relevant stimuli. Red, green and blue colors equally elicited ERPs and there were no differences between the three colors across male and female groups. Moreover, as in first and second color studies, males expressed higher ERP amplitudes, especially P300, than females, which is clearly demonstrated in both the topomaps and topographs.
Figure 9. Visual Evoked Potentials in males and females showing color specific differences
Discussion

Grand Average ERP’s

In the color go-no-go task, ERPs were differentially modulated by relevant color stimuli, which supports our previous studies on an object recognition task that relevant stimuli elicit ERP’s (S. C. Steffensen et al., 2008). There was no effect of relevant stimuli on VEPs like N100, P200 etc. Our studies also provide further evidence that ERPs, especially P300, is elicited by task-related odd-ball stimuli and is maximum at parietal scalp positions. (Sutton, Braren, Zubin, & John, 1965) Selective attention is the ability to pay attention to those things that are considered important and to ignore those that are not. Different studies have been done to understand this process, filtering theory (Broadbent, 1957) and resource theories according to which system allocates more resources to process information coming through particular attended channel than unattended channels. (Norman & Bobrow, 1975). Event related potentials, especially P300, have been associated with selective attention, and the amplitude of the P300 is proportional to the amount of attentional resources engaged in processing a given stimulus. (Johnson, 1984). Another ERP component that was differentially modulated by relevant stimuli was LP. Like P300, LP is expressed to a larger extent with Relevant stimuli. One main difference between LP and P300 was their location of maximum expression. While P300s were more expressed in parietal scalp regions, LP was dominant in frontal scalp regions. A definitive consensus regarding P300 functional meaning has not yet been reached (Knight, 1997), possibly because it is a component generated by multiple sources that reside in cortical structures (prefrontal dorsal-lateral and parietal-temporal cortex) and other sub-cortical structures.
Gender-specific differences

Genetic, physiological, and behavioral processes have been studied for gender differences. However, psychophysiological studies concentrated on ERP’s showing gender-specific differences are rare. As it has been discussed in various studies that there are significant differences in visual processing systems of males and females and male brain respond differently to visual stimuli than female brain. (S. C. Steffensen et al., 2008), (Nash, et al; 2009). In our study we found females have significantly longer reaction times than males on a color task. Another finding was the RTs for males and females in this study were shorter than what we have previously seen in the object recognition task. This might be because of intricate nature of task in object recognition paradigm. In a similar study RT was found to be slower in females than males on a object recognition task but results were not statistically significant.(Vaquero et al., 2004).

Regarding gender-specific differences in ERPs, we found significant results indicating males have higher ERP amplitudes in the both studies as compared to females. These findings were contrary to previous work in our lab on visual object recognition task (S. C. Steffensen et al., 2008) where females consistently have higher ERPs, especially the P300 component, which is typically observed in response to rare, meaningful stimuli, often called “oddball” stimuli, and is maximum at parietal scalp positions (Sutton et al., 1965). The amplitude of the P300 is proportional to the amount of attentional resources engaged in processing a given stimulus.(Sirevaag, Kramer, Coles, & Donchin, 1989). Also they demonstrated that P300 amplitude to primary task events increases with cognitive resource demands. As the amplitude of P300 is related to processing resources demanded by the task, so a higher amplitude in males may be related to involvement of more processing resources as compared to females in
performing a task in color processing. Another study on ERPs suggests a gender-related differential processing during the performance of a visual-spatial attention task (Vaquero et al., 2004). In this study they found higher P300 amplitudes in males as compared to females on a visual object recognition task. They were more concerned with P100 early VEP component which has been characterized as spatial and extrastriate contralateral to visual field of stimulus, also had higher amplitudes in men, supporting many other proposals which indicated better visual-spatial abilities in men than women (Kimura, 1992). However, in this study, only 13 electrodes were recorded as compared to our 64 and 128 electrode recordings (in two studies). Similarly, (Oliver-Rodriguez, Guan, & Johnston, 1999) looked at facial attractiveness and the emotional component and found that P300 amplitudes were greater in male participants. There are inconsistencies among results of gender differences in ERPs, however it is apparent that there are significant differences between visual processing systems of males and females and ERPs are sensitive to gender. Some studies have tried to explain these differences. One hypothesis that has been proposed explains that head size and geometry may account for more of the difference between gender VEPs than actual biological and physiological differences (Guthkelch, Bursick, & Sclabassi, 1987). Other theories explain these gender-specific differences in ERPs with hemispheric asymmetry across genders (Roalf, Lowery, & Turetsky, 2006). Further both males and females expressed LP in response to relevant stimuli and there was no significant difference between males and females on account of LP, unlike P300.
**Color-specific differences**

There is vast literature which supports the notion that males process color differently than females and there are differences between genders on color perception abilities. Studies have found significant sex differences in visual cortical response to blue light, but not red light and correlated that with sex-specific differences in DA function suggesting blue/yellow light response may have utility as a non-invasive marker for dopamine function (Cowan et al., 2000). Color identification abilities were measured across genders and have found that females significantly express more elaborate colors than males (Greene & Gynther, 1995). Another study found that females are more responsive to the long-wave region of the frequency spectrum than males (McGuinness & Lewis, 1976). In our second color study we tried to find differences between red, green and blue color relevant stimuli on modulating ERPs. All three colors equally expressed ERPs and there was no difference in male or females subjects between three different colors. Although we again found higher ERPs in males as compared to females in each color task as relevant stimuli. This indicates that color is not a marker of eliciting ERPs in normal subjects, but it is the relevancy of colors in the go-no-go task which elicited the ERPs.

