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Research article

Color Vision Deficiency and Video Games Performance

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Abstract

Background: Video games are a global phenomenon that may affect functional vision. The impact of color vision deficiencies (CVD) on video game performance is, however, little understood. This study will investigate the impact of color vision deficiency on the individuals' performance of playing video game and how effective are the new implemented color settings.

Methods: Thirty-six healthy (nine with color vision deficiency) adults participated in this study. Of them, fourteen are video gamers, with five CVD people. Basic vision functions such as visual acuity, contrast sensitivity and color vision were measured. An action video game on a PlayStation® 4 Pro (PS4™) was played. Color vision defectives had an extra task to perform with a color vision setting to determine the effectiveness of such a setting.

Results: Video game performance showed a significant difference between subject groups (video gamers vs. non-video gamers) ($F = 60.631$, $df = 1$, $p < 0.0001$). However, there was no significant difference within subject groups (while using color vision defect mode) ($F = 0.901$, $df = 2$, $p = 0.414$), or significant interaction ($F = 0.081$, $df = 2$, $p = 0.923$). The status of color vision did not change the performance significantly for either group. Also, subjects with color vision defects improved their performance minimally, but this improvement was not significant.

Conclusion: This work has determined the impact of color vision deficiency on video gamers and no video gamers' performance. It has also assessed the usefulness of the color setting implemented in some games to facilitate and equalize the opportunities between color vision defectives and normal color vision individuals. Regardless of color vision type, there was no significant difference in performance between gamers and non-gamers (particularly with color settings included in the game). This hypothesis needs to be investigated with a larger sample size of color defective individuals.

Keywords: *Video Games; Color Vision Deficiencies (CVD); Functional Vision*

Introduction

Video games are becoming one of the most popular leisure activities worldwide [1,2]. Lenhart., *et al*. (2008) found that 75% of the high school students in the US play video games at least once a week [3]. They also reported that 49% of American adults (> 18 years) play video games at least a few times a week [4]. Video games have become associated with individuals' eye disorders. Extensive video games may lead to eyestrain. The overuse of video games may also result in headaches, dizziness, and in some cases, nausea and vomiting [3,4].

Even though video games have some impact on visual function, video gamers with normal visual function have shown good performance in their games. Scholars showed the impact of action video games on visual-spatial and temporal resolution. They found that action video gamers have better spatial attention than non-video gamers [3,6,7]. Li., *et al*. (2009) found that the contrast sensitivity function was better in those who play action video games [8]. Green., *et al*. (2007) found that action video gamers show improvement in crowded visual acuity [9]. In addition, chromatic stimuli intensity, brightness, and saturation of a video game environment produce an emotional effect on players. Further, video gamers who regularly play action video games for more than an hour a day enhance their function in daily life activity. The improvement in the new generation of video games has increased the visual and cognitive demands [8,9].

Color vision deficiency is one of the most common vision disabilities; congenital red-green CVD is the most common type, which affects 8% (around 8.3% for males and around 0.5% for females) of the American population [10]. This condition is inherited and caused by a common X-linked recessive gene. People with congenital red-green color vision deficiency have normal visual function, except they have a disability in distinguishing shades of colors. Gamers with color vision deficiency struggle to have a good gaming experience when playing games that are color-dependent tasks.

Video game developers have recently provided a color vision defective setting that could help this group of people to play the game as easily as normal color vision. This was created by an in-game simulator that reproduces the colors in the game to be easily distinguishable. Scholars discussed how games affect the players' emotions and how players with motor difficulties use their eyes instead of their hands to enjoy their gaming experience; however, there is little information available about the color defective and their game's performance. This study will assess how color vision deficiency can negatively impact the player's performance in many games and how useful are the color vision deficiency game settings affecting their performance.

Methods

The study was reviewed and received clearance through the King Saud University Institutional Review Board (IRB E-21-5742) and was conducted according to the Declaration of Helsinki guidelines.

Apparatus

The video game was played on PlayStation® 4 Pro (PS4™) console and controller viewed on a 27" EX Series (EX2780Q) LED with HDRi @144HZ BenQ gaming TV monitor. The monitor was calibrated every four weeks using a Spyder colorimeter (ver 4.5.4; Datacolor, Lawrenceville, NJ) to a white reference of 6500° K correlated color temperature The action video game was a first-person shooter game called "Call of Duty®: Black Ops III".

