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Reaction Times to Recognize Different Tonalities of Colours: A Cross-sectional Study

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Original Article

Abstract

Introduction: Colors have a great influence on the mood and mental states of human beings, and since humans are in close relation with the colors, the colors are very important. Colors play an active and effective role in everyday life. Therefore, they are among the most important visual elements that have emotional and psychological burden. Colors allow people to understand the environment, acquire information and orientate, and interact more with the environment. One of main factors affecting the success rate in computer games is the short enough reaction time to the stimulus. Therefore, the purpose of this study is to compare the reaction time in young people to different tonalities of the four main colors in psychology.

Materials and Methods: The sample consisted of 60 male and female students from Faculty of Multimedia, Tabriz Islamic Art University, Tabriz, Iran, who volunteered to participate in the study. Reaction times to different colors were measured in 20 randomized trials with five different tonalities of the four psychological primary colours (blue, green, yellow, and red). Data analysis was performed by repeated measures analysis of variance (ANOVA) and Tukey post hoc test.

Results: The least mean color reaction time was recorded for blue, which was significantly different from other colors (P = 0.002). In general, the mean color recognition time among females was reported longer than that in males, however this difference was not statistically significant.

Conclusion: The lowest and highest reaction time in young people was associated with blue and yellow, respectively. Therefore, using blue in danger signs may cause the viewer to react faster in order to reduce the risk of injury.

Keywords: Reaction time; Color tonalities; Color recognition; Players; Computer games

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Introduction

In daily life, human beings are in contact with various stimuli and the body system has been programmed in such a way that it can receive and respond to stimuli (1). In order for a human being to respond to a stimulus, the stimulus must first be received through receptors and its information must be transmitted through the peripheral nervous system (PNS) to the central nervous system (CNS), where the appropriate response can be selected and programmed (2). After the desired response is generated, it is transmitted to the target organ through PNS to execute the generated response (3).

The most accurate scientific definition of color is given in Webster's Dictionary. Thus, color describes the characteristic of an object as theme, brightness, and saturation, which stimulates the optic nerve with a visible wavelength (4). The term "primary color" means different colors in different contexts. When mixing pigments, the primary colors "red, blue, and yellow" are used (5). The primary colors in psychology are red, blue, yellow, and green (6). The color value or tonality refers to the darkness or lightness of a color and has eleven ranks in the spectrum of a color that extends from absolute black

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to absolute white. Therefore, for each specific color in practice, this spectrum includes 9 tonalities of each color (5). Man has reactions to colors, and this is the basic psychological definition of color (6). Which color the viewer reacts to faster, or in other words, recognizes faster, is of particular importance in various aspects of daily life such as transportation and design of emergency exit routes, etc. (7).

The human eye is a complex device for receiving light stimuli (8). In the structure of the eyes, there is a three-part system responsible for the sense of sight, with the first, second, and third parts dealing with the perception of shape, being responsible for the perception of color, and being related to the perception of position change and spatial organization, respectively (9).

Computer games are a cognitive activity that can improve cognitive and perceptual processes (10). In their study, Griffith et al. examined the optimal effect of computer games on eye-hand coordination. The subjects' task was to follow a light stimulus that moved at different speeds and in the form of different patterns (circle, square, and triangle) (11). Playing computer games requires fast information processing and providing logical and extremely fast answers (12). On the other hand, the information processing speed is measured by the reaction time to stimuli (1). One of the most important aspects of computer games is the appropriate and rapid reaction to visual stimuli (13). Colors, as one of the main visual stimuli in the design of computer games, are important because as visual stimuli, they stimulate color-related receptors in the player's brain and ultimately, create appropriate reactions in them (14). Green and Bavelier found in a study that computer gamers process visual information faster than others. Therefore, they stated that playing computer games improves visual processing at various levels, some of which have the effect of increasing the sources of attention; however, some others involve changes in the processing mechanism prior to attention (15). Reaction time is a very important indicator of the speed of decision-making and its efficiency and is the time interval between the unexpected presentation of the stimulus to the beginning of the response (16). Calculation of the reaction time begins when the stimulus is presented and ends when the response has begun (17). According to a classification by Schmidt and Wrisberg, reaction time consists of two stages, pre-movement and movement (18). The movement stage is affected by the age, sex, and weight of the organ that needs to move. The pre-movement time also includes three parts: "stimulus identification, response selection, and response planning" (19). Factors affecting the stimulus identification stage include "stimulus clarity, stimulus intensity, contrast between context and stimulus, and movement patterns" and factors affecting the response selection phase include "uncertainty and prediction of the game situation, number of response methods and compatibility between stimulus and response, and the complexity of the technique and the level of accuracy are influential in the response planning stage (18).

