The unusual yellow hue and 65% saturation: the interaction of color hue and saturation on time perception

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Abstract. In previous studies, an effect of color on temporal distance perception was found, but the interaction of hue and saturation on temporal distance perception has not been investigated, so the objective of the present experiment was to determine whether there is an interaction between hue and saturation. This experiment adopted a three-factor mixed design probing the sample effect size by G-power3.1 and using SPSS ibm26 to explore the interaction effects of hue (red, yellow, and blue) and saturation (30%, 65%, and 100%) on visual interval perception. The experimental results showed a significant interaction between hue and saturation type, especially to yellow hue and 65% saturation whose RT covered both the maximum (yellow65%) and minimum values (red 65%) The outcome suggested that there might be some mechanisms that color would effect the time perception ignored by previous studies. Finally, this experiment supported the proposal our team brought about, which would help the subsequent understanding of human visual perception processing mechanisms.

Keywords: time perception, color saturation, color hue, interaction

1 Introduction

Time perception studies the processing of temporal information within milliseconds to approximately 3 seconds, while the processing of temporal information beyond approximately 3 seconds is called time estimation. Theoretical models of time perception include the pacemaker-accumulator model, the resource allocation model, the memory decay model, and the state-dependent network model. The theoretical models include the pacemaker-accumulator model, the resource allocation model, the memory decay model, and the state-dependent network model. Among the resource allocation models, Buhusi and Meck proposed an extended resource allocation model that considers temporal information processing and contextual processing to share

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attentional and working memory resources. The major difference between this model and the above three attention-related models is that the above three models consider that non-temporal information and temporal information processing share only attentional resources, whereas the extended resource allocation model considers that non-temporal information and temporal information processing share attentional resources, working memory resources, and monitoring and allocation of these resources [1].

2 Literature Review

Factors that influence temporal distance perception are human emotional motivation [2-3], interests (e.g., aesthetic experiences, etc.) [4], the nature of sensory channels, the number and nature of events occurring in a given time, and, as our research team will explore, color. The dimensions of color are hue, saturation, and brightness. The results of Chen Yuan's experiments show that hue and saturation have an impact on the accuracy of time perception, with red giving a longer perception of time compared to blue and green for the same actual time, while there is no significant difference between green and blue, and high saturation colors feel longer than low saturation colors feel. At the same time, high color saturation causes color "spillover", which is more likely to occur with red and yellow objects [5], and both hue and saturation affect accuracy, suggesting that hue and saturation may interact in the perception of temporal distance. Meanwhile, Bingxin Lin suggested that temporal distance perception is closely related to many cognitive activities, among which the millisecond-to-second temporal distance perception is important for individuals' motor control and language processing [6], so it is necessary to explore the mechanism of temporal distance perception [7], so this experiment will explore the interaction of two dimensions of color on temporal distance perception.

Our pursuers have learned that color has a differential effect on gender, with males overestimating the time of the red screen and females overestimating the response time of the blue screen [8]. Meanwhile, in Chen Yuan's study, regardless of the effect of emotion on temporal distance perception, the temporal distance overestimation effect was always stable for girls and speculated that it might be due to the differences between the two sexes in the relevant brain structures and physiological characteristics [9], so our team controlled for the gender variable in our experiment. The effects of green and blue on temporal distance perception have not been significantly different in previous studies [5], [9]; yellow and gray have not been introduced simultaneously, yellow has a special national metaphor for Chinese [10] and is a very important color, so our researcher decided to introduce yellow as experimental material in this experiment. Meanwhile, different background colors correspond to different cognitive load degrees, and according to the resource allocation model, the higher the cognitive load, the less time perception, so this experiment predicts. The cognitive load of high saturation is significantly higher than that of low saturation colors, i.e., the higher the saturation, the faster the perception. In addition, previous studies have demonstrated that hue and saturation have different effects on temporal distance perception, so hue and saturation may interact with each other on temporal distance perception, so this experiment will investigate the interactive effects of red, yellow, and blue hues and saturation on visual temporal interval perception.

