THESIS

EXPLORING THE IMPACT OF BELONGING ON COMPUTER SCIENCE ENROLLMENT

USING VIRTUAL REALITY

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Vidya Gaddy

Department of Computer Science

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Master's Committee:

    Advisor: Francisco R. Ortega

    J. Ross Beveridge
    Julia Sharp
    Victoria Interrante

ABSTRACT

EXPLORING THE IMPACT OF BELONGING ON COMPUTER SCIENCE ENROLLMENT

USING VIRTUAL REALITY

Student enrollment in STEM fields of study is critical for the future. Improving our understanding of what motivates young people to engage with material like computer programming is an essential aspect of increasing enrollment. Interest in a topic like Computer Science (CS) begins with a sense of belonging in the field. That essential sense of belonging tends to be quite evasive because it lacks a concrete definition. In this research, the goal was to dissect the main attributes associated with a sense of belonging and highlight the attributes that are key to a student's decision to enroll in CS. The attributes determined to be vital contributors to a sense of belonging were self-efficacy, family background, goal orientation, and demographic characteristics. In order to find which of these factors associated with belonging were most important, a Virtual Reality (VR) simulation and survey were designed. A simple simulated environment was used which had participants embody an avatar that was described as an undeclared first-year college student. While in the simulation, participants were prompted to listen to an audio message from the advising office which asked them if they would like to enroll in a CS course. In the pilot study (N=10), family background was the focus, randomizing avatar gender as well as the control condition and the family background condition between participants. The feedback received from participants informed all the improvements made to the main experiment. For the main experiment (N=24), there were four slightly different audio messages each highlighting one of the four factors associated with belonging in CS. Each participant listened to all four audio messages and answered survey questions about their response to the audio. A Likert Scaled survey was used to determine how likely the participants were to enroll in the CS course given each audio prompt. Results indicated that there was a strong positive reaction to the audio message highlighting goal orientation ($p < 0.05$) and a

strong negative reaction to the audio highlighting demographic characteristics ($p < 0.05$). The responses toward family background and self-efficacy were more neutral. These results demonstrate that people are attracted to CS when they believe it will help them achieve their future goals in life. But perhaps more importantly, a person's demographic characteristics alone being highlighted will not be enough to increase enrollment in the field of CS.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