In the study of color recognition in the peripheral vision of athletes in different sports, Sage showed that red and blue colors were more recognizable than green and white. Therefore, it may be helpful to wear red or blue clothing so that group members can find each other during the competition (2). McMorris evaluated the effect of color on ball performance of the elementary school players using three balls of different colors in two background colors. He found that the individuals' scores when catching blue and yellow balls were significantly higher than white balls, but at the same time blue balls with white background and yellow balls with black background had a positive effect on catching the ball. McMorris stated that manipulating the background and ball colors may have an effect on catching the ball (20).

Hall-Zazueta examined the effect of six different colors through a computer screen on the time of reaction to a visual stimulus in different individuals and reported that the reaction time of the subjects was the lowest on a black background (21).

The simple reaction time is determined as a specific response at the maximum speed to the stimulus presented and the person does not need to recognize the stimulus and response (22). Due to the great importance of the reaction time in human life, various investigations have been carried out in this field and various factors affecting reaction time such as age, gender, number of stimuli, stimulus intensity, type of stimulus, dominant hand, and environmental color have been identified (23). It has also been shown that the reaction time can vary in different moods of individuals (24).

A review of previous studies indicates conflicting results regarding reaction time to visual stimuli. While some studies have reported a rapid reaction time for red compared to other colors, most studies have only examined the primary colors and have not discussed color tonalities. Due to the fact that colors are messengers and are an integral part of the computer game design process, players communicate with different colors in the video game environment. One of the influential and important factors in the success of players is the appropriate reaction time to the stimulus. Given the importance of colors and reaction time in computer games, the present study aims to examine the reaction time in the recognition of different color tonalities among players.

Materials and Methods

This study was a randomized clinical trial conducted at Tabriz Islamic Art University, Tabriz, Iran during two weeks. The present study was approved with ethics code IR.TABRIZU.REC.1399.020 by Tabriz Islamic Art University

When designing a game, the rules, goals, and theory of the game should be specified, along with the entertainment aspect for the players. A two-dimensional game was designed to evaluate the reaction time in detecting color tonalities in this study. The colors considered in the study included four primary colors in psychology including blue, green, red, and yellow (6). To evaluate the reaction time for each color, five steps were considered. In each step, the color tonality was selected from the primary color to the color with a higher or lower degree of saturation to avoid uniformity of the steps. For each color, 5 different color tonalities and in each color tonality, 8 colors (7 similar colors and one color with a tonality or color value of 2 degrees lower or higher) were considered. If the difference in color tonality was less than two degrees, it would not be easily visible to the naked eye (5). Therefore, in the present study, 5 tonalities out of 9 tonalities of each color were selected as every other one (to avoid dissimilarity of tests of each color). The reaction time of each color was measured five times (in different tonalities of each color) by clicking during the test and the average reaction time of the five stages of the test of each color was calculated.

In the game design process, 8 colored circles were considered for each stage, which were arranged around a circle and were moving at a constant speed in a clockwise or counterclockwise direction. In all tests, a gray circle was placed in the center of the circle (Figure 1).

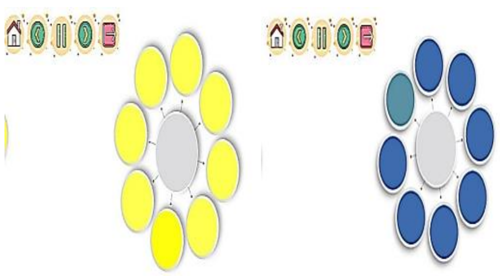

Figure 1. Pictures of the game environment

At each stage, there were 7 colored circles with the same color tonality and 1 circle with different color tonality (with a degree of saturation of two degrees lower or higher). The player had to click on a circle with a different color tonality. Thus, the click time indicated the detection time of a different tonality for that particular color. This process was repeated for five different tonalities of each of the four primary colors. The average time for the five tonalities of each color was reported as the average reaction time of each player to the tonalities of that particular color. To examine the reaction time, each color was measured five times (in different tonalities of each color) by clicking on the color circle with two degrees of saturation lower or higher during the test.

The central circle was gray and the peripheral circles were of the same color. In all the tests, there were 8 peripheral circles, 7 of which were the same color, and only one circle had a different tonality from the others. The player had to select this circle.