3 Method

Participants: Researchers use G-power3.1 to estimate to the investigators used G-power to estimate sample effect sizes for repeated measures of variance and found that 26 people were needed. Finally, 30 healthy undergraduate and graduate students (mean age 20.7 ± 2.3, 15 females and 15 males) at Dali University were selected through the internet involved in the experiment operating from 4.22 to 4.27 after sunset. All subjects were right-handed, had the normal color vision and visual acuity, and had no history of mental illness. The subjects were asked to read and sign the informed consent before the experiment and completed the experiment in a dim room. researcher remunerated the participants 30￥ after the experiment.

Prime: Three-factor mixed experimental design: 3 hues (red, yellow, blue) * 3 saturation (30, 65, 100) * 5 intervals (600 ms, 800 ms, 1000 ms, 1200 ms, 1400 ms).

Target: The experiment was conducted in a small room (Laboratory of Psychology, Dali University) with dim lighting at night to ensure that the subjects were maximally affected by the experimental stimuli. The experimental procedure was produced by E-prime 2.0 and the stimulus consisted of nine square color blocks: three hues of three saturations. All experiments were conducted on a computer with a 17-inch monitor (64-bit true color, resolution 2520*1680), with the stimulus blocks occupying 50% of the screen.

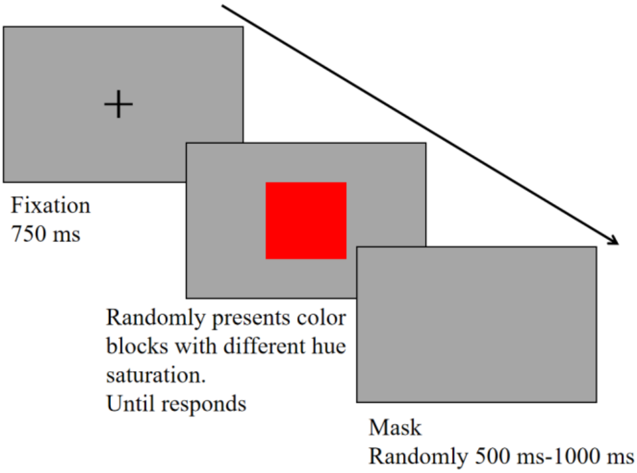

Fig. 1. Flow chart of simple reaction: S-R for color blocks

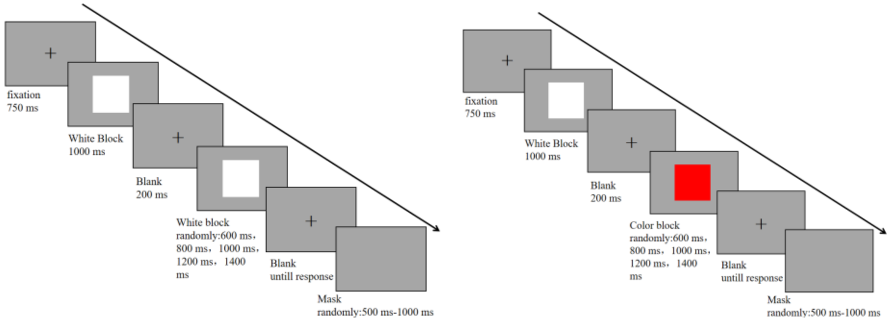

Fig. 2. Flow chart of discrimination reaction (left) and complex reaction (right)

Experiment 1

This experiment was a stimulus-keystroke task to test the subjects' response speed to a color stimulus. In the experiment, a gaze point was presented on the screen and then a color block was presented. The subject's task was to press a key when the color block stimulus appeared. The session was repeated twice, the first time with the left hand by pressing the f key and the second time with the right hand by pressing the j key. After the responses display an empty mask to avoid the adoption after-effect[11,12], so do texperiment 2 &3. A total of 90 trials. The stimulus presentation flow is shown in Figure 1