Chapter 1

Introduction

There has been a persistent decline in the number of diverse students entering computer science (CS) and technological majors for several decades [1]. 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 [2,3]. Figure 1.1 shows the number of degrees awarded by race as of 2019, plot adapted from [4]. The disparity is clear, white students make up over 36% of CS degrees earned. It is important to note that non-resident aliens are students coming from anywhere outside the United States, thus making up a large portion of data. Figure 1.2 displays the extreme gaps in gender as well as race in CS. This plot, adapted from [4] demonstrates the percentage of students earning bachelor's degrees in CS in 2019. 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 [5,6]. Therefore solving the problem of under representation (as defined by the National Science Foundation (NSF) as women, African Americans, Hispanics, Native Americans, and indigenous peoples [7]) 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 being pursued in this project is a unique avenue toward the goal of solving the under representation 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 [8] and especially technological fields of study [9]. For this reason, it is pivotal to understand where a sense of belonging commonly originates among people entering college. The
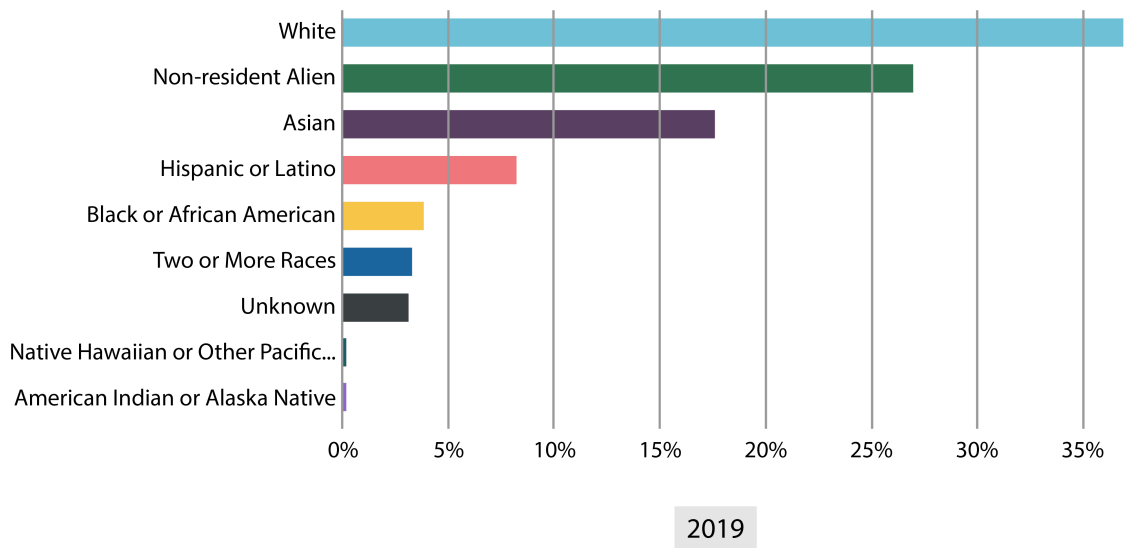
Figure 1.1: A plot of CS degrees awarded by race and/or ethnicity in 2019
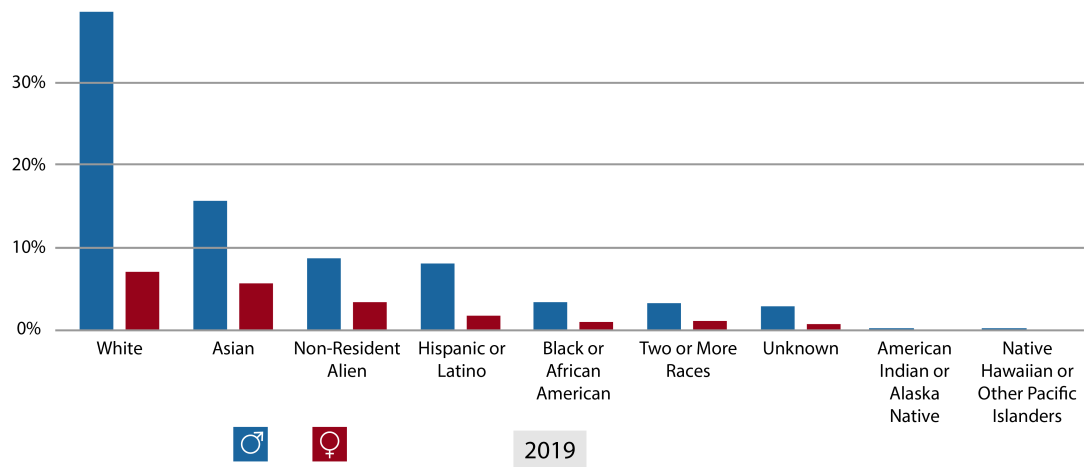
Figure 1.2: A plot of CS degrees awarded by race and/or ethnicity and gender in 2019

factors described below are all associated with belonging in some way. These four factors are the focus of this project.

1.1.1   Family Background

Early role models often influence a person's sense of belonging in a given discipline [10]. 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 [3]. 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 male figures in the field, often making the field feel less accessible to young women [11]. This suggests that the impact one's family background has on their willingness to participate in something new to them is significant.

1.1.2   Self-Efficacy

Self-Efficacy is defined as a person's level of confidence in their ability to achieve a desired outcome [12]. Self-efficacy is clearly a more psychological phenomenon than a person's family background, therefore combating a lack of self-efficacy should look different than making up for a weak family background in CS. CS is not strongly related to other fields. Many people are only exposed to images of highly advanced Computer Scientists in the media. Due to these realities, people automatically believe the study of CS to be out of reach. A person is much less likely to feel a sense of belonging in a field they do not believe they could excel in [13].

