An automatic red-female association tested by Stroop task

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Abstract

Previous studies showed stereotyped color-gender associations (e.g., red/pink is female, and blue/green is male). Here, we investigated the automaticity of color-gender associations using two Stroop-word categorization tasks. Ten Japanese gendered words were chosen as visual stimuli. In Experiment 1, participants were instructed to indicate whether a target word presented in either red, green, or gray font color, was a male or female concept. Results showed a congruent effect of red-female association that red font color facilitated feminine words categorization and inhibited masculine words categorization. Experiment 2 tested whether red-female association could affect perceptual font color categorization. Participants were asked to discriminate the font color that presented in different saturation levels of red or green while ignoring the word's meaning. Results showed that participants responded faster and made fewer errors when categorizing red font color for feminine words than masculine words. Those results suggest an automatic activated red-female association in both conceptual gendered word categorization and perceptual font color discrimination.

Introduction

"Red men green women (   )" — a famous Chinese four-character proverb by Shu Wei (a poet from Qing Dynasty, 1765–1805), meaning men wearing red and women in green, is widely used to describe the flourishing festival scene with young people in gorgeous clothes. From the Tang Dynasty era (618~), the groom wearing red and bride wearing green on the wedding day had become a popular traditional custom in Chinese culture. Thus, color has been associated with gender in social categorization for a long history.

In the western culture, pink and blue colors have been found to associate with gender stereotypes, that girls are often dressed in pink and playing with pink toys, while boys are often dressed and surrounded with blue colors (Frassanito & Pettorini, 2008; Pomerleau et al., 1990; Del Giudice, 2012, 2017; Cunningham & Macrae, 2011). With the developmental influence of these gender-color related social and cognitive processes, both children and adults show gender differences in color preference, possibly leading to female preference for pink/reddish colors and male preference for blue/green colors (Cohen, 2013; Hurlbert & Ling, 2007; Picariello et al., 1990; LoBue & DeLoache, 2011; Chiu et al., 2006; Wong & Hines, 2015; Davis et al., 2021). Moreover, color connotation studies showed that pink/reddish colors are feminine and blue/green are masculine colors (Cunningham & Macrae, 2011; Chen et al., 2020; Jonauskaite et al., 2021).

In Japan, reddish and bluish colors are often used to represent female and male gender symbols in social and public service systems. For instance, the symbol of the female lavatory is often colored red or pink, whereas that of the male lavatory is often colored blue or green (Ishii et al., 2019; Kitagami et al., 2009, 2010). A study of Japanese color preference reported a liking for reddish colors in females and bluish colors in males (Saito, 1996). However, to date there is no direct evidence for color-gender associations in a Japanese population. A previous study showed that red bias sex categorization of human bodies among Japanese participants, where sexually ambiguous body figures are judged as female more often when they are painted in red body colors than in green and gray (Chen, Nakamura, & Watanabe, Under review). It could be possible that people learn color-gender associations from the co-occurrences of color and gender information in the living environment and apply them in gender-related social information processing and behaviors (Kitagami et al., 2010; Jadva et al., 2010; Cunningham & Macrae, 2011; Yeung & Wong, 2018). However, few studies have paid attention to the automaticity of color-gender associations, especially, the effect of the red-female association on cognitive processes and behavior performance. Understanding the automaticity of color-gender associations may give us a better perspective on how color-gender stereotype is formatted and further reducing the levels of gender stereotyping in relation to colors.

The automatic activation of color-gender associations can be assessed with the Stroop word task. The Stroop word task is a neuropsychological test extensively used to assess the strength and automatic processing of implicit associations, well known as the Stroop effect (Richter & Zwaan, 2009; Stroop, 1935; Scarpina & Tagini, 2017). In a classic Stroop task, the names of colors are printed in the ink of another color, and participants are instructed to read the word or name the ink color. It assesses the ability to inhibit cognitive interference, which occurs when the processing of a stimulus feature influences the simultaneous processing of another attribute of the same stimulus (Stroop, 1935). This task relies on the strong overlearned tendency of experienced readers to attend to the meaning of a word and pay less attention to font color. It suggests that participants access the meaning of a word automatically, and they might not be able to ignore the word's meaning even when asked to do so. Longer response times and lower accuracies may indicate struggles in inhibiting the habitual tendency to categorize the concept of color or word's meaning; the Stroop cost is relatively high and robust. Thus, the Stroop word categorization task can be a useful tool to test the automaticity of color-gender association, which has been used in several previous studies investigating the implicit association between red and other conceptual dimensions, such as anger, failure, general negative words, potency, danger, and dominance (Fetterman et al., 2012; Moller et al., 2009; Soriano & Valenzuela, 2009; Pravossoudovitch et al., 2014; Mentzel et al., 2017).

