Exploring the Influence of Avatar Skin Tone in VR Educational Games

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ABSTRACT

The relevance and influence of self-avatars in virtual environments have become increasingly evident and widely acknowledged in the research literature. Studies explore how these avatars influence user experiences, engagement, and embodiment across psychological, social, cognitive, and behavioral domains. As virtual reality (VR) technologies continue to evolve and become more integrated into various domains, understanding the role of self-avatars becomes crucial for designing immersive and effective virtual environments that cater to the needs and preferences of users. To address this issue, this study describes a work-in-progress VR educational game. A fundamental aim of this VR educational game is to understand underrepresented minorities' players' learning outcomes when subject to different skin tone avatars in an immersive virtual environment. This project aims to develop a VR game that allows players to choose an avatar character from a validated list of characters or to customize a character with their preferred skin tone that will self-represent them in a virtual environment. This VR educational game will serve as an informal learning platform accessible through VR headsets.

CCS CONCEPTS

• **Human-centered computing**;

KEYWORDS

Programming Education, Stereotype Threat, Educational Game Design, Avatar Customization, STEM Education

ACM Reference Format:
Olaoluwa Oyedokun, Syed Tanzim Mubarrat, Amogh Joshi, Christos Mousas, and Dominic Kao. 2024. Exploring the Influence of Avatar Skin Tone in VR Educational Games. In *Companion Proceedings of the Annual Symposium on Computer-Human Interaction in Play (CHI PLAY Companion '24), October 14–17, 2024, Tampere, Finland*. ACM, New York, NY, USA, 8 pages. https://doi.org/10.1145/3665463.3678799

CHI PLAY Companion '24, October 14–17, 2024, Tampere, Finland

ACM ISBN 979-8-4007-0692-9/24/10
https://doi.org/10.1145/3665463.3678799

1 INTRODUCTION

Avatars are a self-representation that enables interactions in virtual environments, fostering significant connections and resonating with many individuals [9, 13, 69, 139]. Within virtual environments, avatars are increasingly recognized for their influential role in shaping player behaviors and attitudes [144]. For example, individuals desire to create avatars that mirror their own appearance [43] or aspire to have avatars, (e.g., role models [60, 78]) that resonate with them. Virtual avatars find extensive applications in research simulations, spanning fields such as training, education, and social psychology [31]. Avatars are crucial in creating immersive environments [34, 47, 143]. Past studies have shown that avatars impact embodiment in VR [8, 40, 68, 93, 122], and enhance emotional expression [20]. However, there is bias towards representations of skin tones in VR [126], which connotes the negative effects of racial bias [42, 76, 99, 133]. For example, a study carried out by Sarah et al., [147] on light and dark skin tones in a virtual world shows that participants made more errors and took more time triaging dark-skinned agents than light-skinned agents. Therefore, this makes the design of virtual avatars important for marginalized groups. Hence, researching a variety of avatar skin tones that players can comfortably engage with is essential for gaining deeper insights into players' experiences and learning outcomes.

In response to this need, we propose a project focused on creating and evaluating an educational game. This game aims to introduce players to various skin stereotypes in VR while they learn programming-related skills (e.g., Java). The focal point of this study is to explore the influence of avatar skin tones in an educational game on players' relevant knowledge and skills [125]. Educational games are widely studied for their potential to boost learning performance [52], problem-solving [17], enthusiasm [27, 52, 138], versatility and adjustability [108], and positive emotional encounters [84, 114]. Yet, while a significant number of scholars have mentioned that exposing players to educational computing games is crucial and fosters learning [46, 49, 54, 59, 73, 87, 110], educational games in VR have yet to explore different avatar skin tones on programming skills and learning outcomes. Historically, career-relevant experiences such as internships, practicums, and hobbies, are heavily biased from self-selection [56] and availability of opportunities [53], catering only to a restricted number of students.

Consequently, there is a growing trend among researchers to explore technologies aimed at bringing learning experiences, such as the one described in this paper, directly to students.

The project consists of two phases with the initial phase dedicated to developing the VR computing game itself. Within this computing game, players will solve short computing programs after being introduced to the different avatar skin tone designs. The later phase of this project will focus on understanding the effects of different avatar skin tones on learning outcomes and game experiences. This project is guided by the theoretical frameworks of self-perception theory [12], self-association [76], avatar and self [120, 132, 137], and player identification scale (PIS) [139]. The game design will be based on the Gee's principles of learning [37]. We will employ triangulation in our methodology that will integrate multiple sources of data, including game performance, engagement, and semi-structured interviews. Overall, this project will aim to explore how VR and games can promote diversity in STEM fields.

