Exploring the Impact of Belonging on Computer Science Enrollment Using Virtual Reality

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ABSTRACT

This study was designed to examine the impact of familial background and personal connection on a student's decision to take Computer Science (CS) courses in university. We utilized virtual reality to allow participants to embody an avatar with or without a family background in CS. This study can help determine participants' willingness to enroll an avatar in a CS course despite a lack of personal experience. The decisions made by the participants provides insight into the relevance of family background on CS enrollment according to the participants. The results of this study were largely inconclusive but the feedback provided important information to be applied for future research in the same area of interest.

Index Terms: Human-centered computing—Collaborative and social computing—Collaborative and social computing design and evaluation methods; Applied computing—Education; Applied computing—Law, social and behavioral sciences—Psychology; Human-centered computing—Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Human-centered computing—Interaction design—Interaction design process and methods—Scenario-based design

1 INTRODUCTION

There has been a persistent decline in the number of diverse students entering computer science (CS) and technological majors for several decades [2]. This decline has resulted in lower rates of employment in STEM fields (especially technology fields) for diverse populations during a time when there is an excess of technology-related careers to go around in this country [5, 9]. There is plenty of evidence to suggest that diversity is a major contributor to innovation and a variety of backgrounds are crucial when developing new ideas [4,10]. Therefore solving the problem of underrepresentation is pivotal in the coming years as new innovative technologies become necessary to combat society's ever-growing challenges.

1.1 Motivation

Before diversity can spread within technological industries the reasons behind the decline must be explored and properly dealt with. The research we are pursuing is a unique avenue toward the goal of solving the underrepresentation problem in CS and other technological fields. A lack of belonging has been identified as a major contributor to diverse populations' lack of interest in some majors [14] and especially technological fields of study [6]. For this reason, it is pivotal to understand where a sense of belonging commonly originates among people entering college.

Research suggests that early role models often influence a person's sense of belonging in a given discipline [12]. There is a limited amount of research on how belonging impacts people considering CS specifically. As a relatively new field of study, many people have no exposure to CS early in life. Men have dominated technological fields for decades [5]. Since attempts at mitigating the inequality in this field have not been particularly successful until recently we are seeing the effects of the inequality in the next generation preparing to get an education. Many people who are exposed to CS at a young age only witness their male figures in the field, often making the field feel less accessible to young women [7]. This suggests that the impact one's family background has on their willingness to participate in something new to them is significant.

Virtual reality is one method of exploring how people respond to having a family background in CS without personal experience adding as much variation to their responses. Virtual reality has been used to elicit emotional responses before [3, 8]. Using virtual reality to determine how people feel in a controlled setting has not been explored thoroughly. Virtual reality creates a controlled setting for experimentation especially when it is kept simple [13]. For this experiment virtual reality allows the participants of the study to feel connected with the avatar they will embody but recognize that the avatar is not meant to represent them. This is likely to result in responses that reflect exactly how much weight students give to family background and personal connection when choosing to enroll in CS courses.

1.2 Related Work

The field of CS education has many papers investigating the problem of diversity [6, 7, 11, 12]. The results of most of these studies suggest that increasing diversity is a complex issue that cannot be solved in any singular way. Some papers have tried applying Self-Determination Theory [7], others have tried encouraging students to get involved with formal research experience early in their academic careers [11]. Academic initiatives are constantly being integrated into schools targeted at diverse minorities [1]. Many of these studies focus on including more women in CS [1, 7, 12] but according to some of the most recent research it is not just a gender problem [6, 14].

Recent research that has explored belonging in CS has focused on the levels of belonging that exist in diverse minority students in CS [6]. This research has drawn the conclusion that underrepresented minorities in CS have a significantly lower sense of belonging in their major than other students. The students who do not believe CS can be used to achieve communal goals are the students who feel the least sense of belonging in the field. Communal goals being objectives that are achieved by helping others or being of assistance to something beyond oneself. The students who are not underrepresented who also seek to achieve communal goals are far more likely to consider CS an avenue to achieve these goals than underrepresented students. This suggests that underrepresented students are not being exposed to the many ways CS can be applied to future careers.

1.3 Contribution

This experiment provides a basis for exploring students' sense of belonging in CS in a controlled virtual environment. It attempts to remove personal bias and better understand what belonging means to people as a concept rather than a person's own experience with belonging in the CS field.