1.1.3   Goal Orientation

Goal orientation in CS has been recently researched and discovered to be a significant factor in a students desire to purse a career in CS [9]. Many people do not believe that a degree in technology can offer them a career that will allow them to attain their goals. Work done by Colleen Lewis et al. suggests that many people believe that CS jobs are all desk jobs in which they would be forced to do

math and difficult coding all day [13]. The same study suggests that people desire more than this. People are naturally inclined to want to be outdoors regularly. People want to see their work make a difference [14]. The field of CS has many different facets that the general population are simply not aware of. For example, developing Geographic Information Systems (GIS) from a human-centric computing perspective would expect computer scientists to explore the areas themselves before charting the area if possible. Or doing research for organizations devoted to improving technological access to developing countries. Exposure to the different careers and opportunities CS offers is likely to increase a person's sense of belonging in the field.

1.1.4 Demographic Characteristics

For this project, demographic characteristics are defined broadly as a person's racial/ethnic, cultural, and gender identity. Many researchers have identified that there is a distinct lack of well distributed multiculturalism in CS [15–17]. For example, in 2014, of the intersectional hiring being done by Google, about 1.2% were black women. In 2019, that percentage had risen by one percent [18]. Google is a company that puts a lot of energy into diversifying their employees and they still struggle to see significant growth. In the majority of research done on demographic effects on belonging in CS the results are always fairly similar. People who have a demographic identity that is dissimilar to the majority in their CS courses or in their CS work tend to have a more difficult experience [15]. The results of this research are widespread and well-known even by those outside of the field. The consequence is that people who do not feel they will have a community in CS may not wish to attempt joining the field. If there was some sort of assurance that they would have a community in CS then perhaps they would be more inclined to feel a sense of belonging [15].

It is important to make clear that all these factors are at some level intertwined. For instance, a student's family background is likely to impact their self-efficacy in a given field. However, the approach to addressing these four different factors varies drastically. If people have a highly positive reaction to an appeal to their goal orientation and a negative reaction to highlighting their

demographic characteristics, career opportunities being advertised to incoming freshman would likely be more advantageous than emphasizing meet and greets with students of the same racial identity. By parsing these factors out, and determining whether or not they are equally important to people when choosing to enroll in CS, actionable initiatives can be constructed that are targeted at specific problem areas.

1.1.5 Why Incorporate Virtual Reality

Virtual reality (VR) is one method of exploring belonging in CS without personal experience adding as much variation to participant responses. VR has been used to elicit emotional responses before [19, 20]. Using VR to determine how people feel in a controlled setting has not been explored thoroughly. VR creates a controlled setting for experimentation especially when it is kept simple [21]. For this user study, VR allows the participants of the experiment to feel connected with the avatar (virtual agent within a virtual environment) they will embody. However, the subject recognizes that the avatar is not meant to represent them. This is likely to result in responses that reflect exactly how much weight participants give to each factor associated with belonging.

1.2 Literature Review

This section is a review of recent work done in CS education and other similar fields related to belonging and enrollment. The field of CS education is relatively new due to the relative novelty of CS itself. But the work done in CS education is constantly growing and in need of updating because of the nature of CS. The people most interested in CS are always changing, and the reasons to attend university are always changing. Most of the work cited in this section are no more than a few years old for the reasons stated above.

The field of CS education has many papers investigating the problem of diversity [9–11, 22]. 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 [11], which is a model in behavioral science that attributes a person's internal reward system as a key

aspect of their motivation to achieve. Others have tried encouraging students to get involved with formal research experience early in their academic careers [22]. Academic initiatives are constantly being integrated into schools targeted at diverse minorities [23]. Many of these studies focus on including more women in CS [10, 11, 23] but according to some of the most recent research it is not just a gender problem [8, 9].

Recent research that has explored belonging in CS has focused on the levels of belonging that exist in diverse minority students [9]. Lewis et al. [9] have 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.

A recently published study on using a growth mind-set to improve academic performance in CS was unsuccessful at significantly improving academic performance but they did find that student interest in CS increased [24]. Since this project is focused on enrollment the results from the study done by Burnette et al. [24] are particularly valuable. The psychological approach of a growth mind-set is strikingly similar to what an initiative to improve self-efficacy would look like. The idea is not to externally change the environment students are exposed to, but internally change a student's perspective. The Burnette et al. study [24] indicated no difference in response between genders. This observation suggests that a more psychological approach to improving CS enrollment is not biased toward women, but helpful for all students.

A related study was able to find resilience to be extremely important for performance in CS courses and important for retention [25]. Resilience is another cognitive process very similar to

self-efficacy. This study specifically examined the responses from first-year undergraduate CS students which makes it highly relevant to the project discussed in this report.