2 RELATED WORK

2.1 Significance and Background

Steele and Aronson coined the term "stereotype threat" which describes how individuals from negatively stereotyped groups tend to underperform in certain situations [126]. It has been commonly observed that individuals, particularly racial minorities in academic settings [4, 126], underperform when a negative stereotype about their group is emphasized. In the context of STEM-related subjects, such as computer programming, schools often see underrepresentation from certain racial minority groups [103]. Research has found a correlation between students' educational outcomes and their interactions with faculty members who share their race or gender [21, 106, 112]. Although a significant body of research on stereotype threat has concentrated on aspects such as gender [23, 33, 64, 83, 96], voice [63], and performance [65, 117, 124], the impact of different avatar skin tones in virtual reality (VR) educational environments remains largely unexplored.

Avatars can play a crucial role in facilitating our ability to immerse ourselves in alternate identities [58]. When using avatars, individuals often adopt the identity traits of those avatars and conform to the stereotypes associated with them [107, 143]. This is evident in real-world scenarios where individuals readily accepted a rubber hand as their own [15]. Nevertheless, in terms of VR applications, many avatar customization platforms tend to offer a wider range of options for avatars with lighter skin tones, reinforcing socially exclusive norms [24, 79].

Researchers in the field of VR contend that the wide range of VR applications holds the potential to effect substantial changes in society [98]. These applications span across various fields, such as driving simulations [57], flight simulations [25, 32, 72, 94, 135], surgical training [5, 19, 77, 85, 95, 105], educational games [70, 89, 104], and physical exercises [81, 88, 146]. The prospective user base for these VR applications encompasses people of diverse ages, genders, racial or ethnic backgrounds, sexual orientations, and physical capabilities [9, 48, 100]. This diversity, however, also opens up the possibility of users experiencing stereotype threats due to the skin tones of their avatars in VR environments. While there has been research on the stereotype threats associated with avatars in both VR and non-VR educational games [60, 61, 96, 97], the impact of different avatar skin tones has not been investigated. Although a study by Do et al. [30] highlighted the importance of avatar matching in a VR environment, this aspect was not explored within the framework of a VR computing educational game.

2.2 VR Games and Education

The gaming industry is projected to reach a revenue of approximately 196 billion US dollars by 2022 [141]. Concurrently, the influence of VR technology on this sector is anticipated to escalate, with a projected worth of 36 billion US dollars by 2025 [39]. Advocates for gaming argue that video games provide an interactive learning environment that surpasses mere entertainment, underscoring their capacity to improve cognitive abilities, critical thinking, self-discipline, problem-solving, and creativity [11, 66, 102, 111, 113]. They highlight the educational content embedded in many games, asserting that gaming can be an engaging method for gaining proficiency in various subjects [38]. Educational games, also known as "serious games" [86], "edutainment" [18], and "game-based learning" [38], have proven to be effective in facilitating learning [36, 41, 75, 128, 131]. This approach has been utilized across a range of disciplines, including computer science [16, 55, 59, 119, 121], civil engineering (construction) [10, 28, 29, 136], music [101, 127] and medicine [2, 92].

From an educational and pedagogical perspective, interactive 3D spaces offer numerous advantages over traditional 2D environments [26, 109]. Research indicates that interactive 3D spaces, such as VR environments, enhance problem complexity [90], promote experiential learning [7, 35, 71], facilitate collaborative learning [3, 45], and provide an immersive experience that increases concentration and motivation for problem-solving [6].

2.3 VR Educational Games and Computer Programming

Computer programming, a sequence of coded instructions [14, 82], is recognized as a cognitively challenging task [50]. The exploration of computer programming is theoretically grounded in various theories, which are intrinsically linked with variables that influence an individual's interests, choices, and potential for success [74]. These theories also encompass the identities and roles that individuals adopt and navigate throughout their lifespan [12, 76, 129, 130]. They also involve instruments designed to measure outcomes related to the embodiment of these identities and roles [40, 123, 142]. We are motivated to explore how avatars' appearances can influence outcomes for users based on their social group.