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1.4 Research Questions

(1) Does a familial background or personal connection with CS and the technology community (henceforth, a sense of belonging) influence a student's decision to take CS courses? (2) Does an avatar's sense of belonging influence the participant enough to affect their decision to allow the avatar to take a CS course?

1.5 Hypotheses

(1) Participants without an initial sense of belonging (henceforth, Pw/oB) primed with audio cues in a virtual environment meant to encourage a sense of belonging (positive cues) will be more likely to enroll in a hypothetical CS course than Pw/oB who are primed with audio cues in a virtual environment meant to discourage a sense of belonging (negative cues). (2) Participants with an initial sense of belonging (PwB) primed with positive cues will be more likely to enroll in a hypothetical CS course than Pw/oB who are primed with positive cues. (3) PwB primed with positive cues will be significantly more likely to enroll in a hypothetical CS course than PwB who are primed with negative cues. (4) PwB primed with negative cues are more likely to enroll in a hypothetical CS course than Pw/oB primed with negative cues.

2 METHODS

2.1 Software and Materials

The simulated environment used in this experiment was developed for this study in Unity (https://unity.com), a program designed to assist in the development of games and simulations like this one. Unity uses C# for all scripting purposes and an advanced user interface for design needs.

We used Avatar Creator to create avatars for the participants to embody. Avatar Creator generates realistic-looking avatars. The free trial has a decent selection of customizations for the avatars including poses and skeletons embedded in the avatar for some export options. We were able to export both the male and the female avatars into Unity and embed them in the simulation environment. We attached a camera to the avatars' head for the best virtual reality experience.

We used the Oculus Rift S as the primary virtual reality interfacing tool. It's design allowed for more freedom during the development process because it did not rely on play area towers to function. Unity has built-in virtual reality compatibility features including Oculus devices. Getting the Oculus Rift S set up and working with the simulated environment only required changing a few settings in Unity.

The post-simulation survey was created using Google Forms. It was a short four question survey that took participants under a minute to complete. The survey asked them if they are in a technological field of study. It asked them about their personal family background and personal connection with technological fields. The survey asked if they would feel a sense of belonging in a technological field. And the survey asked if they felt a connection with the avatar they embodied. Google Forms has a feature that allowed the responses from the survey to be automatically inputted into an online spreadsheet. We were easily able to combine all data on the auto-generated spreadsheet for analysis purposes.

To record and mix the audio recording for the simulation we used Audacity (https://www.audacityteam.org) and Free Sound (https://freesound.org). Free Sound is an online website that offers millions of free to download audio clips featuring an ample variety of noises. We were able to find a clip of a standard voicemail bot to use in the audio recording. Audacity was used to record the voice of the disembodied agent in the simulation and it was used to combine the voicemail sound clip and the agent's voice.

2.2 Simulation Environment

The virtual environment that we utilize in this experiment was built explicitly for this study. The environment was kept largely consistent between all conditions of the experiment. An image of the general layout of the environment is displayed in *Figure 1* and *Figure 2*. The furniture that decorates the room that makes up the environment are all free assets downloaded and imported from the Unity asset store. The audio recording is set up to play automatically once the simulation begins. The disembodied agent is heard as a voicemail through a cell phone sitting on the desk. We chose to have the disembodied agent be a voicemail so the participants did not feel compelled to speak to the agent. The mirror placed at the front of the room is useful for the participant to become acquainted with the avatar they are embodying more quickly. It also allows the participant to see the scope of the virtual environment without having to move around.

2.3 Audio Cues

There were two audio cues used in this experiment. Both were recorded using a friendly feminine voice as the disembodied agent. The agent was meant to portray a friend to the character in the simulation, close enough to know about the characters past experiences.

In the control audio cue the agent explains to the character in the simulation that they are interested in taking a computer science course. They note that the character has no computer science experience but complement them on their intelligence and express to the character that they believe they would succeed in the course. The agent mentions that their advisor has specifically encouraged them to take the course. The agent then asks if the character that the participant is embodying will take the course with them.

In the experimental condition the audio cue expresses the same interest in taking a computer science course and again mentions that the character has never taken any computer science classes before. The agent's message changes when she begins to discuss how both the father and mother of the character are in technological fields as careers, and that the character had a friend in high school who was very interested in computer science. She goes on to say these influences "must have rubbed off" on the character therefore she would like it if the character took the course with her. She then asks the character being embodied by the participant if they will take the course with her.

