P300 AND RESPONSE TIME FROM COLOR-EMOTION STROOP TASK

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ABSTRACT

Objectives: The event-related potential (ERP) of color-emotion stroop recognition task is made to study whether color could invoke physiological response. Methods: 52 different colors chosen from LCH color space are displayed on the screen, and

20 healthy college students are asked to report their emotional responses to each color. Then their emotional responses to each color stimulus are averaged. 3 colors, with highest, median and lowest averaged valence representing positive, neutral and negative emotion respectively, are chosen as the background color of 3 kinds of facial expression exhibiting happy, neutral and angry emotions. The expression pictures are covered by different color with 90% opaqueness. The color-emotion Stroop paradigm is designed to study color's effect on the same expression. The EEG is used as physiological measures. Another 18 subjects who have the same color preference as the previous ones are required to identify the expression and to ignore the color.

Result: The LSD results reveal that there are significant differences between the RT under the positive and neutral color on happy expression, that of the positive and neutral color and that of the positive and negative color on neutral or angry expressions. Furthermore, on neutral expression for P300 amplitude, the differences between the positive color paired with neutral color on the electrode F6 and F8, the neutral paired with negative color on AF4, AF8, F8, and FP2 are significant. However, no significant differences are observed for P300 amplitude and latency on happy and anger expression at these electrode sites.

Conclusions: There are strong activities from 200 to 400 ms, while the 5 electrode sites (AF4, AF8, F6, F8, FP2) are located in the forehead, which have the significant difference on P300 amplitude on neutral expression, this might be an indication of the forehead managing the emotional color-expression conflict. We conclude that the color might cause human physiological response.

Keywords: *color-emotion stroop, Event-related potential, P300, Response time*

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1. INTRODUCTION

It is well known that color affects human behavior and feelings. Some colors make people happy, while others make people depressive. "Could the color invoke human physiological responses? Or do human beings respond physiologically to color? Yes and perhaps", Peter K. Kaiser gave an equivocal answer in 1984. Reviewing studies on physiological responses to color, he pointed out that there was no question that there were physiological responses to color, but the association between colors and physiological indexes which included galvanic skin response (GSR), electroencephalograms (EEG), heart rate, respiration rate, eyeblink frequency and blood pressure was indirect and inconclusive, and the results were not yet stringent enough to reveal a general tendency that color could directly invoke human physiological responses [1]. Following this critical view, Detenber et al [2] asserted that color did not cause any effect on the physiological component of emotional experience in 2000. Indeed, research on physiological responses to color had not been active in recent years; while there were much more color-emotions researches which mainly focused on psychological patterns [3–8]. In 2007, Nooshin Yashar developed a color-emotion Stroop task that paired colors and emo- tional expressions, and required nonverbal responses. Participants were asked to identify the expression disregarding the color. In the standard Stroop task, subjects were instructed explicitly to respond to the word and to ignore the color [9–12]. Compared to the standard Stroop task, facial expression were used to instead of words in color-emotion Stroop task. The color-emotion Stroop tasks exhibited a significant but modest Stroop effect [13]. This paper aimed to explore whether human respond physiologically to color using color-emotion Stroop. First was the subjective experiment, the questionnaire of color-emotion was made to find the 3 colors with highest, median and lowest valence to set as the background color of 3 expression(happy, neutral and angry) for next experiment. Next was the ERP study of the color-emotion Stroop task. Subjects were instructed explicitly to identify to the emotion of the expression and to ignore the emotion of color. The paired t-test was used to analyze the color pairs on the same expression at the different electrode site to study the colors effect on ERP. If there existed a significant difference between the RT or ERP on the same expression, these may be due to color's influence.

2. EXPERIMENT 1: QUESTIONNAIRE OF COLOR-EMOTION

2.1. Methods

2.1.1. Stimuli

52 different color stimuli chosen from the CIE Lab Lch color space [14], which is a device-independent color space, were used to induce subjects' emotional response. Table 1 listed the total color stimuli.