Here, we used two Stroop word categorization tasks to examine the automaticity of red-female association. The interference effect of red-female associations was examined by conceptual gender categorization (Experiment 1) and perceptual font color discrimination (Experiment 2). In Experiment 1, masculine and feminine words in three font colors (i.e., red, green, and gray) were displayed as visual stimuli. Green was selected because it is the color opposite to red in many well-established color models, and gray was chosen as an achromatic contrasting color that can be matched for saturation and lightness (Elliot et al., 2010; Pravossoudovitch et al., 2014; Mentzel et al., 2017). Participants were instructed to categorize the word concept as masculine or feminine while ignoring the font color (i.e., red, green, and gray). In Experiment 2, the same masculine and feminine words were displayed in red and green font colors in different levels of saturation. Participants were instructed to discriminate the font color as red or green while ignoring the word meanings (i.e., male or female). We hypothesized an automatically activated red-female association, which could facilitate the behavioral performance in processing both conceptual gendered words and perceptual font colors.

Experiment 1: Stroop-word Gender Categorization Task

Methods

Participants

Twenty-three Japanese college students took part (10 men, *M*age = 20.7, *SD* = 1.8). All participants had normal or corrected-to-normal visual acuity and normal motor functions and were naïve to the purpose of this study. The sample size was set a priori at 21 participants, based on a target of 0.8 power with a medium effect size by power analysis (Cohen's *d* = 0.65; Pravossoudovitch et al., 2014; Mentzel et a., 2017). This experiment, as well as the subsequent experiment, was approved by the institutional review board (IRB) of Waseda University (2015-033), and conducted in accordance with the ethical standards of the 1964 Declaration of Helsinki. Written informed consent was obtained from all participants in advance.

Apparatus and stimuli

E-Prime 2.0 (Psychology Software Tools, Inc.) was used to present the stimuli and collect the data. Stimuli were displayed on a 24-inch LCD monitor (EIZO FG2421, EIZO corp, Hakusan, Japan), with a 1920 × 1080-pixel resolution and a refresh rate of 100 Hz. Participants viewed the monitor binocularly at approximately 60cm.

Ten words representing gender-related concepts that were used in previous studies were translated into Japanese (Male concept: (male), (man), (boy), (boyfriend), (masculine); Female concept: (female), (woman), (girl), (girlfriend), (feminine); Karpinski & Steinman, 2006; Stroessner et al., 2020). The word stimuli were presented in 40 Pt MS gothic font in the center of the screen in one of the three font colors (i.e., red, green, and gray). The color values, including the colors used in the subsequent experiment, are shown in Table 1. The background of the screen was always white (90 cd/m^2).

Table 1. Color values in the CIE LCh color space

	Colors	L	c	h	
Exp. 1	Red	39.49	83.82	40	
	Green	42.34	67.36	136.02	
	Gray	40.32	0.006	296.81	
Exp. 2	R1	40.02	11.46	20.99	
	R2	40.7	7.35	20.36	
	R3	41.87	3.38	19.75	
	R4	42.32	1.67	19.42	
	R5	42.37	0.006	296.81	
	G1	36.52	3.02	144.25	
	G2	36.71	4.53	144.11	
	G3	37.52	10.55	143.59	
	G4	38.4	16.49	143.06	
	G5	39.1	20.87	142.65	

Procedure

The experiment was carried out in a dimly lit room. At the beginning of the task, written instructions were provided on the computer screen. During the task, one of the word stimuli was presented in either red, green, or gray font color. Participants were instructed to press a labelled key (e.g., *z* or *m*) on the keyboard using their index finger to indicate whether the word stimulus was a “male” or “female” concept. They were required to respond as quickly and accurately as possible. At the beginning of each trial, a fixation cross appeared for 500 ms, and then a target word stimulus appeared until a response was made. Trials were separated by an inter-stimulus interval (ISI) of 500 ms (see Fig. 1). The experiment had a 2 (word type: male vs. female) × 5 (words for each group) × 3 (font color: red vs. green vs. gray) × 8 repeated measures design, giving rise to 240 trials in total. Ten practice trials were carried out and feedback was given in order to make the participants fully aware of the expected classification. The main experiment was divided into 6 blocks of 40 trials each. At the end of each block, participants had a self-timed break. The whole experiment lasted for about 5 ~ 10 minutes.

Data analysis

Response times and errors were collected for statistical analysis. Data were analyzed using the statistical software R.4.0.0 (R Core Team, 2020). We employed a linear mixed-effect model to examine the effect of font color on word gender discrimination, with the response time (RT) and errors as dependent variables. The *lmer* function of the “lme4” package (Bates et al., 2015) was used for model analysis. We adopted this approach because a mixed-effect model depicts the response as a combination of fixed and random effects, allowing for variation in effects based on random factors such as participants. The main interest is the interaction effect of word type (male, female) and font color (red, green, gray) on RTs and errors. Thus, the fixed factor was the interaction effect, whereas random factors were intercepts of participants and target words. F and p values were estimated using Satterthwaite approximations using *anova* function in the "lmerTest" package (Kuznetsova et al., 2017). We ran a post-hoc analysis using paired-sample t-test with Bonferroni correction to determine the simple main effects.

