Exploring the Impact of Avatar Color on Game Experience in Educational Games

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CHI'16 Extended Abstracts, May 7–12, 2016, San Jose, CA, USA.
ACM 978-1-4503-4082-3/16/05.
http://dx.doi.org/10.1145/2851581.2892281

Abstract
The color red has been shown to hinder performance, motivation, and affect in a variety of contexts involving cognitively demanding tasks [16, 47, 49, 22, 11, 32, 44, 64, 41]. Teams wearing red have been shown to impair the performance of opposing teams [7, 28, 57, 21], present even in online gaming [27]. Although color is strongly contextual (e.g., red-failure association), its effects are posited to be sub-conscious [15] and operate powerfully even on nonhuman primates, e.g., Rhesus macaques (*Macaca mulatta*) take food significantly less often from an experimenter wearing red [39]. Here, we present one of the first studies on avatar color in a single-player game. We compared players using a red avatar to players using a blue avatar. Using the Game Experience Questionnaire (GEQ) [26], we find that players using a red avatar had a decrease in competence, immersion and flow. Our results are of consequence to how we design and choose colors in single-player contexts.

Author Keywords
Avatar Color; Educational Games; Virtual Identity; Avatars

ACM Classification Keywords
K.8.0 [**Personal Computing**]: General – Games

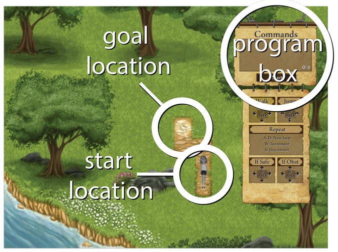

Figure 1: Level 1 in *Mazzy* introduces the basic game mechanics.

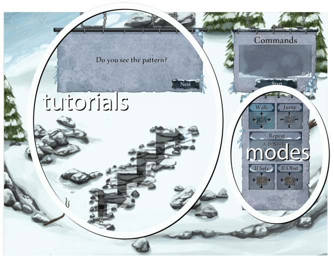

Figure 2: Level 6 introduces looping.

Introduction

Over 120 years of research on color and its effects on humans have led to Color-In-Context (CIC) theory [10]. CIC has six premises: (1) Color carries meaning, i.e., color is more than aesthetics, (2) Color influences psychological functioning, e.g., colors are evaluated to be hospitable or hostile [3, 9, 66, 42], (3) Color effects are outside of conscious awareness [56, 40, 45], (4) Color meaning is both learned and intrinsic, i.e., paired color associations such as pink is feminine; color vision as an adaptation [52, 29, 24, 4], (5) Color perception influences affect, cognition, and behavior, and vice versa [50, 19, 2], (6) Color is context-specific, e.g., pink is frequently viewed as feminine on a baby's blanket, but not on Bazooka bubble gum [65].

This gives us a framework for understanding how color may affect us in digital spaces. For example, most students in primary school are primed to associate red and failure in an evaluative context [62, 61, 51, 47][1]. Moreover, red has associations with blood, danger, fire and anger. Red has been posited to be a distractor signal. Since Hill's seminal paper on the Athens Olympic Games in 2004 in which it was found that red-wearing competitors won more bouts than blue-wearing competitors in four different sports [21], there has been a plethora of research on color, motivation, and achievement. Later work found this work to be consistent in a variety of sporting domains [7, 28, 57, 21], and even in an online FPS game [27].

However, one gap in the literature is color in single-player contexts[2]. To fill this need, we performed a study comparing players using a red avatar to players using a blue avatar, inside an educational game of our own creation. Although there is some question to whether, in the context of a sporting event, the color red is affecting the wearer, the opponents, or the referees, past work has consistently shown that red reduces mood, affect and performance in cognitive-oriented tasks [16, 47, 49, 22, 11, 32, 44, 64, 41]. For example, Lichtenfeld et. al showed that even just peripherally noticing red (e.g., hidden in a question, in the copyright notes at the end of a page, etc.) can have similar effects [44]. For this reason, we hypothesized that, if there were to be any effect on performance and game experience, that it would favor the blue avatar over the red avatar.