Table 1: the color stimuli

Hu	L, C,	L, C,	L, C,	L, C,	L, C,	L, C, H	L, C, H	L, C,
Red	30, 30,	30, 45,	40, 90,	50,40,	70, 30,	26, 61, 38	53, 104, 40	68, 53,
Oran	32, 53,	62, 90,	79,					
Yello	60, 30,	60, 70,	80, 90,	80, 60,	80, 40,	51, 57, 102	97, 97, 103	98, 61,
Gree	30, 30,	40, 45,	50, 60,	40, 40,	70, 20,	46, 72, 136	88, 120, 136	91, 77
Indig	48, 30,	91, 51,	93, 37,					
blue	30, 20,	40, 30,	40, 45,	30, 35,	70,	13, 80, 306	33, 134, 306	60, 71,
Violet	20, 25,	30, 35,	40, 40,	50, 30	70, 20,	30, 69, 329	60, 114, 329	72, 75,
Gray	27, 0	41, 0,	78, 0,	66, 0,				
Black	0, 0, 0							
White	100,0,							

2.1.2. Subjects

20 college students (18 males, 2 females) participated in the experiment, whose ages ranged from 20 to 29, and the averaged age was 23.95. None of them had color blindness. They were required to report their emotion response to color using 9-point scale for valence and arousal [15].

2.2. Results

After the experiment, the emotional responses of the subjects to each color stimulus were aver- aged according to the follow equations.

$$V_j = \frac{\sum_{i=1}^{20} V_{ij}}{20} \qquad A_j = \frac{\sum_{i=1}^{20} A_{ij}}{20}$$

Where, V_{ij} is the i_{th} subject's valence response to the j_{th} color, and A_{ij} is the i_{th} subject's arousal response to the j_{th} color.

The average valence ranges from 2.40 to 5.25, and the average arousal is from 1.85 to 7.00, whose distribution was depicted in Figure 1. From Figure 1, 3 colors which had highest (LCH: 91, 51, 198), median (LCH: 40, 30, 260) and lowest (LCH: 30, 30, 30) averaged valence were picked out for the next experiment.

3. EXPERIMENT 2: ERP STUDY OF COLOR-EMOTION

3.1. Methods

3.1.1. Stimuli

3 colors chosen from previous experiment, which represented positive, neutral and negative emotion respectively, were set as the background of 3 expressions, including happy, neutral and angry. It is easier to recognize the expression than the emotion of the color [13], so picture was covered by the color with 90% opaqueness to increase the difficulty of the task.

Happy expression were covered with positive, neutral and negative color separately with the ratio 2 : 1 : 1. Neutral expression were covered with these 3 colors with the ratio 1 : 2 : 1. Anger expression were covered with these 3 colors with the ratio 1 : 1 : 2.

3.1.2. Subjects

18 college students (16 males, 2 females) participated in experiment, whose ages ranged from18 to 31, and the averaged age was 25.00. They were all right-handed. None of them had color blindness. They had the same color preference as the previous colors. This was achieved by filtering out people with other color preference from the previous experiment.

3.1.3. Recording conditions

EEG activity was continuously recorded using a Quik-cap (NeuroScan Inc) with 64 Ag-AgCl electrodes arranged in an extended 10-20 system montage, the referenced electrode was placed behind earlobe, while the ground electrode was placed at the midpoint between FPZ and FZ. Bipolar electrooculographic activity (EOG) was recorded to monitor eye movements using Ag- AgCl electrodes placed above and below the right orbit and on the outer canthus of each eyes, and the electrode impedances were kept below 10 Kohms. Neuroscan Synamps2 bioamplifiers with a 24 bit A/D converter and ±200mV input range, were used to continuously digitize (250 HZ sample rate), amplify (gain of 10), and filter (0.01 to 50 HZ band pass filter rate) the raw EEG signal in AC mode, EEG activity was recorded using Neuroscan Scan software (v 4.3.1).