Results

Response times

Error trials (3.50%) and trials in which response times fell out of the outliner (mean RT ± 2.5sd) for each participant in each color condition were excluded from data analysis (2.72%).

The linear mixed-effect model [RT ~ Font color*Word type + (1|Participant) + (1|Word)] showed a significant interaction effect between word type and font color, $F(2, 5147.2) = 13.22$, $p < .001$. Post-hoc multiple comparison analysis showed that for feminine word categorization, participants responded faster in red font color (469.71 ms, $sd = 58.06$) than green font color (485.37 ms, $sd = 64.51$; $t(22) = 2.86$, Bonferroni corrected $p = .027$, Cohen's $d = 0.61$), and gray font color (486.73 ms, $sd = 62.55$; $t(22) = 3.26$, Bonferroni corrected $p = .012$, Cohen's $d = 0.70$), and no difference between green and gray font colors ($t(22) = 0.27$, Bonferroni corrected $p = 1$, Cohen's $d = 0.06$). For masculine word categorization, participants responded slower in red font color (515.39 ms, $sd = 76.88$) than green font color (498.65 ms, $sd = 75.61$; $t(22) = 3.05$, Bonferroni corrected $p = .018$, Cohen's $d = 0.65$), and gray font color (494.45 ms, $sd = 70.98$; $t(22) = 5.08$, Bonferroni corrected $p < .001$, Cohen's $d = 1.08$), and no difference between green and gray font colors($t(22) = 0.84$, Bonferroni corrected $p = 1$, Cohen's $d = 0.20$; See Fig. 2).

Accuracy

Participants made 3.50% of error trials in all. As there were few errors, the random effect of target word was removed from model analysis. Linear mixed-effect model [Errors ~ Font color*Word type + (1|Participant)] showed a significant interaction effect between word type and font color, $F(2, 110) = 3.73$, $p = .03$. Paired sample t-test showed no significant difference between red and other font colors for both masculine and feminine target words (all ps > .05; see Fig. 3).

In summary, participants responded faster when categorizing feminine words in red font color than in green and gray, while responded slower when categorizing masculine words in red font color than in green and gray. Thus, red font color facilitated the categorization for feminine words and inhabited that for masculine words, providing evidence for the congruency effect of red-female associations on categorizing gender conceptions. Previous studies suggested that higher-order cognition could affect early low-level perceptual processing (Bubl et al., 2010; Chen & Watanabe, 2021). If red-female association was strong enough, it may also activate and interrupt the low-level perceptual processing for color discrimination (Richter & Zwaan, 2009). In the following experiment, we aimed to test whether red-female association could be automatically activated to the perceptual processing of red colors at different saturation levels.

Experiment 2: Stroop-word Color Categorization Task

Methods

Participants

Twenty-three newly recruited college students (13 men, *M*age = 20.3, *SD* = 1.5) from Waseda University participated in Experiment 2. All participants had normal or corrected-to-normal visual acuity and normal color vision and were naïve regarding the purpose of the experiment.

Apparatus and Stimuli

The equipment and setting were identical to those in Experiment 1. The same Japanese word stimuli were used. Experiment 2 had a 2 (word type: male vs. female) × 2 (font color: red vs. green) repeated measures design. The word stimulus was presented in 40 Pt MS gothic font and assigned to one of two colors in red and green varied along 5 levels of saturation and lightness (see Table 1 for detailed color information). Each pair of red and green color words shared the similar level of saturation.

Procedure

The experimental setting was identical to Experiment 1. At the beginning of the task, written instructions were provided on the computer screen, followed by 20 practice trials with feedback. For each trial, a fixation cross appeared at the center of the display for 500 ms, and then a target word stimulus in red or green font color was shown until a response was provided (or for the maximum of 2000 ms). Trials were separated by an inter-stimulus interval of 500 ms. Participants were instructed to discriminate the font color of a word target being red or green by pressing two labelled keys (e.g., "*z*" for red, and "*m*" for green) on the keyboard. The labelled key positions were counterbalanced across participants. The word stimuli and font colors were randomly assigned to each trial. There were 2 word-categories (male vs. female) × 5 words (5 words in each group) × 2 font colors (red vs. green) × 5 levels of saturation × 2 repetitions, resulting in 200 trials. In order to be consistent with the previous experiment, 240 trials were generated in total. The experimental session was divided into 6 blocks of 40 trails each. At the end of each block, participants had a self-timed break. The whole experiment took approximately for 5 ~ 10 mins to be completed.

Data analysis

Linear mixed-effect modeling was used to examine the interaction effect of font color (red, green) and word type (male, female) on response times and errors, with random effects for participants and target color saturations (as data analysis in Experiment 1). Post-hoc analysis using paired-sample *t*-test with Bonferroni correction was performed to determine the simple main effects.