[1]This association is not necessarily true across culture. For instance, an upward rise in China's stock market is represented in red [67, 30].

[2]Multiplayer studies on color exist [27, 5, 58], as do a few on colored environments [54, 31], but there are few studies on avatar color in single-player games.

Motivation

The work here is based on the premise that, along with factors such as subject mastery and affect toward the subject, a sense of identity as a STEM learner and doer is necessary for developing literacy and agency in computing [20]. The standard paradigm of computer-science education research traditionally focuses almost exclusively on cognitive challenges apparently inherent to particular computational concepts (e.g., [1]). Veeragoudar Harrell states that developments in the learning sciences suggest that computer-science curricula should embrace a broader conceptualization of learning: human reasoning, it is proposed, is embodied, distributed, and situated, and learning must be accordingly perceived as inherently collaborative, contextualized, and instrumented [6, 17, 25, 43, 20]. A result of this broader view of human reasoning and learning in the STEM disciplines is the emergence of research on relations between student identity and learning [18, 43, 53]. Recent work has shown that carefully selected colors can help induce student emotions that facilitate comprehension and transfer [60]. Digital manifestations of such phenomena are important areas for investigation since avatars are now frequently used in videogames, Massive Open Online Courses (MOOCs) and forums, intelligent tutors, and more.

The Game

The experiment takes place in a STEM learning game called *Mazzy* [35]. *Mazzy* is a game in which players solve mazes by creating short computer programs. In total, there are 12 levels in this version of *Mazzy*. Levels 1-5 require only basic commands. Levels 6-9 require using loops. Levels 10-12 require using all preceding commands in addition to conditionals. See Figures 1 and 2. *Mazzy* has been used previously as an experimental testbed for evaluating the impacts of avatar type on performance and engagement in an educational game [38, 36, 34, 37, 33].

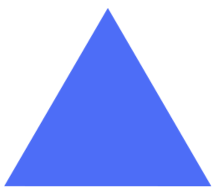

Figure 3: Blue Avatar.

Methods

Our experiment aims to compare two colors of avatar: (a) blue avatar, and (b) red avatar. The goal is to see if participants using the two colors of avatar have differing game performance and game experience as measured by the GEQ. We strongly suspected ahead of time that results would favor the blue avatar.

Avatar Conditions

The two avatar conditions we tested were:

a. Blue Avatar
b. Red Avatar

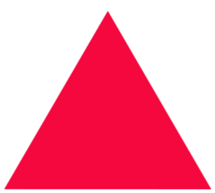

Figure 4: Red Avatar.

The avatar was a triangle shape in both conditions, colored either blue or red. Color is defined by lightness, chroma, and hue. We keep lightness and chroma constant using the Munsell color system [12]. Only colors that can be displayed with good accuracy on a computer screen were considered[3]. The specific colors chosen were *7.5PB 5/18* (▲) and *5R 5/18* (▲). See Figures 3 and 4. Inside the game, the avatar consists of a 60 x 60 pixel game character that moves according to the user's programs.

[3] http://www.andrewwerth.com/aboutmunsell/

Quantitative and Qualitative Measures

For performance, we only analyze the number of levels completed by players. For measuring game experience, we use the GEQ [26].

Participants

507 participants were recruited through Mechanical Turk. The data set consisted of 278 male, and 229 female participants. Participants self-identified their races/ethnicities as white (407), black or African American (29), Asian Indian (24), Chinese (5), Korean (4), American Indian (3), Vietnamese (3), Japanese (2), Filipino (1) and other (29). Participants were between the ages of 18 and 65 (M = 30.3, SD = 8.7), and were all from the United States. Participants were reimbursed $1.50 to participate in this experiment.

Design

A between-subjects design was used: avatar color was the between-subject factor. Participants were randomly assigned to a condition.

Protocol

Prior to starting the game, players were informed that they could exit the game *at any time* via a gray button in the corner of the screen. When participants were done playing (either by exiting early, or by finishing all 12 levels), participants returned to the experiment instructions, which then prompted them with the GEQ and then a demographics survey.