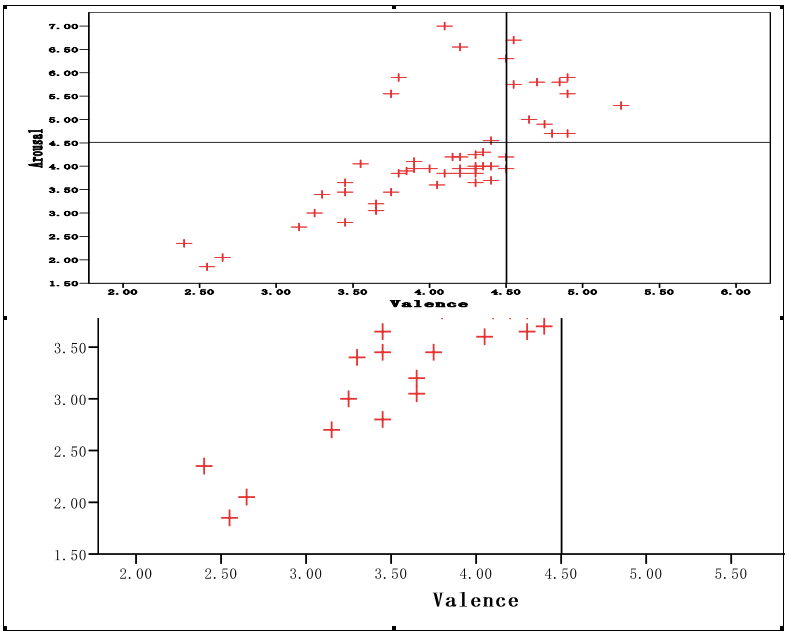

Figure 1: The distribution of the average of the 52 colors

3.1.4. Procedure

Subjects were seated on a comfortable sofa in a soundproof room, 0.5 m from the screen with a keyboard resting on their laps. Stimuli were displayed on the Samsung 19' color monitor. Subjects were told they would be performing an expression recognizing task without considering the emotion of the color. They were instructed to press the right number key '1', '2', '3' to indicate whether the expression was happy, neutral, or angry. To avoid eye movements, they were instructed to look ahead at the monitor rather than down at their fingers during task. They were asked to respond quickly and with as few errors as possible. The flow chart of a trail in experiment was depicted in Figure 2.

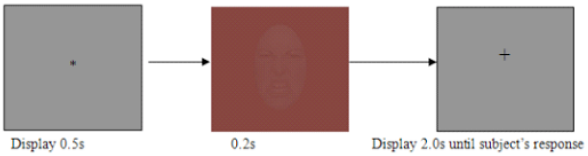

Figure 2: The flow of the color-emotion stroop

First, there was a grey screen with a star at the central of the screen, which lasted for 500 ms before the stimulus appearance. Next was the stimulus displayed 200ms. The last was the inter-stimulus which was a grey screen with a plus at the central of screen, with interval was 2000ms until the subject pressed the number key (1-3). After subject pressed the number key or the interval over 2000ms, there was a next trial.

Before the experiment, there were 15 trials so that subjects can rehearse the mapping of expres- sion onto fingers to make them familiar with the experiment. Each block consisted of 48 trials, with stimulus probability equated on the 3 kinds of expressions. There were 5 blocks with a total of 240 trials in experiment. Between blocks there was a rest, and the amount of the rest time was controlled by the subject himself. Stimulus presentation, timing, and measurement of behavioral response time and accuracy were controlled by Psychophysics toolbox (Psychtoolbox Win 2.54).

3.2. Results

3.2.1. Behavioral data

One way analysis of variance (ANOVA) with Least significant difference (LSD) post-hoc analysis was used to compare RTs under different color on the same expression over the subjects. The level of statistical significance of differences is $P < .05$. Figure 3 illustrates the mean RT from each color on each face. Table 2 listed the statistic analysis of the RTs on each facial expression. There were significant differences on all of the 3 expressions. The LSD results revealed that there were significant differences between the RT under the positive and neutral color on happy expression, that of the positive and neutral color and that of the positive and negative color on neutral or angry expressions.

