Original article:

Gender Influences on Colour processing: An event related potential (ERP) study

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Abstract

Background*:** We assessed cognitive function by using different colours. Colour has been used in different neuropsychology tests for diagnostic and therapeutic purposes. ***Purposes: As male and female hormones are different, it is important to investigate the effect of different colours on the male and female groups for planning their therapeutic strategy in different diseases. ***Methods:*** This prospective study was done between 2012 and 2014. We used the 128-sensor net for an event related potential (ERP) study in male and female groups (n= 22 in each group). Different colours were used as stimuli. Subjects pressed 'button 1' when they liked the colour and 'button 2' when they disliked it. Reaction time (RT) and differences in like and dislike stimuli were analysed. The values of the mean differences of like and dislike stimuli were calculated using a 10-20 electrode system of 19 electrodes. The amplitudes and latencies of the N200 and P300 ERP components were analysed. ***Results:*** No significant differences were found in the mean differences of the amplitudes and latencies of the N200 and P300 ERP components between the male and female groups across 19 electrode sites. RTs were non-significantly longer in the male group. However, colour reflected on the frontal-right occipital area in the female group and the frontal-left occipital area in the male group. ***Conclusion:*** There might be a possibility of delayed decision-making due to difficulty assessing emotion in the male group compared with the female group.

Keywords: Colour; Male; Female; Cognition; Like; Dislike.

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Introduction

Different colours were used as a diagnostic tool in neuropsychology fields to detect cognitive deficits that are important for the therapeutic plans for the patients. The Weigl Colour-Form Sorting Test[1], Wisconsin Card Sorting Test (WCST), Stroop Test [2, 3] and others use different colours for diagnostic purpose. Colours are also used in the 'Ishihara chart' for the colour deficiency test [4, 5]. In addition, colour therapy can be used for cancer therapy[6]. Graphic comprehension can be improved using different colours to stimulate learning[7, 8]. However, male and female patients react differently due to hormonal differences. This gender differentiation might have an effect on management strategies. Hence, it is vital to know the influence of gender on colour processing. The male and female brains are different in many aspects, for example, biochemical reactions[9, 10] visual cognition [11, 12, 13] emotion [11, 14] etc. The main reason appears to be hormonal differences[15] that regulate different neuronal signalling[10] between the male and female groups. Our perspective on the previous research of colour perception is that there may be differences between males and females. Gender differences were clear during auditory and visual processing in different ERP components[12, 13, 16]. The male's reaction is usually based more on the entirety and in a global way, whereas the female's

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reaction is usually in a more focused and specific way[13, 17]. Gender differences depend on the types and the complexity of the paradigms, and it is believed that colour is one visual feature that influences emotional processing[16] that may be reflected on the electrophysiological level.

Reaction time (RT) and event related potential (ERP) can be measured in electrophysiological recording. The time starting from stimulus presentation until the participant's reaction can be assessed as RT[18]. No response, one response and multiple responses can be detected in recognition, simple and choice RT, respectively[19, 20]. RT is significantly differing in males and females depending on lifestyle[21]. The quicker muscular response of RT emphasizes faster nervous system processing time [22], therefore it is assumed that RT is related to higher cognitive function, mainly attention [23]. In our study, we used RTs as an indicator of cognitive processing speed. The ERP tool was also used with RT analysis in this study. ERP is painless, non-invasive and less expensive than other neuroimaging techniques[24, 25]. ERP has high temporal resolution (in milliseconds) for perception and attention studies [26, 27] that evaluate neural activity directly during a specific event [28, 29]. ERP waveforms carry different cognitive information through ERP components with different polarities, timing, scalp distribution and sensitivity[25], which reflects the functional connections between different brain areas[29].