Results

Response times

One participant was excluded from data analysis due to poor performance (less than 50% accuracy).

Error trials (18.35%) and trials in which response times fell out of the outliner (mean RT ± 2.5sd) for each participant in each color condition were excluded from data analysis (3.39%).

The mixed-effect model [RT ~ Font color*Word type + (1|Participant) + (1|Color saturation)] showed a significant interaction effect between word type and font color, $F(1, 4135) = 38.02$, $p < .001$. Post-hoc multiple comparison analysis showed that for red font color categorization, participants responded faster in feminine words (565.00 ms, $sd = 83.61$) than masculine words (609.11 ms, $sd = 107.55$; $t(22) = 4.08$, Bonferroni corrected $p = .001$, Cohen's $d = 0.87$). For green font color categorization, a marginal significant difference was observed on RTs between feminine words (611.97 ms, $sd = 95.00$) and masculine words (593.40 ms, $sd = 100.53$; $t(22) = 2.18$, Bonferroni corrected $p = .08$, Cohen's $d = 0.46$; See Fig. 4).

Accuracy

Participants made 18.35% of error trials. A linear mixed-effect model [Errors ~ Font color*Word type + (1|Participant)] showed a significant main effect of font color, $F(1, 84) = 5.13$, $p = .03$, no effect of word type, $F(1, 84) = 0.13$, $p = .72$, and a significant interaction effect between word type and font color, $F(1, 84) = 6.83$, $p = .01$. Post-hoc analysis showed that when discriminating red font colors, participants made fewer errors for feminine words (10.50, $sd = 6.43$) than masculine words (14.77, sd = 8.47; $t(21) = 4.18$, Bonferroni corrected $p < .001$, Cohen's $d = 0.91$). For discriminating green font colors, participants made more errors with feminine words (11.00, $sd = 6.26$) than masculine words (7.77, $sd = 5.37$; $t(21) = 4.34$, Bonferroni corrected $p < .001$, Cohen's $d = 0.95$; See Fig. 5).

Those results replicated the results from Experiment 1 that the implicit red-female associations could be tested by Stroop word categorization task. When discriminating red font color, the feminine words could facilitate the recognition efficiency and improve the accuracy.

Discussion

In the present study, we used two Stroop-word categorization tasks to test the automatic activation of red-female association in both conceptual and perceptual word processing. Experiment 1 showed that red font color facilitated categorization of feminine words and deteriorated categorization of masculine words, compared with green and gray font colors. Experiment 2 showed that the discrimination of red font color in low saturation levels could be enhanced by feminine words. Those results indicated an automatically activated association between red and female concept, which could accelerate word processing for both conceptual gender categorizations and perceptual color discriminations.

In Experiment 1, when categorizing masculine and feminine words, font colors were automatically processed. The learned associations between color and gender concept could be activated implicitly, interrupting the gendered words processing. When the gendered words and font colors were congruently associated, the categorization performance could have been accelerated, otherwise, it could have been impeded. Participants responded faster at categorizing feminine words presented in red font colors than in the other colors, whereas responded slower at categorizing masculine words presented in red font colors than in the other colors. Thus, a congruency effect of red-female association could have been activated, thereby biasing the gender categorization. Those results provided further evidence for the effect of red on female gender perception. For instance, a red colored body was more easily to be judged as female than male (Chen, Nakamura, & Watanabe, Under review).

Meanwhile, the congruency effect of red-female associations could also modulate the perceptual color discrimination. In Experiment 2, when discriminating low-saturated red font colors, the word meaning was automatically processed, congruent red-concept could also accelerate font color processing (Richter & Zwaan, 2009). Our participants responded faster and made fewer errors for discriminating red font colors in feminine words than masculine words. This enhanced discrimination performance for red font colors by feminine words indicated a congruent effect of red-female associations. Thus, feminine words could be readily to be perceived as red more than masculine words. Those results provided further evidence for the automaticity red-female associations, which could be strong enough to interrupt the perceptual color processing. Previous studies suggested that learned higher-order cognition could routinely “penetrate” early low-level perception. For instance, visual perceptions can be influenced by language representations, knowledge, emotions, motivations, and other such states (Collins & Olson, 2014; Bannert & Bartels, 2013; Bubl et al., 2010; Chen & Watanabe, 2021). Notably, limited congruency effect of green-male associations was observed. It might be related to that masculine concept was associated with blue colors more than green colors (Cunningham & Macrae, 2011; Chen et al., 2020; Jonauskaite et al., 2021). Future studies are in need to address the blue/green-male associations and testing the automaticity of those color-gender associations.