2.4 Participants

The participants in this study were all students at Colorado State University. We recruited 10 participants (40% female). Most of the participants were graduate students in Computer Science. One participant came from outside the Computer Science department. Half of the participants had a family background in or personal connection with technological fields of study. According to survey results, 8 of the participants personally felt a sense of belonging in Computer Science. Some participants were more familiar with virtual reality than others.

2.5 Setup

Prior to every experiment session, we sent the participant a link through email. The link was generated by Google Forms to share the survey that participants are meant to complete once they have finished the experiment. We opened the project in Unity and randomly selected one of the four scenes created for each of the four conditions in the experiment. We connected the Oculus Rift S to the computer and confirmed it was working properly. At this stage, we also confirmed that the participant would be inside the game area when entering the simulation.

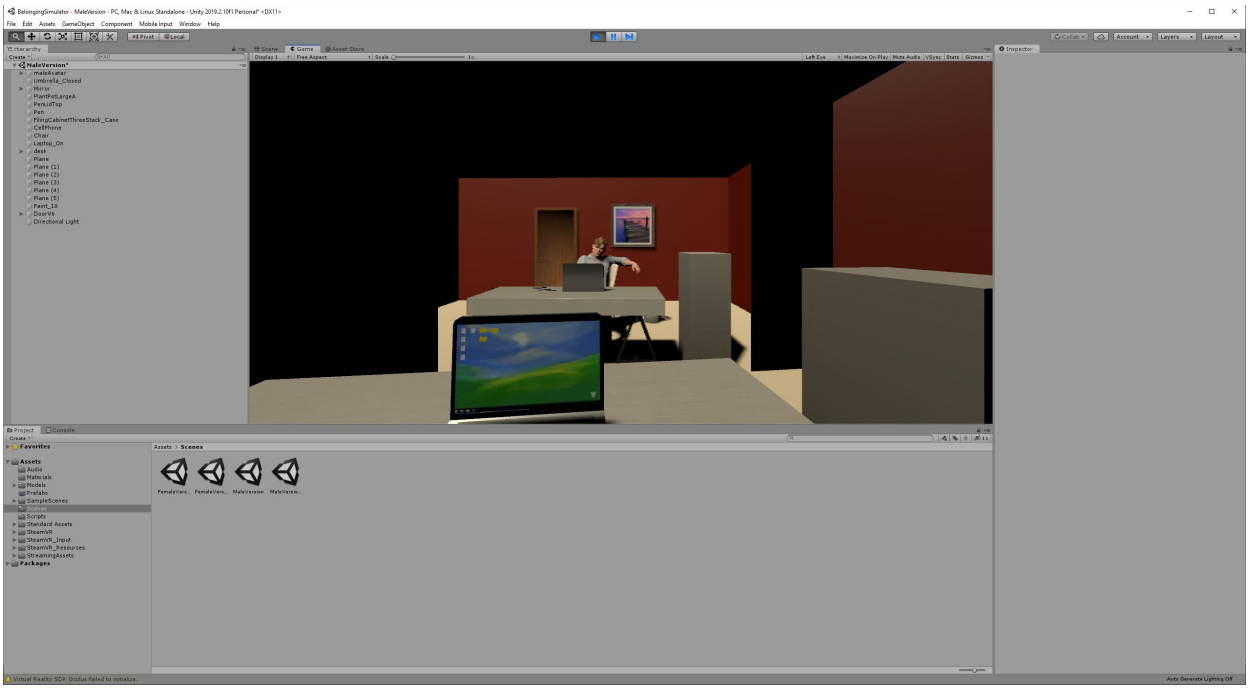

Figure 1: Screenshot of the Unity simulated environment during an active simulation - male condition