In our present study, we analysed the N200 and P300 ERP components because both components are linked with the cognitive processes such as attention [30, 31]. The N200 or N2 is a negative directional waveform that usually ranges from 180-325 ms post visual or auditory stimuli[30]. In addition, this N200 component was found as a posterior negativity during visual stimuli [32] or over the vertex[33], and it can be seen during the colour discrimination task [34]. Scalp distribution of the N200 is the frontal and superior temporal cortex[35], fronto-centrally[17]. A marker of response inhibition is the P300 ERP component[36], which can activate the executive system of the frontal lobes[37]. The P300 ERP component is a positively directed waveform that can be recognized during cognitive tasks, and its range is usually from 250 ms to 900 ms with the amplitude of 5-20 μV for auditory and visual evoked potentials, although this amplitude can be as high as 40 μV depending on the task [31]. The P300 or P3b or classical P3 is frontally oriented with the short latencies [38], and it reflects broad recognition and memory updating processes with attention tasks[39]. The P300 can be found in the Strop task experiment[40] where colour reflects an identical task. However, there is still a lack of information on the influence of gender in colour processing in the human brain at the electrophysiological level. Therefore, we aimed to study the influence of gender on colour processing with RT analysis and ERP studies.

Methodology

Ethics

This study is a prospective study and was done between January 2012 and July 2014. Before starting the experiment, we received human ethical approval from the ethics committee of Universiti Sains Malaysia [USMKK/PPP/JEPeM (232.3(8)]. All subjects gave their written informed consent before starting the experiment.

Sample size

A total of 44 subjects were recruited (n= 22 in each group: male and female groups) and the results were calculated using PS software. All participants were recruited by e-mail/internet advertisement. Demographic data of both groups are shown in Table 1. The participants were age and education matched. Mean, Minimum (Min) and Maximum (Max) values of age and education are shown in Table 1.

Study procedure

Experiments were done in the EEG/MEG laboratory at Hospital Universiti Sains Malaysia (HUSM). Participants were seated comfortably in a dimly lit and sound treated room. Different colours were used as stimuli with an image size of 13 × 17 cm each. E-Prime software was used for the stimulation, and subjects observed the stimuli on a 22" LCD computer that was set 1 m distance from the subject's eye. The stimulation paradigm is shown in Figure 1. A total of 20 different colours were used randomly for the stimuli. Each stimulation was visible for 1.4 sec with an interstimulus interval (ISI) of 1 sec. Subjects were instructed to push 'button 1' for 'like' and 'button 2' for 'dislike'. The EEG/ERP signals were recorded from the scalp of the subjects using Geodesic sensor net (GSN) 128 (128-sensor net), which was described in our previous study[41].

Data analysis

We used Net-Station software to obtain the mean amplitudes and latencies of the N200 and P300 ERP components. The data were filtered with a 0.03-50 Hz band-pass filter, segmented with (-100) to 800 ms. Eye movement, eye blinks and movement artefacts were removed with artefact removal tools. Baseline was corrected 100 ms before the stimuli. To observe the significance level, we used SPSS-22 software[41]. Non-parametric Mann-Whitney test was used with

independent t-test to find the significance level between groups. The *p* value was set as a minimum of ≤ 0.05.

Results

The values of the mean differences of like and dislike stimuli were detected. The Grand average waveform of the N200 and P300 ERP components are shown in Figure 2a (for the male group) and Figure 2b (for the female group) at 19 electrode positions, FP1, FP2. Fz, Cz, Pz, F3, F4, F7, F8, C3, C4, P3, P4, T3, T4, T5, T6, O1 and O2.

N200 ERP component

There are no significant differences of the amplitudes and latencies of the N200 component between the male and female groups across all the electrode sites. However, we observed that the female group evoked non-significantly higher amplitudes of the N200 at most (11 sites out of 19) of the electrode sites (FP1, F3, FP2, F4, C3, T4, P4, T6, O2, Fz and Cz) (Figure 3b). On the other hand, the male group evoked higher amplitudes of the N200 at the other eight (8) electrode positions. Indeed, colour perception was dominant in the female brain at mid-frontal (Fp1, F3, Fp2, and F4) and right temporo-occipital (T4, T6, and O2) areas. However, in the male brain, colour effects were in the left temporo-occipital (T3, T5, and O1) areas (Figure 3a). In the case of the latencies of the N200, the female group induced slightly longer latencies (non-significant) compared to the male group at most of the electrode sites (10 sites: F3, F7, F4, C3, C4, P3, P4, T6, Fz, and Cz; 9 electrodes were shorter) and the remainder of the electrodes evoked longer latencies in the male group (Figure 3b).