Experiment 2

This experiment was a stimulus-keystroke task to test the response speed of subjects' temporal spacing judgments. In the experiment, a gaze point was presented on the screen, and two white blocks were presented successively, the latter at five random time intervals of 600 ms, 800 ms, 1000 ms, 1200 ms, and 1400 ms. Subjects were asked to refer to the white baseline time (1000 ms) block presented first in each trial, and to judge the time interval of the latter white block, which was shorter than the former by pressing The second white block would appear 6 times at each time interval. A total of 50 trials. The stimulus presentation flow is shown in Figure 2

Experiment 3

Sharing the same time-varying pattern (five intervals) and procedure with Experiment 2, Experiment 3 only differs from Experiment 2 in target blocks which were color blocks of 9 versions (three hues*three saturations). Total 450 trials for Experiment 3.

4 Analysis

The data analysis software was SPSS ibm 26, and the subjects' correct judgment rate and RT at reaction time were analyzed experimentally. RT at reaction time was calculated as RT=RT3-RT2. Where RT3 indicates the average reaction time for each time distance judgment under the influence of each color, which was obtained from Experiment 3; RT2 indicates the average reaction time for each time distance judgment, which was obtained from Experiment 2. A total of 13,500 data were collected, and this research excluded some invalid data according to the different basal response times of each subject, and then excluded a total of 4,042 invalid data after removing the extreme values according to the box plot, leaving 9,458 valid data. Two-factor repeated measures analysis of variance (ANOVA) was used to analyze the subjects' correctness and RT values, respectively. The analysis factors included hue (blue-red-yellow), Saturation (30%,65%,100%) not conforming to the spherical hypothesis were corrected using the Greenhouse Geisser method, and the partial Eta-squared (eta-squared, η p2) was calculated as a measure of the amount of effect.

5 Results

Statistical analysis of the experimental results was performed using SPSS 26.0 software. First, a two-factor repeated measures ANOVA of 3 (hue: blue, red, yellow) x 3 (saturation: 30%, 65%, 100%) was performed on the reaction time, and the results are shown in table 1 and fig 3 which were drawn by the author: (1) The main effect of hue type was significant ($F=6.401$, $p<0.01$, i.e.), the difference in reaction time was judged significantly at different hues of time distance. (2) The main effect of saturation type was not significant ($F=0.422$, $p=0.656$) the difference in response time of the temporal distance judgment under different saturation was not significant. (3) Hue and saturation type interaction were significant ($F=2.919$, $p<0.05$).

Further simple effects analysis revealed that when the saturation prime was fixed, the difference was marginally significant at 30% saturation for items with blue-yellow tones ($p=0.052$) in RT; at 65% saturation, the difference was significant for both red & blue hues ($p=0.007$) and red &yellow hues ($p=0.003$) in RT; and at 100% saturation, the difference of RT was marginally significant for items with blue & yellow hues ($p=0.081$) .When stablized the hue primes, difference between 65% and 100% saturation item responses in yellow hue only ($p=0.039$)There was no significant difference at all other hue levels in the response of individual items. The authors' data collection and statistics are presented in table 2 and table 3.

Table 1. RT: Hue &Saturation

	df	F	Sig.
Saturation * Hue	4	2.919*	0.02
Hue	2	6.401**	0.002
Saturation	2	0.422	0.656

a.R^2 = .003 (adjusted R^2 = .002)
b.*: $p<0.05$, **: $p<0.01$

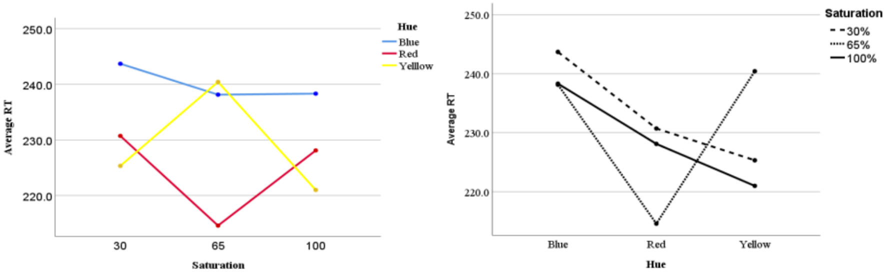

Fig. 3. Average RT of Three Hue levels (*left*) & Average RT of Three Saturation Levels (*right*)