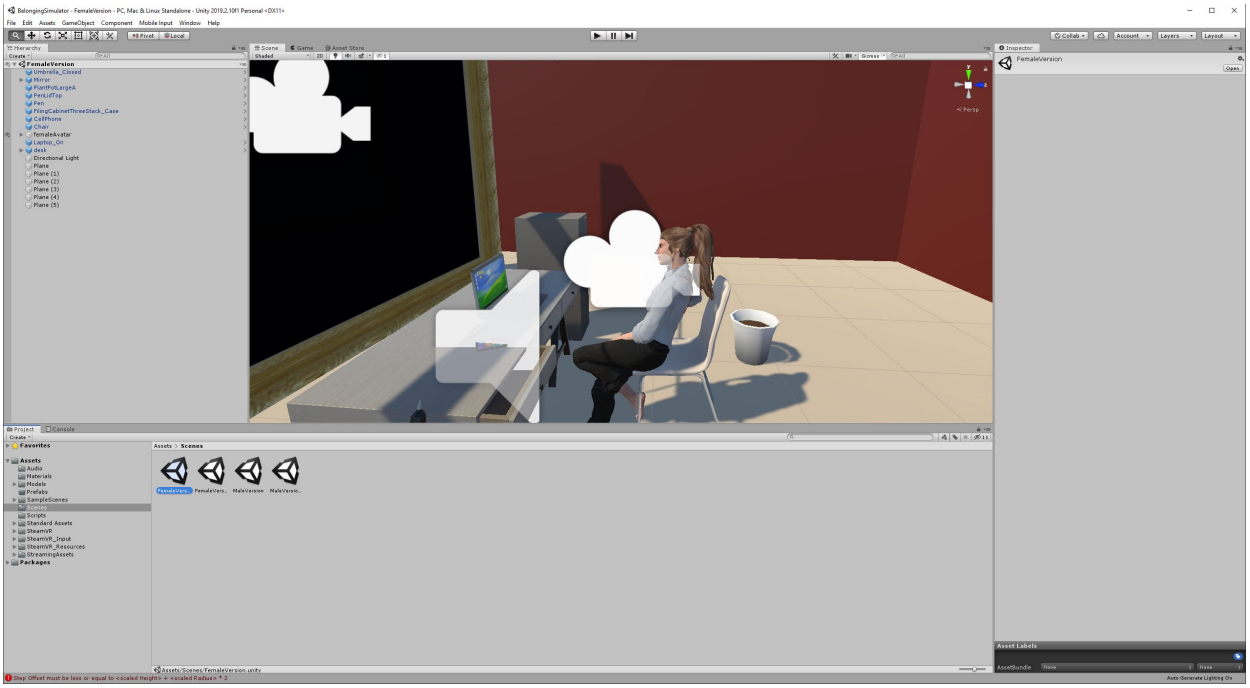

Figure 2: Screenshot of the Unity simulated environment: development view - female condition

2.6 Procedure

We recruited participants through word-of-mouth and email correspondence. We utilized class communication tools such as Piazza, Slack, and Canvas to advertise the experiment. Through email, we provided a link to the post-simulation survey with instructions not to open the survey until the experiment was complete. Each participant came to the on-campus lab of the researchers for the experiment. Prior to the start of the experiment, they read and signed a consent form. We read a pre-written script that described the duration of the experiment (30 seconds), a description of the experimental procedure (wearing an Oculus Rift S sit and immerse yourself in the simulated environment), and what condition they would be randomly assigned (male or female). We made it clear that the avatar they are going to embody is a 1st-year undergraduate student who has not declared a major and who has never taken a computer science course before. We emphasized that the participant must respond verbally to the question posed to the avatar by the disembodied agent in the simulation. We described the position of the avatar in the simulation and asked the participant to sit in that position during the simulation. The participant then put on the Oculus Rift S virtual reality headset, adjusted the head strap so the device fit comfortably on their head, and we had them verbally confirm that they were within the play area. We then commenced the simulation.

The participants were randomly assigned one of four conditions. The participant embodies either a male or a female avatar. They hear an audio cue that suggests that the avatar has a family background in and personal connection with technological fields. Or the participant hears an audio recording that suggests that they do not have a family background in or personal connection with technological fields of study. The participant has been instructed to listen attentively to the audio recording before responding. The simulation lasts about 30 seconds in all conditions.

Once the participant has answered the question posed by the disembodied agent they are asked to remove the headset. After they remove the headset we asked them to go to the survey linked to them via email. They complete the four question survey while in the presence of the researcher. The entire procedure ran approximately 5-7 minutes per participant.

After the participant left, the researchers noted their response to the disembodied agent as well as the participant's gender and the experiment condition they were assigned. All data were combined in an online spreadsheet protected by a password.