The robust red-female associations may stem from statistical learning with social gender categorizations. The mere exposure to co-occurrences of gender and color information in the social environment could provide a basis, which became deeply embedded through statistical learning and language development. For instance, the gender-stereotyped colors of toys and clothing since the early development, that parents commonly dress their baby girls in red/pink and their baby boys in blue/green colors (Auster & Mansbach, 2012; Cohen, 2013; Picariello et al., 1990; LoBue & DeLoache, 2011; Davis et al., 2021), and the widely using of red in female clothing and cosmetics in later life (Frank, 1990), may help to construct the red-female associations. Moreover, gender differences in color preferences, that female tend to prefer reddish colors (Saito, 1996; Hurlbert & Ling, 2007), may also lead to those associations. Furthermore, red colors are commonly used to represent love and romance (e.g., red-heart symbol for valentine's day), and wearing red can increase sexual attractiveness (Elliot et al., 2010; Elliot & Pazda, 2012; Kramer & Mulgrew, 2018). The semantics associated with red and feminine concept may also contribute to red-female associations. These findings, together with other observed associations between red and different concepts (e.g., dominance, danger, anger), strengthen the nurture component of color associations (Fetterman et al., 2012; Moller et al., 2009; Soriano & Valenzuela, 2009; Pravossoudovitch et al., 2014; Mentzel et al., 2017). Future studies may explore cultural differences in those color-gender associations. For instance, in traditional Chinese culture, male in a higher official position was often dressed in red and female in green in some social occasions (e.g., "red-men green-women"), which may lead to different color-gender associations. Future studies may also explore whether color-gender associations can be established and/or mitigated by training. For instance, through repeatedly learning phrase with new color-gender associations and testing the strength of those associations to show the learning effect on the formation of color-gender associations. These future studies are valuable in revealing the nature of color-gender associations and further getting rid of gender-stereotypes in relation to colors.

One limitation of the current study is that the trial numbers for each saturation levels of red and green font colors in Experiment 2 were not equal (with 536, 544, 514, 529, 515 trials for each green font colors separately, and 528, 526, 530, 534, 524 for each red font colors separately). In data analysis, we used a mixed-effect modeling approach, including the color saturation as a random effect to control for this effect. Future study should set the color saturation levels as six instead of five. Moreover, it could be interesting to fit the psychometric function with well-controlled saturation levels of colors to show the effect of color-gender associations on color perception. Furthermore, future studies may examine how the color dimensions (i.e., lightness/saturation/hue) interacting with gender conceptions, to determine the precise variant of reddish color that associate with female concept.

In summary, we observed an automatically activated red-female association in both conceptual gendered word categorization and perceptual font color discrimination. Those results added to a growing body of evidence for learned color associations, pointing to the gender signaling value of red in social categorization. We propose that future studies examining how learned color-gender associations activating high-level semantic knowledge and low-level perceptual color processing are necessary to understand the learning process the stereotypes/associations are formed.

Declarations

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Conflicts of Interest

The authors declare that there no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Availability of data and material

The raw data and R code for this article are available online https://osf.io/r5u76/

Authors' contributions

All authors contributed to the study design. N. Chen coded the experimental paradigm, collected and analyzed the data, and drafted the manuscript. K. Nakamura and K. Watanabe provided critical revisions. All authors approved the final version of the manuscript for submission.

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Figures

Figure 1

Example of the trial sequence. Participants were required to categorize the gender of the word stimulus (male or female) by pressing two keys.