Table 2. Simple effect analysis of RT

Attribute			MD	SE	Sig.
	B	R	12.981	7.702	0.276
30%	B	Y	18.374	7.718	0.052
	R	Y	5.393	7.698	1
	B	R	23.557*	7.788	0.007
65%	B	Y	-2.289	7.814	1
	R	Y	-25.845*	7.788	0.003
	B	R	10.216	7.791	0.569
100%	B	Y	17.33	7.843	0.081
	R	Y	7.114	7.763	1
B	30	65	5.559	7.768	1
	30	100	5.378	7.797	1
	65	100	-0.181	7.843	1
R	30	65	16.135	7.722	0.11
	30	100	2.613	7.696	1
	65	100	-13.521	7.736	0.242
Y	30	65	-15.104	7.764	0.155
	30	100	4.334	7.764	1
	65	100	19.438*	7.814	0.039

a. B for blue hue; R for red hue; Y for yellow hue.

b.*. The significance level of the difference of the means was 0.05.

Table 3. The mean of nine attributes each & ANOVA of attribute and RT

Attribute	M	SD	SE	df	F	Sig.
R65	214.58	172.42	5.31	8	3.164**	0.001
Y100	220.99	168.07	5.21			
Y30	225.32	174.89	5.36			
R100	228.1	178.86	5.48			
R30	230.71	178.13	5.44			
B65	238.14	182.46	5.66			
B100	238.32	182.17	5.70			
Y65	240.43	174.97	5.43			
B30	243.7	189.22	5.80			

a.*: $p<0.05$, **: $p<0.01$

Furthermore, our team performed two-factor repeated measures ANOVA on RT using the attributes of the color block and interval as independent variables, no significant interaction between Attribute and Interval time were found (F=0.736, P>0.05). Data collection and statistics by authors are showed in table 4.

Table 4. RT: Attribute & Interval time

	df	F	Sig.
Attribute * Interval time	32	0.736	0.86
Attribute	8	2.881**	0.003
Interval time	4	167.728***	0.000

a.R^2 = .071 (adjusted R^2 = .067)

b.*: p<0.05, **: p<0.01, ***: p<0.001

Meanwhile, the inter-subject effect was tested on gender and color attribute: (1) The main effect of gender and attribute was both significant (F=5.772, p<0.05; F=3.203, P<0.01). (2) There was no significant interaction between Gender and attribute type (F=1.074, p>0.05). Data collection and statistics by authors are showed in table 5 and Fig 4.

Table 5. RT: Gender & Attribute

	df	F	Sig.
Gender * Attribute	8	1.074	.378
Gender	1	5.772*	.016
Attribute	8	3.203**	.001

a.R^2 = .003 (adjusted R^2 = .002)

b.* : p<0.05, **: p<0.01

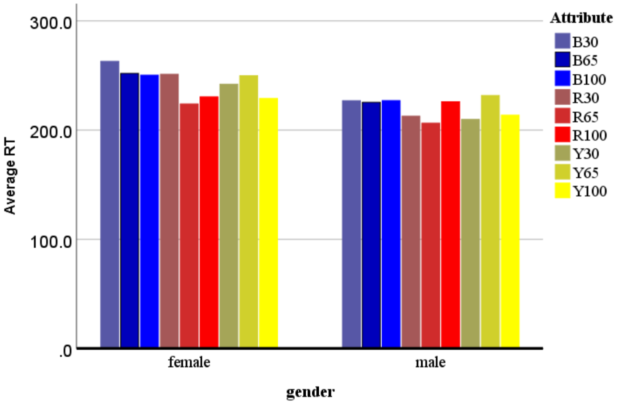

Fig. 4. RT of nine attributes in each gender

Our team also conducted a two-factor repeated measures ANOVA on the accuracy rate of 3 (hue: blue, red, yellow) * 3 (saturation: 30%, 65%, 100%), indicating no significant difference between the accuracy under each hue and saturation condition. The results showed: (1) Hue type main effect was not significant (F=0.919, p>0.05) (2) The main effect of saturation type was not significant (F=0.285, p>0.05). (3) Hue and saturation type interaction on accuracy were not significant (F=0.362, p>0.05).