3 Results

Of the participants, nine were enrolled in a technological field of study. Five of the participants had a family background in technology. Eight of the participants felt that they would or do feel a sense of belonging in technological fields of study. Six of the participants felt connected to their avatars. And eight of the participants agreed to take the CS course with the disembodied agent.

Of participants who came into the study with a sense of belonging twice as many chose to enroll their avatar in a CS course when provided a positive cue ($p = 0.1340$). The difference was not significant with $N = 8$. The results could have occurred by chance with such a small sample size.

4 Discussion

There was not enough participation to perform statistical analysis on some of the data. There were too few participants who did not feel a sense of belonging in technological fields to get conclusive data on hypotheses 1, 2 or 4.

4.1 Implications

Both of the participants who did not feel a sense of belonging in CS agreed to take the CS class in the simulation no matter what audio cue they received. This result does not support the first hypothesis. This may suggest that family background is not what determines a person's sense of belonging. It may also suggest that family background does not factor into a person's decision to take a CS course as we thought it would. The most likely reason for these results is that there was not enough data collected to obtain meaningful results.

The participant who did not feel a sense of belonging did enroll their avatar in the CS course when provided a positive cue while several participants who felt a sense of belonging in CS did not enroll their avatars in the CS course. These results do no support the second hypothesis. This suggests that the participants' sense of belonging in the technology field does not impact their decision to allow their avatar to enroll in a CS course. This result also vaguely suggests that the simulation was successful in separating the participants' personal experience in CS with the avatar's experience. Without more data, these results are not conclusive.

Hypothesis 3 was not supported suggesting that the positive and negative cues in the simulation did not impact the participants' decisions to enroll the avatar in the CS course. Hypothesis 4 was not supported given that the participant who did not feel a sense of belonging in CS who was given a negative cue chose to enroll their avatar in the CS course. Several participants who did feel a sense of belonging in CS did not choose to enroll their avatar in a CS course, but this data set is not large enough to analyze. Both participants who chose not to take the course embodied female avatars but were male participants. If future work finds this same trend it could provide evidence that there is an implicit bias against women in technological fields.

4.2 Limitations and Challenges

Priming and bias effects were introduced due to various circumstances for several of the participants. Some of the participants were present when we discussed the purpose and motivations for doing this experiment prior to their participation.

The pool of participants was limited, most of the people who participated were from a graduate-level Computer Science course. This lack of diversity meant we could only explore the relationship people who have chosen computer science as a major have with belonging in their field.

The avatars in the virtual environment are stationary throughout the simulation. The participant can move their head and look around the room during the simulation. The participant can see that the avatar is motionless because of the mirror at the front of the room. This could result in a higher risk of motion sickness. The lack of motion may also lead the participant to anthropomorphize the avatar less. If the participant does not recognize the avatar as a person their choice for that avatar loses value.

Participants may have been exposed to the scene before entering the simulation because it was visible on the screen of the computer in front of them while the experiment was being described to them. The impact of this exposure is limited because the important elements of the scene, such as the avatar was obscured by various components visible only in the development view of the simulation. A potential improvement to the study could be to turn off the screen of the computer until the participant has put on the headset.

The disembodied voice was not meant to be extremely friendly, it was designed to be somewhat irritating but all feedback suggested that the participant enrolled in the course because they wanted to support their "friend" the disembodied agent.

5 Conclusion

This study is only the beginning of this research. With more participants, it will be easier to analyze data. There were no conclusive results determined by this study but it was useful as a way to obtain feedback from participants.

5.1 Future Work

Future work will include a much larger pool of participants from a wider variety of disciplines. This will enable future researchers to get more data on people who do not feel a sense of belonging in CS prior to the start of the study. The simulation can also become more advanced in the future. It could allow the participant to move around more and feel more connected with the avatar they will be making a decision for. There are plenty of alternative avenues this research could take as well. Instead of family background, it could look at existing relationships in the field, willingness to explore new things in general, or any variety of options that may result in a sense of belonging.

Future research will include other factors that have been shown to impact belonging in students. A more advanced method of analysis will be used, including Likert scales for determining preference. A within subject design may be more appropriate for future studies in order to parse the different levels of impact various facets of belonging have on participants. The expectation is that family background will have the strongest impact on a participant when choosing to take the course presented in the simulation. Family background will be compared to goal orientation, demographic influences, and self-efficacy as well to determine a more robust understanding of belonging and it's impact.

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