Screening for inclusion criteria

After giving their informed consent, subjects conducted an oral questionnaire on basic demographics, general and ocular health, medications and video gaming questions. The participant's binocular visual acuity was determined using their usual spectacles, which were defined as those worn while driving, walking, and other daily life tasks. At a distance of 4 meters, visual acuity (VA) was determined using the ETDRS visual acuity chart "R," which is available from Precision Vision (www.precision-vision.com) [11]. The chart's luminance ranged from 80 to 120 cd/m^2. Visual acuity was measured in logMAR using by-letter scoring [13,14].

Contrast sensitivity was measured using Pelli-Robson chart (Precision Vision, IL, USA), available from Precision Vision (www.precision-vision.com). Test was performed binocularly wearing habitual correction if applicable at 1 meter.

Subjects were given two color vision tests; an Ishihara (the 38-plate edition, Kanehara & Co., Ltd, Tokyo, Japan, 1996) plates for screening, followed by the Hardy, Rand, Rittler (HRR) test 4th Edition (Richmond Products, Albuquerque, NM). A LED lamp (NEW POWER, Model no: G45-14 E27) with a correlated color temperature of 6500K illuminated the test. The correlated color temperature and CRI are the manufacturer's specifications. Illuminance was 1000 lux (± 5%) in the horizontal plane of a white table where the tests were located. Subjects viewed all the tests binocularly from approximately 50 cm and were asked not to touch the colored portion in each test. The examiner records the subjects' responses for each plate.

Subjects

Subjects were students and staff recruited voluntarily from at the College of Applied Medical Sciences, King Saud University and their friends or family members. The study included participants aged between 16 to 40 years. There were two groups of participants: video game players, who spend more than 5 hours/week in action video gaming, and non-video game players. Each group was divided into two sub-groups: normal color vision and congenital color vision defective. The color vision defective groups were compared to reference (normal color vision) groups. All groups consisted of subjects with best-corrected visual acuity of at least 6/7.5 (20/22.5) or better binocularly with no general diseases known to affect vision or have any ophthalmic abnormalities that affect vision or cause acquired color vision deficiency. The final sample size was N = 36 approximately two-thirds of the participants (n = 22) identified as non-video gamers (63%), video gamers: N = 14 (37%). In terms of color vision defect, there were nine color vision defective participants. Five of them were video gamer, and 4 were non-video gamer (Table 1).

The PlayStation® 4 Pro (PS4™) video games

A PlayStation® 4 Pro (PS4™) console with a joystick controller was used for the video game. Players were assigned to play a first-person shooter video game called "Call of Duty Black ops III". This video game has a color vision defective setting for protans, deutans and tritans. Participants received a short introduction to the game and its controller. To familiarize themselves with the game controls, participants first played the training match for about one minute. When players felt comfortable with the controls, they played one complete game set for three minutes.

The task was to play as a member of a team of four against four enemies. First task was done through standard color setting first; then, color defectives setting was applied if color vision deficiency is detected. The performance was assessed in terms of eliminating as many enemies as possible and avoiding being eliminated. The score was given at the end of each round. Additionally, the death/kill ratio, where the number of killed enemies was divided by the number of player deaths was calculated. The game simultaneously measures the players' performance according to their final score at the end of the game. The results of this task will be then compared to players with normal color vision.

Results

The study consists of two main groups (video gamers and non-video gamers). For each group, there are two categories of subjects (normal color vision and color vision defects). On the color vision defected groups, the new implemented color setting was conducted. Table 1 summarizes the descriptive data for each category, including the sample size, mean, and standard deviation of score performance.

A two-way analysis of variance (2-Ways ANOVA) test was conducted to analyze the results. The video gamer status (video gamer vs. non-video gamer) was considered as a between-subject group factor and the color vision status (normal color vision, color vision defect, color vision defect with color setting) was within the subject group factor. The two-way ANOVA test showed that there is a significant difference between subject groups ($F = 60.631$, $df = 1$, $p < 0.0001$), but there is no significant difference within subject groups ($F = 0.901$, $df = 2$, $p = 0.414$), or significant interaction ($F = 0.081$, $df = 2$, $p = 0.923$). Taken together, these results showed that video gamer subjects had a higher performance score compared to non-video gamer subjects. Figure 1 shows the results. However, the status of color vision did not change the performance significantly for either group. Also, introducing filters to subjects with color vision defects improved their performance somewhat but not significantly.