P300 ERP component

In the case of the P300 ERP component, there are also no significant differences of the mean differences of the amplitudes and latencies between the male and female groups across all the electrode locations (Figure 4a, 4b). The male group evoked non-significantly higher amplitudes of the P300 component at 11 electrode positions (F4, F8, C4, T3, T4, P3, T5, P4, O1, Cz, and Pz) (Figure 4a). On the other hand, the female group evoked non-significantly higher amplitudes of the P300 component at eight (8) electrode sites (FP1, F3, F7, FP2, C3, T6, O2, and Fz). In the case of the latencies of the P300 ERP component, the female group induced slightly longer latencies compared to the male group at most of the electrode sites (10 sites: F7, Fp2, P3, T3, T4, T5, T6, O1, O2, and Pz), and at the remainder of the electrode sites, the male group evoked longer latencies (Figure 4b). The reflection of the P300 component in the female group was the fronto-right occipital areas (Fp2, Fp1, F8, Fz, F4, Pz, F7, O2, and T6), and for the male, it was more on the fronto-left occipital areas (FP1, FP2, F8, F4, O1, and Pz) according to the pattern of the amplitudes of the P300 component.

Reaction times (RTs) were analysed, and we found that the male group took a non-significantly (p=0.30) longer time to react (mean±SD) (986.243±310.674) compared to the female group (940.786±345.75) (Figure 5).

Discussion

We investigated the influence of gender on different colour processing using RT analysis and an event related potential (ERP) study. The values of the mean differences between like and dislike responses for the amplitudes and latencies of the N200 and P300 ERP components were analysed in the ERP study. We found that there were no significant differences among groups in terms of the amplitudes and latencies of both the N200 and P300 components. Important findings of this study were that colour reflected on the right occipital areas for the female group and on the left occipital areas for the male group according to both of the ERP components analysis. In addition, the male group also had a longer reaction time compared with the female group.

In this study, our task was to have participants choose for themselves their like and dislike of the different colours. Therefore, we can calculate only RTs but not error rate. We found that the male group had a longer reaction time, which means they took a longer time to choose their liking or disliking of the different colours compared to the female group, but the difference was not statistically significant (Figure 5). Longer RTs indicated task difficulty [8, 42] or delayed decision-making [43]. Therefore, we assume that male group felt difficulty during choosing like or dislike the colours compared to the female group, although this difference was not significant (Figure 5).

There were no significant differences in the amplitudes and the latencies of the N200 and P300 ERP components between groups across all electrode locations. We found the tendency toward higher amplitudes and longer latencies of these two components between the two groups. Event related component results for both the N200 and P300 components are consistent. Non-significantly higher amplitudes and longer latencies of the N200 ERP component were found in the female group at 11(out of 19) electrode sites (higher amplitudes) and longer latencies at 10 sites out of 19 sites compared to the male group. The male group evoked non-significantly higher amplitudes and longer latencies of the N200 component in nearly equal numbers of

electrodes as the female group (Figure 3a, b). Higher amplitudes (enhanced negativity) of the N200 ERP component related with higher attention and with greater difficulty tasks[44]. The longer latencies of the posterior N200 component were elicited during both easy and hard colour discrimination tasks. The N200 latency was delayed more during difficult tasks[7]. Supporting these interpretations, we propose that there might be a possibility for the male group to have greater attention, but to have greater difficulty, in the task of choosing like or dislike of the colours compared to the female group, thereby contributing to the results of the RTs.