3.2.2. ERP amplitude and latency processing

The recording epoch began 100ms before the appearance of the stimulus and lasted 600ms. Waveforms were digitally smoothed with a low-pass filter using cutoff of 30HZ prior to component analysis. Analysis was restricted to trials on which the subject made the correct response. Component amplitudes and latencies were assessed with Neuroscan's peak-detecting method. The P300 component was defined as the largest positive peak occurring at all electrode sites with a latency window between 250 and 400ms. Mean differences between conditions were assessed using paired t-test method to analyze the color (happy, neutral ant negative colors) pair effect at the same expression (happy, neutral and angry) and different electrodes(AF3, AF4, AF7, AF8, F5, F6, F7, F8, FP1, FP2) for ERP data.

3.2.3. P300 amplitude

Figure 4 presents the grand averaged ERP waveforms from the 3 colors (positive, neutral and negative) on 3 expressions (happy, neutral and anger) at the 5 electrode sites. P300 event-related potential with a latency window between 250 and 400 ms was identified in response to the 3 colors on each expression at each electrode site. Table 3, 4, 5 presented the mean P300 latency and amplitude on 5 electrode sites (AF4, AF8, F6, F8, FP2), because only the differences on these 5 electrode sites were significant by the following analysis.

The paired T-test was used to analyze the two colors on the same expression at each electrode site. For instance, on happy expression, the positive color and neutral color was paired, if there was a significant difference on P300 amplitude or latency in this pair on a electrode site, these differences were caused by color. The same argument held for the neutral and negative expression.

Table 6 listed the paired t-test result with significant difference. It can be seen that only differences on neutral expression were significant, they were listed as follow:

the positive color paired with neutral color on the electrode F6 ($t = 2.279$, $p < .05$), the positive color paired with neutral color on the F8 ($t = 2.181$, $p < 0.05$),

the neutral paired with negative color on AF4 ($t = -2.743$, $p < .05$), the neutral paired with negative color on AF8 ($t = -2.173$, $p < 0.05$), the neutral paired with negative color on F8 ($t = -2.826$, $p < .05$),

the neutral color paired with negative color on FP2 ($t = -2.126$, $p < 0.05$).

However, no significant difference on P300 amplitude under different color on happy and angry expressions at these 10 electrode sites was observed.

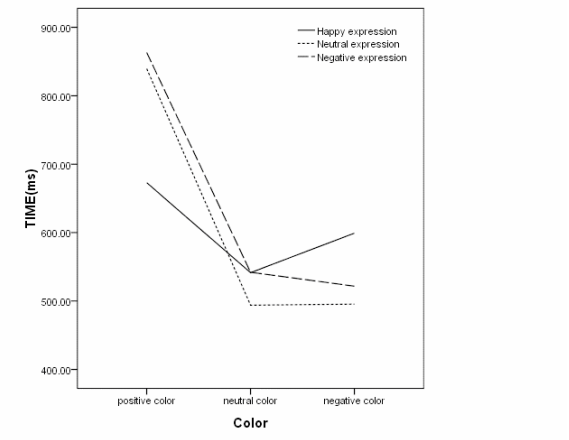

Figure 3: Mean response time for each color on each face

Table 2: the result of ANOVA on each expression

Expressio	Sources	SS	df	MS	F	Prob > F
Positive	Colum	156536.4	2	78.268	3.32	0.0442
	Error	1203160.2	5	23591.		
	Total	1359696	5			
Neutral	Colum	1.42825e+00	2	714132.	15.33	6.1192e-006
	Error	2.37543e+00	5	46577		
	Total	3.80369e+00	5			
Negative	Colum	1.32254e+00	2	661269.	18.75	7.86781e-007
	Error	1.7986e+00	5	35266.		
	Total	3.12114e+00	5			

Table 3: the happy expression

	P300 latency (ms)			P300 Amplitude (uV)		
	Positi	Neutr	Negati	Positive	Neutr	Negativ
AF	344	372	3	8.40588	7.72278	7.99415
AF	344	352	3	9.61705	8.51940	9.43457
F	344	352	3	4.64210	5.26803	3.94733
F	348	352	3	4.00945	4.52707	5.40493
FP	348	352	3	14.63296	13.5526	14.36892

Table 4: the neutral expression

	P300 latency (ms)			P300 Amplitude (uV)		
	Positi	Neutr	Negati	Positive	Neutra	Negativ
AF	392	324	3	6.60748	8.12170	13.90655
AF	396	324	3	10.96115	8.85351	13.90655
F	392	324	3	8.17961	3.78214	6.98456
F	392	324	3	7.62877	2.34093	6.87273
FP	332	336	3	11.70909	15.92129	20.50846