Numerous scholars have investigated the potential of both VR and non-VR games (with and without avatars), including simulation games, role-playing games, and arcade games, to stimulate interest in computational programming [16, 55, 59, 60, 62, 89, 91, 119]. For instance, *Mazzy*, a non-VR game, allowed players to learn programming by using role models as their avatars within the game environment. This approach demonstrated positive outcomes in terms of player experience and engagement with their avatars [60]. Similarly, in a VR game *VR-OCKS*, the avatar was designed to be accessible to all ages, resulting in significant behavioral changes among the participants [119]. Furthermore, a study carried out

by Peck et al. [96] found a significant correlation between gender swapping and cognitive workload during a VR math experiment. The study revealed that participants' cognitive demands altered when they switched genders within the virtual environment, highlighting the impact of embodied experiences on cognitive processes in VR-based learning.

Nevertheless, while a considerable amount of research has been dedicated to the impact of gender-based stereotype threats on avatars in gaming contexts [23, 33, 64, 83, 96], there has been limited research on exploring the stereotype threats associated with avatar skin tones in computer programming games. In one study [60], a non-VR game centered around computer programming was developed to evaluate learning outcomes influenced by role models. The results of the gameplay demonstrated that players tend to select role models from their racial group. In a separate study [96], researchers explored the impact of gender body swap embodiment on working memory in VR and found positive effects.

Researchers have studied the effects of gender-specific and different skin tone avatars on stereotype threat in educational games, aiming to understand how avatar representation influences user experiences and learning outcomes. To the best of our knowledge not much research has been done in exploring different avatar skin tones. In our research, we are primarily focusing on examining the influence of skin tones between users' persona and their self-avatar on the sense of embodiment and learning outcomes.

3 METHODOLOGY

3.1 Overview

This study's objective is two-fold: firstly, to develop a VR educational computing game, and secondly, to examine the effects of avatar skin tones on gaming experience and learning outcomes. To understand how skin tones influence game design, we will conduct two comprehensive multivariate studies, offering a variety of avatar skin tones. Through these studies, we will attempt to address the following research inquiries:

RQ1. How does the representation of avatars with various skin tones affect the gaming experience and learning outcomes in a computing game?
RQ2. How does the programming game influence the players' exploration of computing concepts and affect their overall gaming experience?

We believe this research will provide invaluable insights for educational game designers, equipping them with the knowledge to navigate the intricate landscape of integrating avatar skin tones within their gaming platforms. By leveraging this information, designers will be able to make informed decisions, creating games that not only engage players but also facilitate a deeper understanding of computing through immersive experiences.

3.2 Theoretical Framework

The theoretical framework to support this project is based on self-perception theory [12], which primarily examines individuals' identities concerning stereotypes, outcome expectations, and learning objectives. Complementing this, we will also draw upon self-association theory [76], which theorizes that avatars symbolizing individuals from outside one's immediate group or community can still bear significant resemblances to those individuals in terms of physical appearance, cultural background, or behavioral patterns. This could foster a sense of connection or identification between the avatars and the individuals. Furthermore, we will incorporate principles from computer programming theory [44], which outlines the significant impact of programming education and its potential applicability across various domains. Collectively, these theories provide invaluable insights into the embodiment of player experiences within virtual environments. To specifically analyze player-avatar embodiment, we will employ the player identification scale (PIS) framework [139], which offers a structured approach to understanding these experiences in virtual contexts.

3.3 Game Design

The game will be set in a VR environment where players can enhance their programming skills by solving levels through the creation of short computer programs. It will challenge players to develop their coding skills by navigating through 12 levels of programming puzzles, with a focus on object-oriented programming (OOP) concepts, such as objects, methods, setters, getters, method arguments, and garbage collection, using Java as the primary language. The initial levels, numbered 1 to 5, will introduce basic commands to establish a strong foundational understanding of the players. As players advance to levels 6 to 9, the game will introduce more intricate challenges that incorporate loops, encouraging players to apply logical and iterative problem-solving techniques. The final stages, levels 10 to 12, will require players to synthesize all previously learned commands and techniques, with the introduction of conditionals. This structured progression will ensure that players have a comprehensive understanding of essential programming principles by the end of the game. The OOP concepts and their corresponding exercises within the game are detailed in Table 1 of the online Appendix[1]. Players will encounter these concepts through interactions with both familiar and stereotype-threat avatars.