Analysis

Data was extracted and imported into Statistical Package for Social Science (SPSS) version 22 for data analysis us-

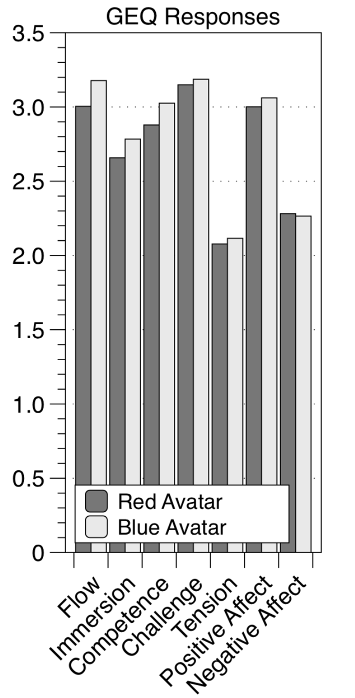

Figure 5: Game Experience Questionnaire (GEQ) responses for all participants.

ing multivariate analysis of variance (MANOVA). The dependent variables were- *GEQ items*; and the independent variable was- *avatar color (blue or red)*. All the dependent variables are continuous variables. The independent variable avatar color (i.e., 0 = blue, 1 = red) was a dichotomous variable. To detect the significant differences between blue avatar and red avatar, we utilized one-way MANOVA. We also ran an independent-samples t-test on the variable- *levels completed*. These results are reported as significant when p<0.05 (two-tailed). Prior to running our MANOVA, we checked both assumption of homogeneity of variance and homogeneity of covariance by the test of Levene's Test of Equality of Error Variances and Box's Test of Equality of Covariance Matrices; and both assumptions were met by the data (p>.05 for Levene's Test, and p>.001 for Box's Test).

Results

Aggregate

A MANOVA revealed a statistically significant difference in GEQ responses based on the participant's avatar color, F(42, 464) = 1.43, p <.05; Wilk's λ = 0.885, partial η^2 = .12. See Figure 5. Pair-wise comparisons revealed that the blue avatar GEQ rating was higher on "I was fully occupied with the game" (*flow*), p = .015, "It felt like a rich experience" (*immersion*), p = .018, and "I felt competent" (*competence*), p = .044. Blue was marginally higher on "I felt completely absorbed" (*flow*), p = .058, "I forgot everything around me" (*flow*), p = .077, "I lost track of time" (*flow*), p = .056, "I felt imaginative" (*immersion*), p = .099, "I felt that I could explore things" (*immersion*), p = .094, "I felt skillful" (*competence*), p = .068, "I was good at it" (*competence*), p = .059, and "I felt successful" (*competence*), p = .061. The other dimensions (challenge, tension, affect) showed no significant differences. Levels completed by players using red (7.80) did not significantly differ from players using blue (7.74), p >0.05.

Gender

We wanted to investigate if the previous differences appeared to affect both genders. From Figure 6, we can see that the general trend is the same as in Figure 5 for both genders (i.e., blue > red across the three measures). However, the effect appears to be weaker in female participants. The effective difference in male participants compared to female participants is 12x larger for *flow*, 3x larger for *immersion*, and 1.3x larger for *competence*. These results are consistent with literature that suggests red is more impactful on men [21, 23].

Text Responses

Using Linguistic Inquiry Word Count (LIWC) 2015 [59], we analyzed text responses of participants' answers to "Describe how you felt about your avatar". LIWC found that negative sentiment was significantly higher for players using the red avatar (6.09) than for players using the blue avatar (3.29), t(503) = 1.973, p <.05. Positive sentiment in players using the red avatar (8.18) did not significantly differ from players using the blue avatar (8.85), p >.05.

Were the colors hard to see?