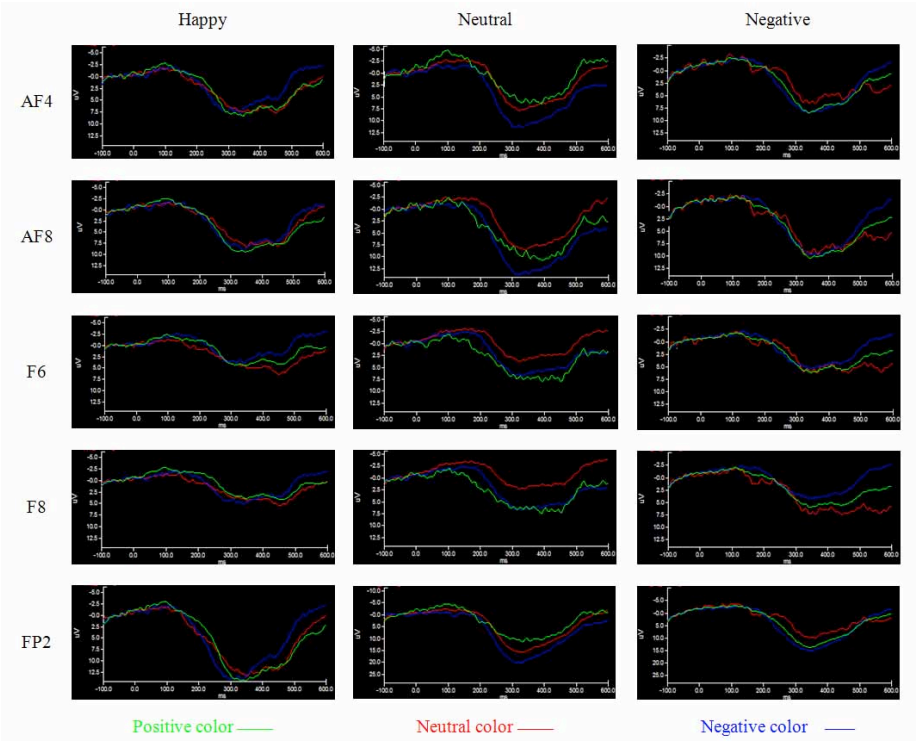

Figure 4: Grand averaged ERP waveforms from the 5 electrode site

Table 5: the angry expression

	P300 latency (ms)			**P300 Amplitude (uV)**		
	Positi	Neutr	Negati	Positive	Neutra	Negativ
AF	344	364	3	8.61737	6.75554	8.68737
AF	344	364	3	10.63496	9.88144	9.95503
F	344	364	3	6.41333	6.38030	5.56994
F	344	360	3	6.12509	7.56115	4.23799
FP	344	364	3	14.08001	10.24215	15.26342

Table 6: The paired t-test on the neutral face at 5 electrode sites

	Mea	std.	Std. Error	t	d	Sig. (2-
F6 122 – F6 222	6.3280	11.78183	2.77700	2.27	1	.0
F8 122 – F8 222	6.5039	12.64979	2.98158	2.18	1	.0
AF4 222 – AF4	-	6.34882	1.49643	-	1	.0
AF8 222 – AF8	-	11.03764	2.60160	-	1	.0
F8 222 – F8 322	-	7.67757	1.80962	-	1	.0
FP2 222 – FP2	-	9.81990	2.31457	-	1	.0

In these table, as ān example of F6 122, the F6 represent the electrode site, the 1 represent color(1-3 represents positive, neutral and negative), the first 2 represent face (1-3 represents happy, neutral and negative expression), the second 2 represent subject press the number key.

3.2.4. P300 latency

However, no significant difference between P300 latency under different color on 3 expressions at these 10 electrode sites was observed.