At the start of the game, players will be presented with the opportunity to choose a character from a wide variety of options, allowing them to choose one that they feel comfortable with, identify with, or even one that resembles them [21, 106, 112]. The avatar of these characters will be selected from a study by Tiffany et al. [31] (Figure 1). These characters will serve as guides, providing players with basic information, instructions, and explanations of the command prompts. In addition, the initial setup phase will also allow players to customize the landscape by determining the placement and quantity of elements like houses and trees, aligning the virtual world with their personal goals and the activity's requirements.

3.4 Research Design

Our proposed research plan is structured into two sequential phases. The initial phase is dedicated to the development of a computing exploration game for VR, employing an iterative design methodology. This approach allows for the creation of preliminary prototypes, which can be evaluated and refined or discarded promptly, thereby

[1]A full list of figures and mock-ups pertaining to the game design can be found in the online Appendix: https://osf.io/zw3bq/.

Figure 1: Example of avatars that we will use in our study (taken from [31]).

facilitating rapid progress and refinement of the game's mechanics and features [51].

In the second phase, we will carry out two distinct studies. The first study (Study A) will investigate the impact of avatar customization options, specifically skin tone, on players' gaming experience and decision-making processes. The second study (Study B) will examine the effects of the computing game on participants' learning outcomes. The entire project is anticipated to span two years, with a detailed timeline presented in Figure 3 of the online Appendix[1].

3.4.1 Phase 1: Game Development. This phase will involve a comprehensive examination of the game's design, mechanics, and overall structure. We aim to create a compelling and immersive gaming experience through meticulous attention to detail and iterative refinement. In addition, the game's design has been thoughtfully informed by relevant theoretical frameworks (see Figure 1 of the online Appendix [1]). Furthermore, Phase 1 will encompass rigorous testing and evaluation, with a focus on usability and learnability, to ensure that the computing game adheres to the desired standards of quality and functionality [22]. We believe this dedicated focus on designing the game will lay a solid foundation for the subsequent phases of the project.

3.4.2 Phase 2A: Avatar Skin Tone Choices in the Computing Game. **RQ1.** *How does the representation of avatars with various skin tones affect the gaming experience and learning outcomes in a computing game?*

Intervention: In this study, we aim to investigate how the presence or absence of relatable avatar skin tones affects the gaming experience and learning outcomes. We will conduct an experiment where participants will interact with avatars that reflect their self-identified skin tone, as well as variations of this tone. Please refer to Table 1 in the online Appendix[1] for further details.

Participants: For this study, we aim to recruit young adults aged 18 to 25 from our university who self-identify as Black, Hispanic, or female. We chose this demographic based on prior research, which suggests that individuals within this age group, regardless of gender and race, are more receptive to interventions that may influence their decision-making process regarding a career in computing [145].

Procedures: Each participant will be instructed to select an avatar that best represents their self-identified skin tone from a range of available avatars. Subsequently, four additional avatars, each representing a variant of the chosen skin tone, will be automatically selected (Table 1 in the online Appendix[1]). Each participant will then play the game for 30 minutes under each of the five skin tone conditions:

- **MD** - Much Darker Skin Tone
- **SD** - Slightly Darker Skin Tone
- **NO** - No Change condition (Self Identified)
- **SL** - Slightly Lighter Skin Tone
- **ML** - Much Lighter Skin Tone

Qualitative and Quantitative Measures: Data will be gathered through a combination of surveys administered to participants and the analysis of in-game metrics and behaviors, known as game analytics. Moreover, we will investigate the predictive capacity of various factors, including but not limited to the virtual environment, in forecasting the outcomes of computational exploration. We will conduct a thorough analysis of how design features, interactivity, and environmental cues within the virtual setting influence the exploration process and ultimately shape the results obtained through computational methods. By incorporating these additional variables into our analysis, we aim to gain a comprehensive understanding of the complex dynamics involved in computational exploration.

Table 1 provides a comprehensive overview of the various tools, techniques, and methodologies that we will utilize to gather data and assess the variables under investigation. The validation procedures for these survey instruments have been meticulously designed by previous researchers, ensuring their reliability and accuracy in capturing relevant data. To illustrate, we will employ statistical tests, such as Cronbach's alpha, to evaluate the internal consistency and reliability of the survey items before incorporating them into the research framework.