A person's identity is often discussed in literature related to CS education. Identity is key, especially now that narrative has been shown to have an amazing influence on people's interest in CS [26, 27]. A narrative perspective as it relates to CS varies slightly between studies but it is always based on students' backgrounds. Constructing narratives around new information that incorporates subject matter that relates to a diverse set of experiences has been shown to really support the learning process [26]. A study found that women often find their identity threatened when considering entering the CS field [28]. The participants in this study done by Cheryan et al. [28] felt that they would not succeed if they did not repress some aspects of their femininity.

The research discussed above all informed the choices made for the project moving forward. These articles indicate that there is evidence to support the idea that there are all sorts of factors that are involved in a person's decision to choose CS and stay in CS. What these papers lack is perspective on whether what they have found to be significant is, in fact, the most significant factor involved in a student's sense of belonging.

1.3 Contribution

This experiment provides a basis for exploring people's 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. This project dissects belonging into four factors: self-efficacy, goal orientation, family background, and demographic characteristics. These factors are evidently involved in a sense of belonging as well as a student's choice to enroll in CS. This research explores differences in response to these four factors individually rather than as a whole. The data from this work can be used to develop specialized initiatives that reflect what people really find important when choosing to enroll in CS.

Chapter 2

Beginning the Exploration

The original idea for this research was exclusively interested in the significance of family background. This was based on the idea that even without direct experience exposure to the material that CS offers makes the idea of entering into the field far less daunting. A great deal of CS is learning new languages. When someone is raised in a bilingual household they often are capable of speaking both languages. If a person raised in a bilingual household cannot speak both languages they can at least recognize the language they do not speak. The same logic could potentially be applied to the language associated with CS. The language associated with CS is not in reference to programming languages such as C++ or Java though programming languages do have an impact on how programmers in CS speak. The day to day jargon that people in CS use such as "method compilation" or "distributed systems" which have completely unique meanings in a CS context is something especially alienating to people who have yet to be exposed to such language. Children who grew up in a "CS speaking" environment are potentially far more likely to be able to acclimate to CS courses and communities than those who have never had exposure to the language prior to college or university.

Virtual reality was used in this study because it created a highly controlled environment. In addition, VR provides a level of immersion ("being there") that no other medium is able to provide. Surveying techniques used in the past have a plethora of issues. For instance, response bias, a tendency to answer according to social norms or expectations, is common when surveying. Recognizing that surveying would have to be used to gather participant responses to the various conditions created for the pilot study experiment, I wanted to mitigate bias as much as possible. VR allowed me to ask participants about their personal reactions to stimuli while simultaneously depersonalizing the experience to acquire a more generalized response.

Table 2.1: Questions on Pilot Study Questionnaire and participant responses

Questions	Yes	No	Maybe
Do you have a family background or past personal connection with the technological field?	5	5	N/A
Do you feel like you do/would feel a sense of belonging in a technological field?	8	1	1
Did you feel a personal connection with the avatar in the simulation?	6	4	N/A
Are you enrolled in a technology-related field of study?	9	1	N/A

2.1   Pilot Study Design

In the pilot study, participants were read a script describing the avatar they would be playing as while in the VR simulation. Participants would then enter the simulation via head mounted display (HMD) and listen to an audio cue that acted as the independent variable. The control audio cue would ask the participant if they would like to enroll in a CS course. The experimental audio cue would suggest that the participant had a family background in CS then ask if they would like to enroll in a CS course. The participant verbally responded to the question posed by the audio cue in the simulation and the researcher made note of their response. The participant was then asked to fill out a short questionnaire about their personal experience in CS as well as a few demographic questions. The questions asked as well as participant responses can be seen in Table 2.1

2.1.1   Apparatus

All development for the pilot study and final experiment was completed using a Windows 10 x64 operating system on an Alienware personal computer, Intel(R) Core(TM) i7-8700K CPU @ 3.70GHz, 3696 Mhz, 6 Core(s), 12 Logical Processor(s).

The simulated environment used in this experiment was developed for this study in Unity [29], a program designed to assist in the development of games and simulations like this one. Unity version 2019.2.10f1 was used to develop the preliminary simulated environment.Unity uses C# for all scripting purposes and an advanced user interface for design needs.