To determine if the color negatively interacted with the game background, participants were asked "The avatar was hard to see" (1: *Not at all*, to 5: *Extremely*). Both blue participants (M = 1.36, SD = 0.76) and red participants (M = 1.30, SD = 0.70) had low scores, suggesting both avatar colors were clearly visible. Scores did not differ between the two conditions, p >.05.

Limitations

Color stimuli varies on hue, lightness, and chroma. According to Elliot et. al [10], nearly all existing studies fail to control for these in color manipulations. This makes both interpretation and replication impossible. For example, the majority of research uses hues which the investigators believe

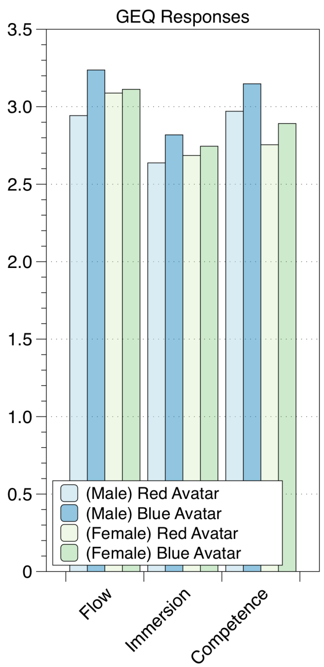

Figure 6: Game Experience Questionnaire (GEQ) responses for male and female participants.

are the most ideal representatives. However, the problem is that this almost undoubtedly confounds color properties; for instance, “prototypical red” is more intense than “prototypical yellow”.

The colors in this paper were selected from the Munsell color system, such that the following criteria were met: (1) the colors are equal in lightness and chroma, (2) the colors do not clash with the game interface, and (3) the colors are accurate on calibrated monitors.

Nonetheless, users each have their own individual monitors, graphic cards, and calibration settings. Not all users will see “exactly” the same color (as in a laboratory setting), but this approach strengthens external validity and reflects realistic applied settings. We do note that our participants were all from the U.S.

Discussion

We summarize our results:

- Blue led to **higher flow** than Red
- Blue led to **higher immersion** than Red
- Blue led to **higher competence** than Red
- Blue led to **higher (avatar) affect** than Red

Our results suggest that avatar color has significant effects on player flow, immersion, and competence. Although we have only investigated two of the colors most prevalent in literature [49], it’s reasonable to hypothesize that other colors may also impact players. For instance, it was found in [31] that different colored *environments* may impact affect. To the best of our knowledge, this is one of the first studies to research the effects of avatar color in a single-player context. These results extend and support work on first-person shooter (FPS) multiplayer games in which it is hypothesized that blue teams are at a disadvantage because they “see red” [27].

In this study, we found that red had a negative effect on participant flow, immersion, competence, and avatar affect. Biologically, it has been hypothesized that the color red is a distractor signal to humans. Red causes a lower so-called high frequency heart rate variability (HF-HRV), measured via an electrocardiogram (ECG) [8]. These lower levels of HF-HRV are correlated to an increase in worry and anxiety [14, 13, 49].

However, color is context-specific. Although the color red has been found to hinder motivation, performance, and affect in cognitive tasks [16, 47, 49, 22, 11, 32, 44, 64, 41], red has been shown to promote approach-like tendencies when in the context of “dating” [48]. The current investigation used as a setting a computer science learning game, and so it is reasonable to predict that red is hindering. Such effects may translate to changes in academic self-concept [63]. However, were the color red presented in the context of, e.g., a social game ([46, 55], etc.), it’s possible that it’s effects would be less negative.

Conclusion

This paper has explored the effects of avatar color. Our results suggest that the color of game avatars does impact player experience in significant ways. Game developers should be aware of the cognitive effects of using colors, both general as well as context-sensitive impacts. Information about general results, such as articulated in this paper in a case study considering our use of red, can lead educational game developers to make more informed choices about color in specific settings in light of user and developer needs and values.

Acknowledgments

We would like to thank the anonymous reviewers for their valuable feedback. This work is supported by NSF STEM+C Grant 1542970 and a Natural Sciences and Engineering Research Council of Canada (NSERC) fellowship.

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