Analysis: We will primarily be studying differences across the five skin tone conditions using ANOVA. We will compare the collected survey data and the insights derived from game analytics across different experimental conditions. Additionally, these data will serve as predictor variables in regression analyses, enabling a deeper investigation of the relationship between game design decisions and participant responses. These predictor variables (collected as post-test variables) will include: self-representation in the avatar skin tone conditions, self-association and player identification with the avatar, and relatedness with in-game avatar skin tone design.

3.4.3 Phase 2B: Effects of the Computing Game Exploration on Players' Experience. **RQ2.** *How does the programming game influence the players' exploration of computing concepts and affect their overall gaming experience outcome?*

Intervention: In this study, we will undertake a comprehensive examination of the impact of our computing game over six months. Throughout this time-frame, each participant will be assigned a personalized avatar to accompany them through their gaming experience. Following the conclusion of the extended gameplay period, we will conduct an extensive survey to assess the enduring effects and impressions of the computing game. This longitudinal approach

Table 1: Measurement instruments in Study A.

Conceptual Group	Instruments	Time
Avatar Embodiment	Avatar Embodiment. A Standardized Questionnaire [40]	Pre/Post
Game Experience Outcomes	Player Experience of Need Satisfaction [115] Player Experience Inventory [1] Intrinsic Motivation Inventory [80]	Post
Avatar Identification	Player Identification Scale [139]	Post
Measure of Immersion	A questionnaire to measure the user experience in immersive virtual environments [134] Presence questionnaires in virtual reality [118]	Pre/Post
Performance, Engagement, and Persistence (game analytics)	Player Data (progress, in-game scores, time played, successes and failures)	During

Table 2: Measurement instruments in Study B.

Conceptual Group	Instruments	Time
Avatar Embodiment	Avatar Embodiment. A Standardized Questionnaire [40]	Pre/Post
Game Experience Outcomes	Player Experience of Need Satisfaction [115] Player Experience Inventory [1] Intrinsic Motivation Inventory [80]	Post
Interest in Computing	Computing Interests Survey (adapted from [67]	Pre/Post
Computing Self-Efficacy	Computer Science Attitude Survey [140]	Pre/Post
Interview	Semi-Structured Interview	Post
Performance, Engagement, and Persistence (game analytics)	Player Data (progress, in-game scores, time played, successes and failures)	During

will provide insights into how the game influences various aspects of the participants' experiences and perceptions over time.

Participants: The same group of participants from Study A.

Procedure: Each participant will select their preferred familiar avatar. Subsequently, they will be instructed to play the game for 30 minutes daily for four months. After this period, participants will complete various questionnaires and undergo a brief semi-structured interview to gather their insights and experiences (Table 2).

Qualitative and Quantitative Measures: Data will be collected through a series of surveys and questionnaires (Table 2) administered to the participants conducted both before and after the gameplay sessions. Participants assigned an avatar will take part in a 15-minute follow-up interview during the post-test phase. The interviews will investigate participants' perspectives on the effectiveness of different avatar skin tones in a VR educational game.

Analysis: To characterize participants' perceptions of computing activities within various game-problem conditions from interview data, we will employ the established grounded theory methodology by Saldana [116], which involves segmenting the transcripts into thematic codes and identifying patterns [116].

4 CONCLUSION

The objective of this study is to gain meaningful insights into how avatar skin tones affect participant experiences and behaviors. This methodological approach aims to provide researchers with a detailed understanding of the influence of different game components on all participants. Single-session user studies will assess the effectiveness of avatar skin tone choices in creating stereotypes and influencing player outcomes. Comprehensive data from exploratory studies will help understand the impact of various avatar skin tone options on learning outcomes. Using multiple data sources in a triangulated approach will enhance the study's validity. Key metrics for evaluating the effectiveness of avatar representation will include motivated behavior, in-game progress, learning outcomes, and overall gaming experience.

Our research offers scholars and educators a valuable resource for systematically investigating this field. By thoroughly analyzing the findings of our project, we anticipate it will inspire heightened interest and exploration in future research endeavors. We aim to delve deeply into the potential of educational games and the intricacies of avatar representation, providing abundant data and insights for further study and advancement in this area.

ACKNOWLEDGMENTS

This research was supported in part by the National Science Foundation under the award number IIS #2338122. Any opinions, findings, conclusions, or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

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