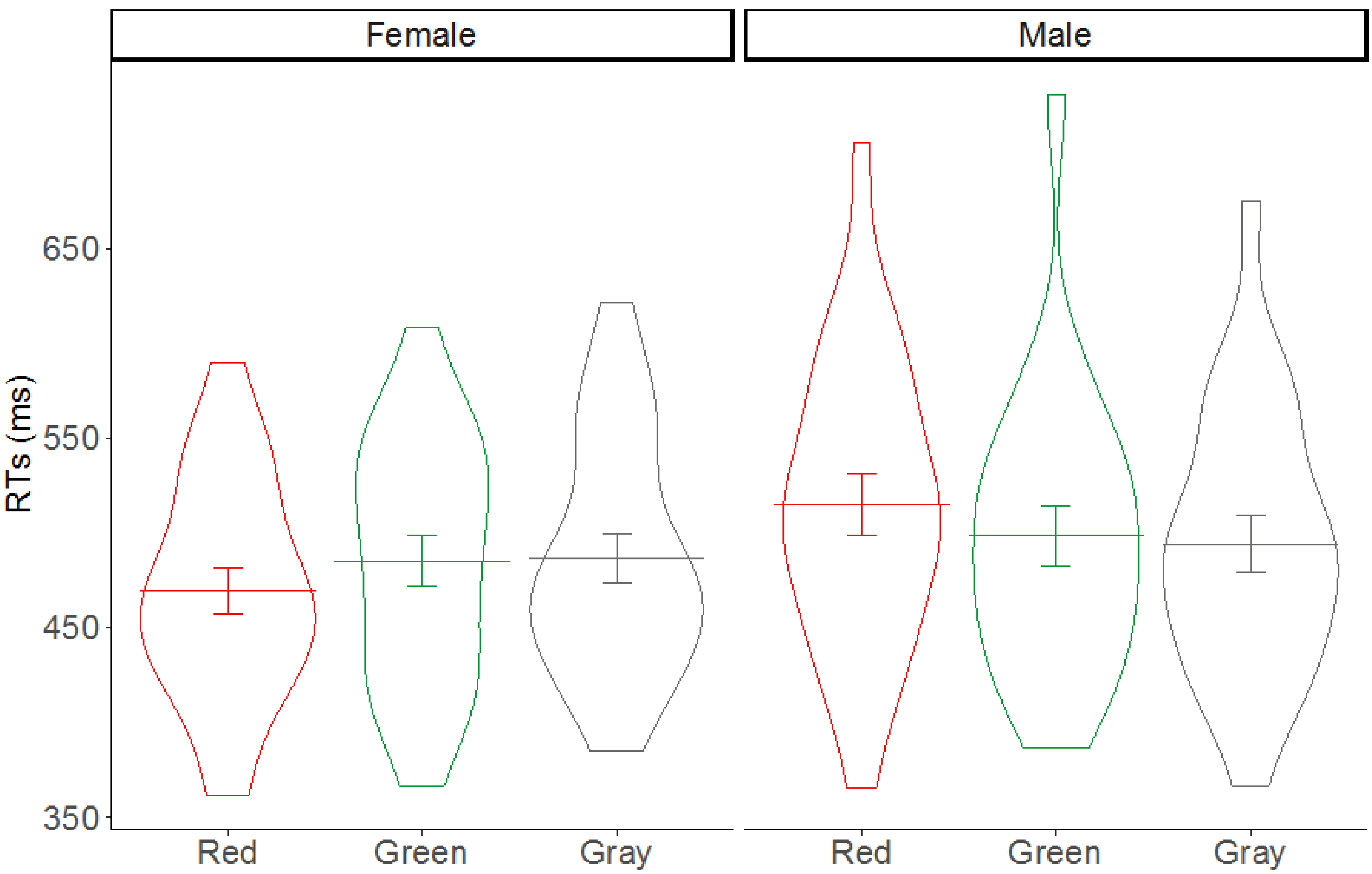

Figure 2

Response times in categorizing gendered words in red, green, and gray font colors. Error bars represent the standard error of the mean.