The selection of 20 test steps was performed randomly by random selection of colors; this means that in the present study, the order of the tests with different colors was different for the subjects; So that not everyone experienced the same sequence. If the players clicked correctly on a different colored circle, they would receive a positive score and enter the next stage, and if they clicked incorrectly, they would be returned to the first stage after three wrong clicks.

The study group consisted of male and female undergraduate and graduate students of School of Multimedia, Tabriz Islamic Art University. After the announcement of the invitation to participate in this project at Tabriz Islamic Art University, 60 volunteer students were selected by the convenience sampling method. The study inclusion criteria included age over 18 years and familiarity with the basics of visual literacy. In addition, visual defects (color blindness) were considered as the exclusion criteria. Prior to the start of the test, an informed consent was received from the participants and their demographic information was obtained before the test. In the next step, the process of the test steps was explained to the participants, however no explanation was provided to them regarding the objectives of the study.

To measure the initial data in the present study, the time measurement section of Unity software (Unity 2019.2.2.13f1 <DX11>, Unity Technologies, San Francisco, CA, USA) was used along with the test (by clicking the examinee). The participants took the test after sitting in the test site for a few minutes to relax and concentrate. First, a test was performed as a pre-test to familiarize the participants with the game environment, and the main test, which consisted of 20 steps, was performed randomly (by lottery) and by randomly selecting colors.

The normal distribution of the data of each variable was assessed using the Shapiro-Wilk test. Descriptive statistics were used to examine the mean and standard deviation (SD) and inferential statistics were used to examine the difference in color reaction time. In order to compare the color stimulus reaction time in different environments, the repeated measures analysis of variance (ANOVA) and Tukey post hoc test were employed to determine whether the time of reaction to the stimulus of different colors differed. Independent t-test was utilized to compare the time of reaction to the colors in both sexes. Data were analyzed using SPSS software (version 22, IBM Corporation, Armonk, NY, USA). $P < 0.05$ was considered as the significance level and the test power was determined by the Eta squared method.

Results

The demographic characteristics of the study samples are given in table 1.

Table 1. Demographic characteristics of the subjects

Variable		Value
Age (years) (mean ± SD)		21.75 ± 3.09
Gender [n (%)]	Female	30 (50.0)
	Male	30 (50.0)
Visual impairment [n (%)]	Healthy	23 (38.3)
	Near-sighted	22 (36.7)
	Far-sighted	2 (3.3)
	Astigmatism	13 (21.7)
	Colorblind	0 (0)

SD: Standard deviation

Color recognition time descriptive statistics: In the data reported for the reaction time of the four studied colors, according to the results of the Levene's test, variance homogeneity was established ($P \leq 0.055$). The results of the repeated measures ANOVA test suggested that the colors' reaction time was different from each other ($F_{(3,236)} = 18.998$, $P \leq 0.001$). Based on the findings in table 2, the mean reaction time to yellow was longer than the other colors. The reaction time following yellow was long for red and then green, and was shortest for blue.

Table 2. Average reaction time of tonality detection of each color in terms of time

Color examined	Number	Reaction time to color (seconds)	SE
Blue	60	1.84 ± 0.85	0.109
Yellow	60	3.56 ± 1.66	0.215
Red	60	2.74 ± 1.05	0.136
Green	60	2.57 ± 1.39	0.089
Total	240	2.68 ± 1.39	0.089

SE: Standard error
Data are reported as mean ± SD.

Recognizing the presence of a significant difference in the time of reaction to the four primary colors of psychology, the Tukey's post hoc test was used to determine whether the reaction time to each color pair examined was significantly different from each other. The results of the pairwise analysis of color reaction time are presented in table 3.

Table 3. Results of pairwise comparison of the mean color reaction time

Target color pair	Mean difference	SE	P
Blue-yellow	-1.720	0.229	≤ 0.001
Blue-red	0.900	0.229	≤ 0.001
Blue-green	-0.733	0.229	0.002
Yellow-red	0.922	0.229	≤ 0.001
Yellow-green	0.990	0.229	≤ 0.001
Red-green	0.167	0.229	0.466

SE: Standard error

The mean reaction time to red and green colors did not show a significant difference (Mean difference = 0.167, $P \leq 0.466$); while for all other color pairs, a significant difference was observed in the reaction time ($P \leq 0.002$). The difference in the mean reaction time for blue and yellow was more than that of any other pair (Mean difference = -1.72). The comparison between the male and female subjects revealed that despite the shorter color reaction time in the males for all four colors, this difference was statistically insignificant (Table 4).