Alternatively, regarding the P300 component, the male group evoked non-significantly higher amplitudes of the P300 component at 11 (out of 19) electrode positions (Figure 4a) with non-significantly longer latencies of the P300 at 9 (out of 19) sites (Figure 4b). Shorter amplitudes and delayed latencies of the P300 component are evidence of difficulty in discrimination processes during the comparison of stimuli [45, 46]. To support this evidence, in our study we can say that both the male and female groups reflected almost the same difficulty when making colour choices.

Analysing the amplitudes of both the N200 and P300 ERP components, we found that the amplitudes were gradually increased from Fp2, Fp1, Fz, F4, O2, T6, and F3 for the female group (see Figures 3 and 4). The effect of the P300 amplitudes and latencies are on the frontal and posterior electrode sites[47]. In agreement with Comerchero et al. (1999) regarding the P300 component and other studies [17, 35] of the N200 component, we can say in our study that scalp distribution of colours in females are at frontal to right temporo-occipital areas and for males, it is more on the fronto-left occipital area (highest amplitudes at Fp1, F8, Fp2, F4, and O1) (Figures 3 and 4).

For both the N200 and P300 components, the male and female groups reflected the same response for choosing different colour stimuli. Comparing both the behavioural and ERP data, we assume that in our study, the male group experienced slightly more difficulty in choosing colour preferences compared to the female group as the RT was non-significantly longer than the female group (Figure 5). In addition to this, the male and female choices were different as the males' were more global and the females' were more specific and focused in choosing stimuli [13, 17]. Male's global choosing resulted in longer RT. There have not been many electrophysiological studies investigating gender differences in colour processing. The higher amplitudes and unchanged latencies of the P300 component were found in the female group compared to the male group [12]. No changes in the amplitudes and latencies of the N170 and P300 components in the arousal paradigm between the male and female groups were observed[16]. The larger amplitudes and longer latencies of the N170 in the male group were found during the emotion paradigm, but in that case, the female evoked the higher amplitudes and the shorter latencies of the P300 component[47]. In a previous pain study, the higher amplitudes of the P300 component were found in the female [48]. However, whether the gender differences were found or not, it depended on the experimental paradigm complexity. Our paradigm was simple in only choosing the colours. Hence, we found no significant differences. We need further study to investigate gender differences during colour choosing with a complex/difficult paradigm.

Conclusion

Influences of gender on different colour processing were done using RT and an ERP study. Based on the ERP data and reaction time analysis, we concluded that there might be a possibility of delayed decision-making due to difficulty in assessing feelings while choosing colours by the male group compared to the female group.

Limitations

1. ERP has poor spatial resolution.
2. We have a small sample size. A larger sample size might give us more reliable results.

Authorship Contributions: FR and TB designed the experiment. RAH and TB performed the data acquisition and data analysis. FR and TB did interpretation. RAH wrote the first draft of manuscript. TB reviewed the final draft of manuscript.

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Table 1: Demographic data for male and female groups.

Groups	Age (years) (Mean, min, max)	Education (years) (Mean, min, max)	Handedness
Male	29.55, 20.30, 50.00	13.16, 11.00, 18.00	19 R, 3 L
Female	33.58, 22.40, 49.40	12.16, 5.00, 17.00	20 R, 2 L

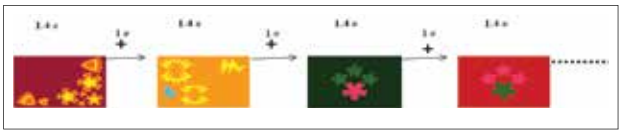

Figure 1. Experimental paradigm: Stimuli were different colours for 1.4 s with 1 s ISI.

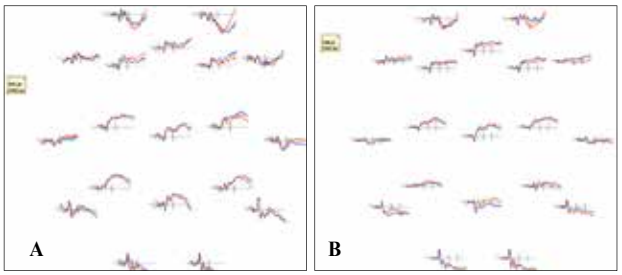

Figure 2a: Grand average waveform of the N200 and the P300 ERP components at 19 electrode channels in the male group. Blue and red colours are like and dislike stimuli, respectively. **b:** Grand average waveform of the N200 and the P300 ERP components at 19 electrode channels in the female group. Blue and red colours are like and dislike stimuli, respectively.