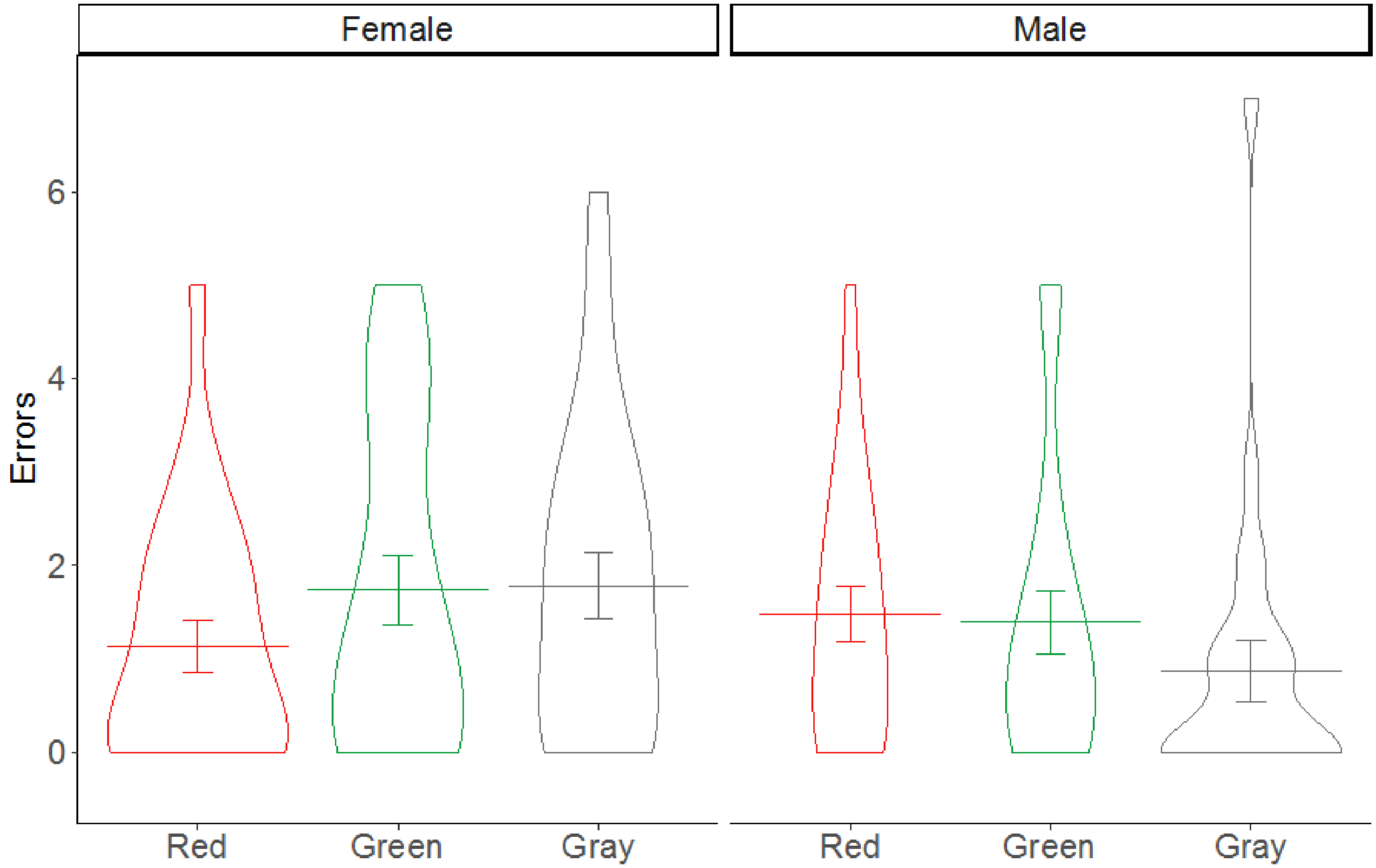

Figure 3

Errors in categorizing gendered words in red, green, and gray font colors. Error bars represent the standard error of the mean.