6 Conclusion

Firstly, our research team members found the eccentricity of the yellow hue and 65% saturation. From the experimental results, Subjects had the shortest and fastest response times for *red 65%, yellow 100%*, and *yellow 30%*, and the slowest response times for *blue 100%, yellow 65%,* and *blue 30%*. What is striking is that yellow 65%, which is considered as warm color that should be recognized as quickly as red, displayed a longer RT than bule. And this disparity is remarkable in the yellow hue prime (F=3.416, p=0.003).

Subsequent simple effects analysis showed significant differences in time-distance perception between yellow and 65% saturation (p<0.05, p<0.01). In contrast to saturation, for red and blue, subjects had shorter reaction times to 65% saturation than to 100% 30% saturation, i.e., they perceived it longer, which overrides previous studies that found longer perception times for higher saturations [5] therefore 65% saturation seems to be an arrestive condition. In contrast to red and blue, subjects reacted longer to yellow at 65% saturation than to its 100% and 30% saturation, i.e., they felt it for a shorter period of time. The same uniqueness of yellow and 65% appears in the comparison of the different hues: subjects reacted longer to yellow blocks at 65% saturation compared to 30% and 100% saturation, giving a shorter perception time.

What is noticeable is that the yellow hue almost encompassed the second fastest and second (yellow 65%) slowest RT items, which seems to contradict previous findings on the perception of warm and cold colors on temporal distance perception, but little research on the effect of color on temporal distance perception is known for yellow. The different temporal distribution of yellow responses compared to red and blue may be influenced by color metaphors, such as yellow representing imperial power, or by the unique Chinese national culture, which causes differences in the processing of yellow [13-14] which our researchers contends that this contribute to specific culture of china [15]. Different genders also have different metaphors for yellow at the same time [10], and gender variables should be considered in subsequent studies.

The subjects in the experiment were composed of multiple majors, and this research found, quite interestingly, that the two subjects from sports majors had superior correct rates (Accuracy rate: 98%,87%) and response times, while the two subjects from certain other majors with sports habits had similarly superior correct rates and response times (Accuracy rate: 92%, 89%), which may result from un explored psychological or physiological traits brought about by long-term sports habits, replenishing the statement of Zheng Wei-Qi et that the expert advantage of Ming's long-term motor experience is mainly reflected in the temporal distance perception of the auditory channel[7], it might also conduce to the visual channel. And this finding buttress the movement effect for the color perception [16]

In summary, the influence of color on the perception of time is multidimensional and cannot be explored in isolation from a single factor of color hue or saturation on the perception of time. As the results show, the effect of color on temporal perception is non-linear. For instance, our researchers found that yellow does not guarantee a faster perception of time than blue, blue 100% faster than yellow 65%, therefore a multidimensional approach is required. On the other hand, since the existing definitions focus on the psychological sensations and associations that colors bring to people, the dimension of colors (e.g. warm colors &cold colors etc.) are not clear, for example, purple and green are taken as intermediate colors in some literature, while others take black, white, gray and brown as intermediate colors. To explore the influence mechanism of colors in depth, researchers need to further clarify the relevant dimension.

What is unsatisfactory is that this experiment used a gray background for stimulus presentation which is a vital element should be carefully controlled before the experiments [17]. But in the recent past other researchers found significant differences between blue and gray for time perception [18], suggesting that this may have some effect on the experimental results especially for bule prime. Succeeding experiments should avoid using the gray background as experimental material.

From the perspective of the current development in China, although the research on temporal distance perception has developed relatively quickly, there are still limitations in theoretical research and practical implementation and less research has been conducted to improve it. This study will only partially complement the research on perceptual perception, and more research is needed in the future.

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