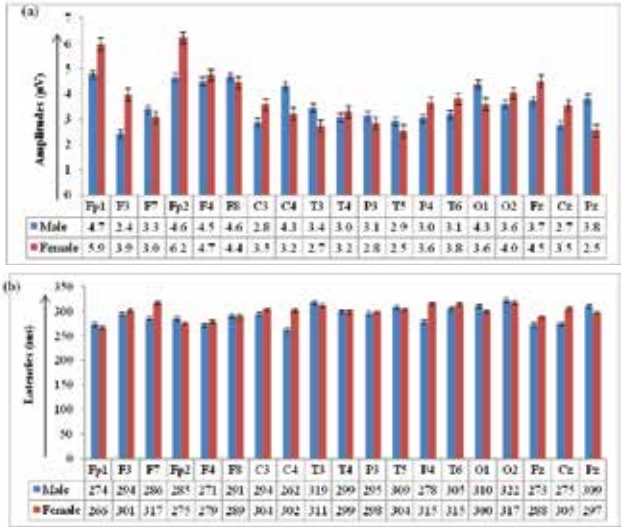

Figure 3: Bar graph shows the amplitudes (a) and the latencies (b) of the N200 ERP component during different colour stimuli between the male and the female groups. I-symbol indicates error bars with standard error.

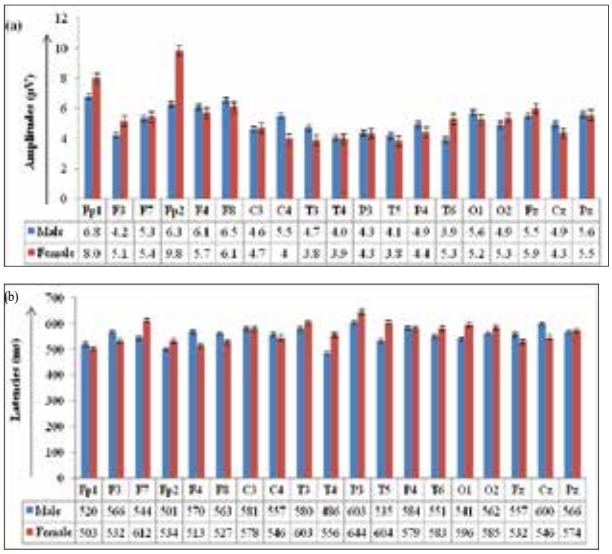

Figure 4: Bar graph shows the amplitudes (a) and the latencies (b) of the P300 ERP component during different colour stimuli between the male and the female groups. I-symbol indicates error bars with standard error.

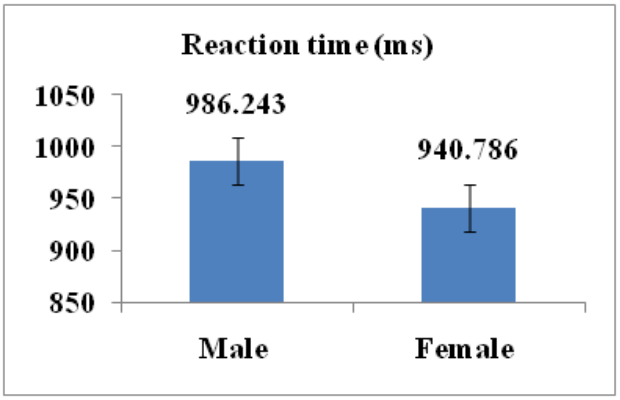

Figure 5: Reaction times (RTs) were shown between the groups. I-symbol indicates error bars with standard error.

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