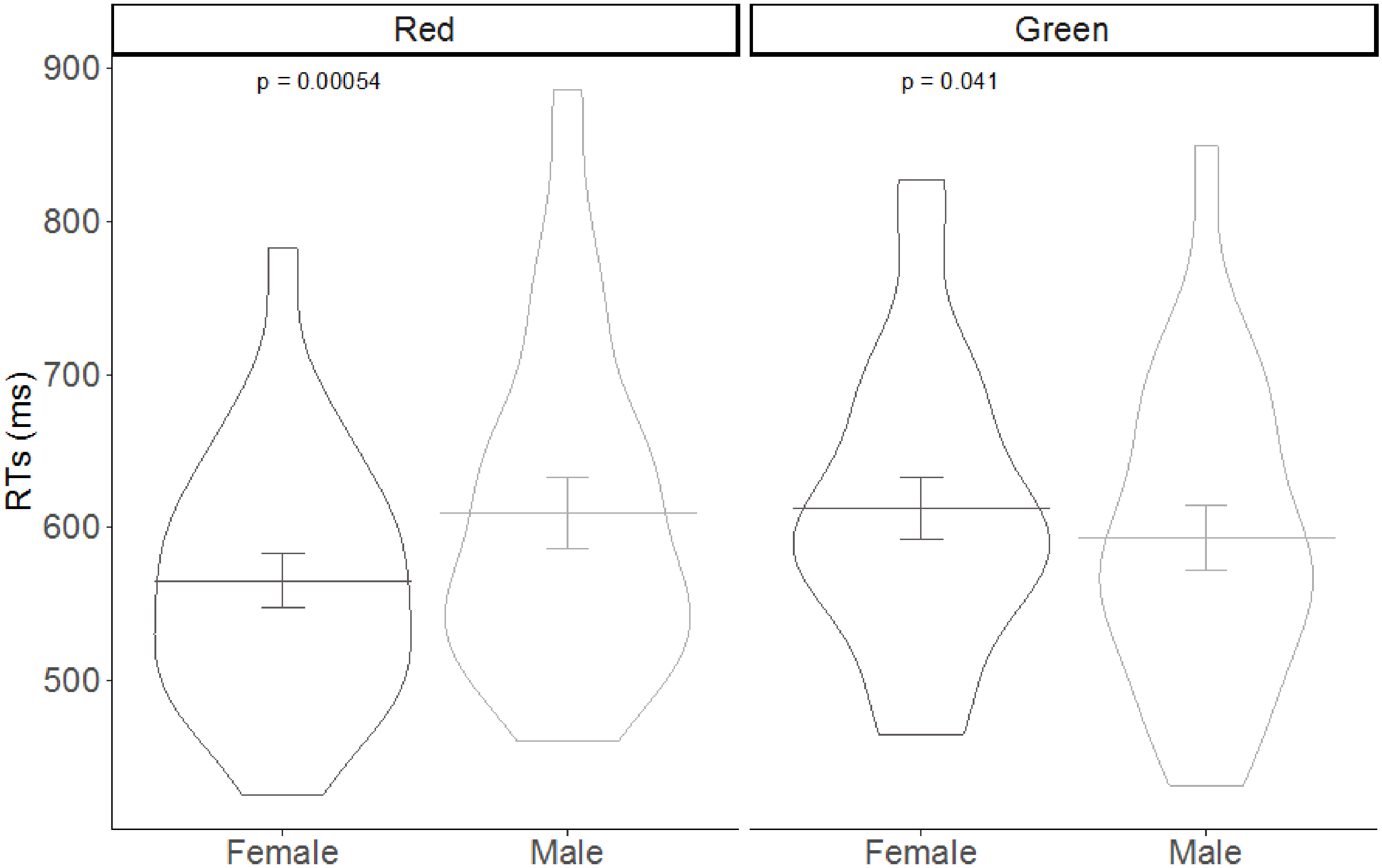

Figure 4

Response times in discriminating red/green font color in gendered words. Error bars represent the standard error of the mean, *p* values from paired-sample *t*-test.

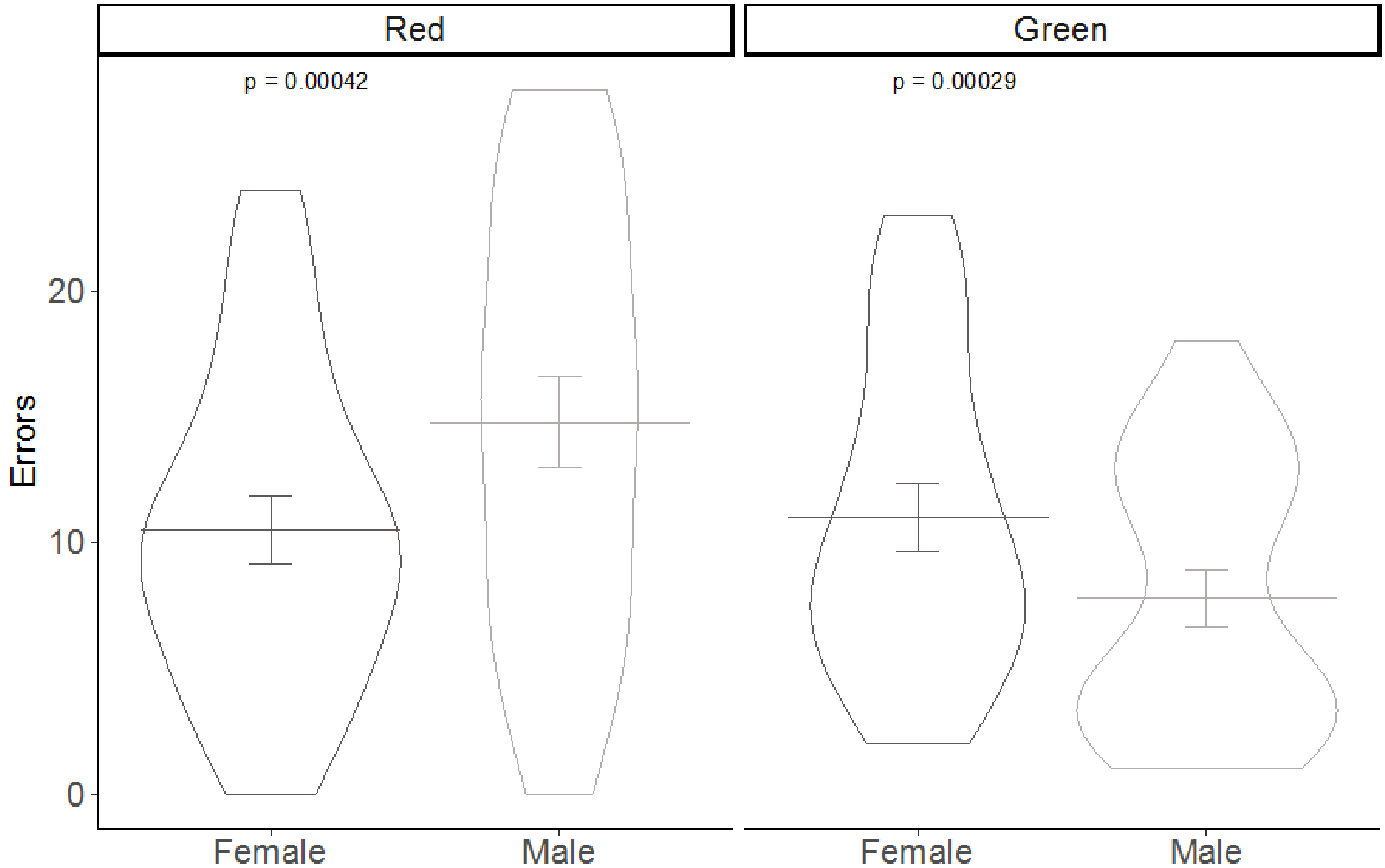

Figure 5

Errors for red/green font color categorization in gendered words. Error bars represent the standard mean error, *p* values from paired sample *t*-test.