Groups	Color Vision Status	N	Score Mean	Score Std. Deviation
Video Gamer	NCV	9	2344.44	989.77
	CVD with no color setting	5	2030	400.94
	CVD with color setting	5	2350	777.82
Non-Video Gamer	NCV	18	811.61	353.49
	CVD with no color setting	4	500	324.037
	CVD with color setting	4	637.50	370.52

Table 1: *Summary of the descriptive data for each group of subjects (N = 36).*

**N: Sample Size, NCV: Normal Color Vision, CVD: Color Vision Deficiency.*

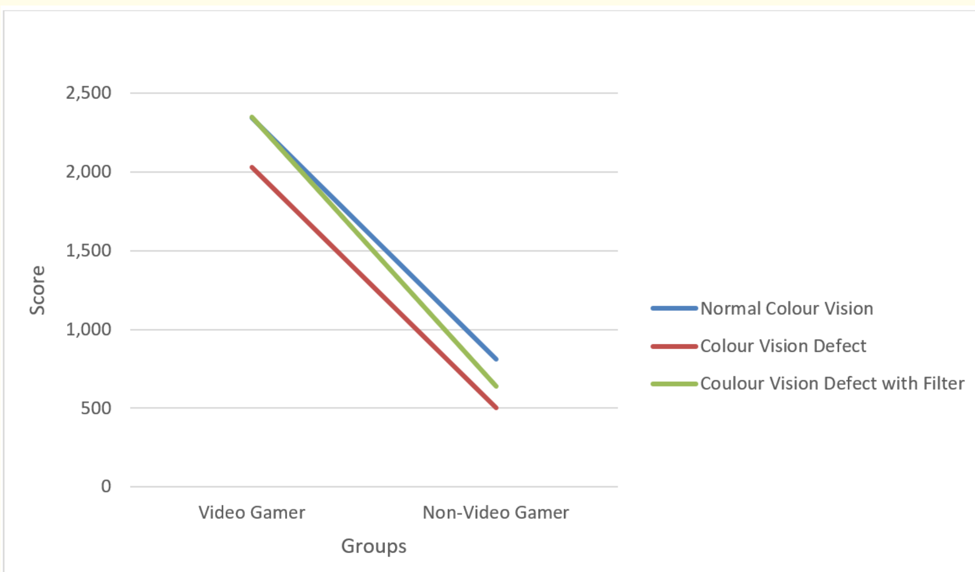

Figure 1: *The performance of video gamers compared to non-video gamer subjects.*

Discussion

In the modern world, video games are no longer played only for pleasure and entertainment. In addition to their financial benefits, video games become crucially involved in medical, perceptual and attentional stimulation and treatment [14-17]. This study aimed to measure the impact of color vision deficiency on performance for gamers and non-gamers and the usefulness of recently implemented color enhancement settings to facilitate and equalize the opportunities between color vision defectives and normal color vision individuals. The primary outcome of this work was showing a significant effect between gamers and non-gamers. This was expected and had been evaluated in the literature [19]. On the other hand, there was no significant difference between normal color vision, color vision defect, and color vision defect with the color setting. This might be related to the smaller sample size and the severity of color vision defect. The more severe cases are expected to perform better when using the color vision defective setting. Nevertheless, recruiting a larger sample and considering the severity of color vision deficiency would probably come up with opposite or different findings. Despite the slight improvement revealed in our study utilizing game-embedded color vision setting, it was not significant enough to improve their scores; that might be explained by the way these setting is manipulated. Most, if not all color vision defective setting is manipulating colors only which is rarely yet could improve the performance in case of very mild CVD. Contrastingly, instead of changing colors to improve contrast, which is entirely reliant on color distinction abilities, using a unique curser (i.e. a different icon, symbol) or involving other modalities could be sufficient. Hairston., *et al*. (2005) proved that using multisensory (audio and visual in this case) stimuli or cues would improve temporal and spatial recognition abilities [18]. Therefore, implementing sonification is also suggestive of enhancing the usefulness of these color setting. Further work is needed by assessing the severity and obtaining the use of these color setting among the color defective group with different types and levels of severity. Moreover, employing games that allow the use of unique curser.

Gaming and streaming games, in addition to attending organized competitions, have become a full-time job and the only source of income for many young adults, especially males, where color vision deficiency is also more common. Most of these games are based on attention and visual abilities. Strategy games are mainly based on camouflage, which is dependent on color vision. Moreover, playing sports games where the opponent's jersey is similar to your team's would raise the difficulty of winning to the highest levels. This highlights the importance of developing new color vision defective's setting to increase their chances of getting more involved in the gaming industry.

Conclusion

This work has determined the impact of color vision deficiency on both the video gamer's and non-video gamer's performance. It has also assessed the usefulness of the color setting implemented in some games to facilitate and equalize the opportunities between color vision defectives and normal color vision individuals. There was no significant effect between gamers and non-gamers' performance regardless of their color vision status. This hypothesis needs to be tested with a larger sample size of color-deficient individuals.

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