3.2.5. The topography of filtered ERP

Figure 5 was the topography of filtered ERP of the grand average on neutral face from 0 to 600ms after the stimuli offset, the first was the positive color covered on the neutral expression,

the second was the neutral color and the last was the negative color. It can be seen that there were strong activities from 200 to 400 ms, while the 5 electrode sites (AF4, AF8, F6, F8, FP2) are located in the forehead, which had a significant difference on P300 amplitude on neutral expression, so it could be thought that the forehead is managing the emotion color-expression conflict.

4. CONCLUSION

This research investigates the physiological effects of different colors on 3 expressions. The 3 colors, including the highest, lowest and median collected by the psychological experiment, were separately covered on happy, neutral and angry expressions. The color-emotion Stroop paradigm was designed to study color's effect on the same expression. The EEG was used in this experiment as physiological measures. The behavior result showed that there were significant differences between the positive and neutral color on happy expression; and the same held for the positive and neutral color, the positive and negative color on neutral or angry expressions.

Furthermore, on neutral expression for P300 amplitude, the positive color paired with neutral color on the electrode F6 and F8 had a significant difference. The same held for the neutral paired with negative color on AF4, AF8, F8, and FP2. However, no significant difference between P300 amplitude and latencies on happy and angry expression at other electrode sites was observed.

It can be seen that there were strong activities from 200 to 400 ms from the topography of filtered ERP, while the 5 electrode sites (AF4, AF8, F6, F8, FP2) were located in the forehead, which had a significant difference on P300 amplitude on neutral expression, so it could be thought that the forehead manages the emotion color-emotion conflict.

5. DISCUSSION

In color-emotion Stroop task, only the displayed expression was task-relevant, while the emotion of color was ignored. The emotion due to color unconsciously influenced responses to the emotion due to expression, so that the subjects were unable to ignore the emotion of color, even though it was irrelevant to task performance and color recognition was not faster than expression recognition. Behavioral Stroop effects were obtained: the positive and neutral color on happy expression, the positive and neutral color, the positive and negative color on neutral or angry expression had a significant difference. In contrast, P300 latency demonstrated no significant difference across the 3 color on 3 expressions, only the P300 amplitude demonstrated significant difference in the positive and neutral color, the neutral and negative color on neutral expression at some electrode sites of forehead. The ERP findings indicated that the Stroop effects occurred after stimulus evaluation had been completed, and it was that the forehead may manage the emotion color-expression conflict. Therefore, we concluded that the color could invoke human physiological response. However, the reason for no significant on happy and negative expression requires further research.

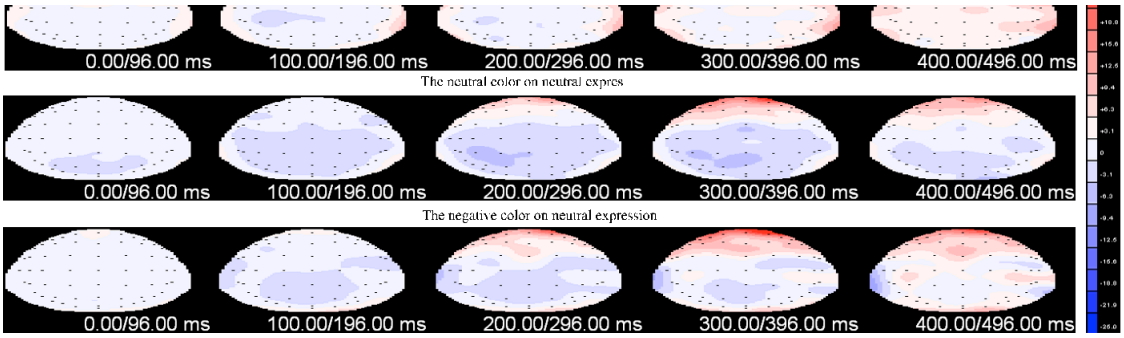

Figure 5: The topography of filtered ERP on neutral face from 0 to 600 after the stimuli offset

6. ACKNOWLEDGMENTS

The authors would like to thank all the observers who participated in the experiments. This paper is supported by National 863 Program (2008AA01Z122), Anhui Provincial Natural Science Foundation (No.070412056) and SRF for ROCS, SEM.

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