Table 4. Mean time of reaction to colors by gender

Colors	Gender	Number	Color reaction time (seconds)	P	Power analysis
Blue	Female	30	2.01 ± 1.02	0.116	0.0780
	Male	30	1.66 ± 0.59		
Yellow	Female	30	3.75 ± 1.93	0.382	0.0511
	Male	30	3.37 ± 1.34		
Red	Female	30	2.88 ± 1.93	0.297	0.0621
	Male	30	2.59 ± 0.77		
Green	Female	30	2.73 ± 1.52	0.351	0.0587
	Male	30	2.41 ± 1.04		

Data are reported as mean ± SD.

Power analysis showed that the sample size was suitable for this study; however, a larger sample is needed to compare women and men.

Discussion

In the present cross-sectional study, the mean reaction time to the four primary colors of psychology in 5 different tonalities was examined among healthy young subjects. The findings demonstrated that the reaction time to the blue visual stimulus was less than that of other colors (green, red, and yellow). In fact, the healthy young viewer responded to the blue stimulus faster than other colors. The short reaction time to this color may be due to the higher speed of information processing or the transmission of related neural messages in the body (25).

In a study, Lockley et al. concluded that blue light had the greatest effect on circadian rhythms affecting melatonin (26). This effect may be due to the stimulation of blue light-sensitive cone receptors (wavelength about 460 nm) (27). In a study by Zeitzer et al., it was found that 6.5 hours of daily exposure to blue light with a wavelength of 460 nm affects circadian rhythm, alertness, and melatonin secretion twice as long as exposure to yellow light with a wavelength of 555 nm (28). This effect depended on the intensity, duration, and wavelength of the blue light and may have been due to the processing of this light in the upper logic of vision (26). According to Zeitzer et al., this phenomenon can be one of the factors influencing the overall reaction time. Perhaps the reaction time to blue light is shorter due to its effect on insomnia and consciousness level (28).

Studies have shown that blue light in both humans and animals causes sensitivity of retinal ganglion cells (RGCs). These cells are sensitive to short wavelengths, i.e. blue, and indirect processing of blue light in these areas may increase consciousness in the blue environment by 30% (29); this was consistent with the findings of the present study. Because the examinees also reacted to blue less compared to other colors and it can be concluded that the participants performed better against this color due to increased consciousness. In their study, Muzaffar et al. showed that blue is the best and most popular color for the exam hall, which probably goes back to the calming effects of this color, as well as reducing the level of arousal and stress in humans (30). This finding suggests that blue may be a better option for marking high-risk routes and reducing the risk of accidents, as well as marking equipment and tools for individuals with cognitive and motor disabilities, and that yellow and red are not suitable to these goals, contrary to the public belief. Additionally, in case of need to use two colors at the same time, the best possible combination is yellow-blue, which attracts visual attention without creating arousal.

Limitations

Due to the limited statistical population of the subjects (students of School of Multimedia), the results obtained from the present study cannot be generalized to all members of the community (in terms of age and education).

Recommendations

In order to increase the accuracy of the test results, a more diverse statistical population in terms of age and education is required, which can be achieved by using the Internet (which is available to most people in the community). The results of the present study can be used in the design of web pages and computer advertisements, and even in the field of reducing traffic accidents or any other situation that requires a quick reaction or even a lack of quick reaction.

Conclusion

The reaction time for blue and yellow was respectively shortest and longest in the young participants. The use of blue color to show danger signs may cause the viewer to react faster and reduce the risk of injury.

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Authors' Contribution

Nasrin Shahabi: Study design and ideation, attracting financial resources for the study, supportive, executive, and scientific study services, providing study equipment and samples, analysis and interpretation of results, specialized statistical services, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Elaheh Ghorbani: Study design and ideation, attracting financial resources for the study, supportive, executive, and scientific study services, providing study equipment and samples, data collection, analysis and interpretation of results, specialized statistical services, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments; Yoones A. Sekhavat: analysis and interpretation of results, manuscript preparation, specialized evaluation of the manuscript in terms of scientific concepts, approval of the final manuscript to be submitted to the journal office, the responsibility of maintaining the integrity of the study process from the beginning to the publication, and responding to the referees' comments.

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Conflict of Interest

The authors declare no conflict of interest.

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