Research in subjects having altered DA machinery as in ADHD, Parkinson’s disease, and chemical addiction, have found consistent gender and color-specific differences. ADHD diagnosis is found approximately 2.5 times more frequently in males than females ("Mental health in the United States. Prevalence of diagnosis and medication treatment for attention-deficit/hyperactivity disorder--United States, 2003," 2005). Similarly, studies have found male preponderance of Parkinson’s disease in European countries and in the United States (G F Wooten et al. 2004), (Kuopio et al., 1999), (Mayeux et al., 1995). It has been shown that discrimination along the blue-yellow axis (compared to the red-green axis) is particularly
impaired in various disorders involving altered DA mechanisms. Thus, specific blue-yellow color vision disturbances are found in Tourette syndrome (Melun et al., 2001), Parkinson's disease (Buttner, Kuhn, Muller, Patzold, & Przuntek, 1995); (Haug et al., 1995) and Huntington's disease (Paulus et al., 1993). Changes of retinal DA levels arising from cocaine-withdrawal (Desai et al., 1997; A. Roy et al., 2003; M. Roy et al., 1997) and normal aging (Bannon et al., 1992; Djamgoz et al., 1997) have been associated with blue yellow color vision losses. Furthermore, in another study, delay in VEPs have been found in Parkinson’s disease and these abnormalities have been corrected by levodopa preparations (Bodis-Wollner & Yahr, 1978).

Much research supports gender and color-specific differences in DA altered conditions. Although our studies didn’t find any significant differences in event-related potentials with red, green and blue as relevant stimuli in normal subjects, it will be interesting to compare subjects having altered DA machinery on ERPs having red, green and blue as relevant stimuli to see how they perform across three different colors. Also, it will be interesting to compare normal subjects with ADHD and Parkinson’s subjects for ERPs across gender & color. In addition to ERPs, one can also include other standardized color processing tests like Color detection tests, Color binocular rivalry test and Hue tests to make more inferences.
Study Limitations

We used ERPs to elucidate visual processing system differences in males and females on a color task. Use of standardized color tests (Color detection test, Color binocular rivalry test and Hue tests) along with ERPs will help in better understanding color processing mechanisms in males and females. As our study was focused on color processing we had to exclude participants that were color blind.
Conclusions

Our studies have found significant gender-specific differences in ERPs on a color task where males predominantly showed higher ERPs, especially P300s, compared to females. These results were contrary to a previous study in our lab where females have higher ERP amplitudes than males on a visual object recognition task. We didn’t find effect of any particular color on modulating ERPs, as all three colors as relevant stimuli equally expressed P300 amplitudes. Further studies incorporating standardized color tests along with ERPs will help in better understanding color processing mechanisms across gender and color in normal subjects and in subjects having altered DA neurotransmission.
References


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EDUCATION

Master of Science (Neuroscience), Brigham Young University, Provo, UT  
Sept. 2007 - Dec. 2010

- Project Title: “Color and Gender Specific Differences in Visual Evoked Potentials”
- Participated in Annual Neuroscience Conference at San Diego in Nov. 2007
- GPA- 3.3/4.0

Bachelor of Veterinary Sciences, GADVASU, Ludhiana, India  

- Major: Veterinary Sciences  
- Minor: Animal Sciences  
- 6 month rotatory internship in small animal medicine and surgery  
- GPA-4.0/4.0

Certifications/Standardized Tests -

- Enrolled in ABRET Certification Program  
- North American Veterinary License Exam  
- Member of Society of Neuroscience  
- Punjab State Veterinary Practitioner’s License  
- Member of Punjab Science Congress  
- TOEFL -250/300  
- GRE -1330/1600

WORK EXPERIENCE & SKILLS

EEG Research Assistant, Brigham Young University, Provo, UT  
Jul. 2008 – Present

- Prepare participants (Measuring of head size and putting on suitable Geodesic sensor net)  
- Recording EEG’s in three projects on Visual Evoked Potentials  
- Utilize E-prime program to run visual attention task  
- Acquire and analyze data with Netstation software including designing scripts  
- Compute Grand averages of males and females and comparison of topomaps and topographs  
- Statistical analysis of data with both SAS application and statistical calculations in Microsoft excel  
- Exporting files to IGOR Pro and making presentable figures and graphs for journals & papers  
- Evaluate results and comparison with previous studies in the field of Neurophysiology

Neuroscience Teaching Assistant  
Fall 2009, Winter & Fall 2010

- Identified and aided 25 + struggling students with coursework  
- Prepared rat brain slices for class with help of Cryostat-Microtome  
- Responsible for supporting class teachers in grading, photocopying and other support tasks  
- Advising students after class hours regarding coursework, answer their questions and help them prepare for exams

Research Assistant (Lab rotations), Brigham Young University, Provo, UT  

- Participated in project related to early perceptual learning and cognitive development in infants  
- Organized the participants (Parents) including filling up consent forms, answering relevant questions  
- Conducted Audio-visual taping experiments and recorded the results  
- Performed Intravenous catheterizations in rats
• Recorded in vivo from GABA containing neurons in the VTA in freely moving rats
• Executed PCR & Western Blotting Techniques

**INTERESTS**

• EEG Research
• Evoked Potentials
• Neurophysiology

**SCHOLARSHIPS**

• Neuroscience Graduate Scholarship
• Various TA & RA stipends
• Tuition Scholarships