Character Creator v3.11 [30] was used to create avatars for the participants to embody. Character Creator generates realistic-looking avatars. Character Creator v3.11 has a decent selection of customizations for the avatars including poses and skeletons embedded in the avatar for some export options. I was able to export both the male and the female avatars into Unity and embed them in the simulation environment. A camera was attached to the avatars' head for the best VR experience.

The Oculus Rift S was used as the VR 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. The questions on the survey are shown in Table 2.1. Google Forms has a feature that allowed the responses from the survey to be automatically input into an online spreadsheet. All the data were easily combined on the auto-generated spreadsheet for analysis purposes.

To record and mix the audio recording for the simulation I used Audacity [31] and Free Sound [32]. Free Sound is an online website that offers millions of free-to-download audio clips featuring an ample variety of noises. A clip of a standard voicemail bot was used in the audio recording. Audacity was used to record the voice of the disembodied agent (a virtual character that has no virtual body) in the simulation. Audacity was also used to combine the voicemail sound clip and the agent's voice.

2.1.2   Simulation Environment

The virtual environment that was utilized 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 Figures 2.1 and 2.2. 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. I 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.
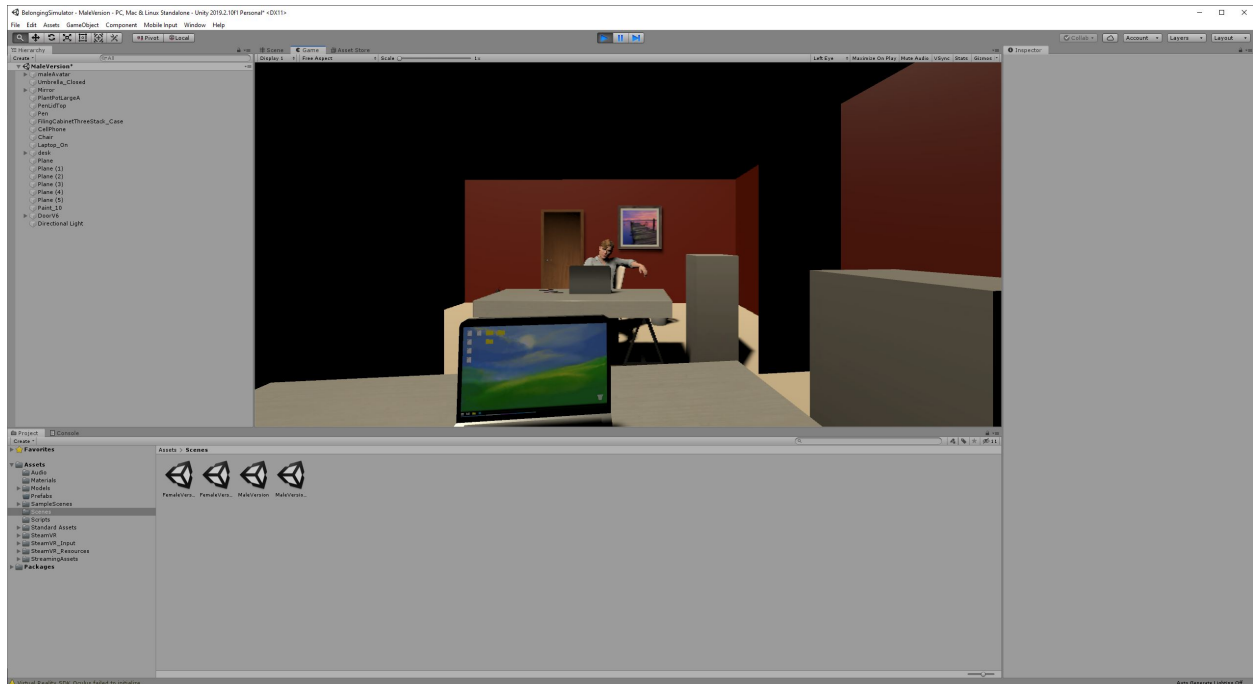
Figure 2.1: Screenshot of the Unity simulated environment during an active simulation - male condition

2.1.3   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

11
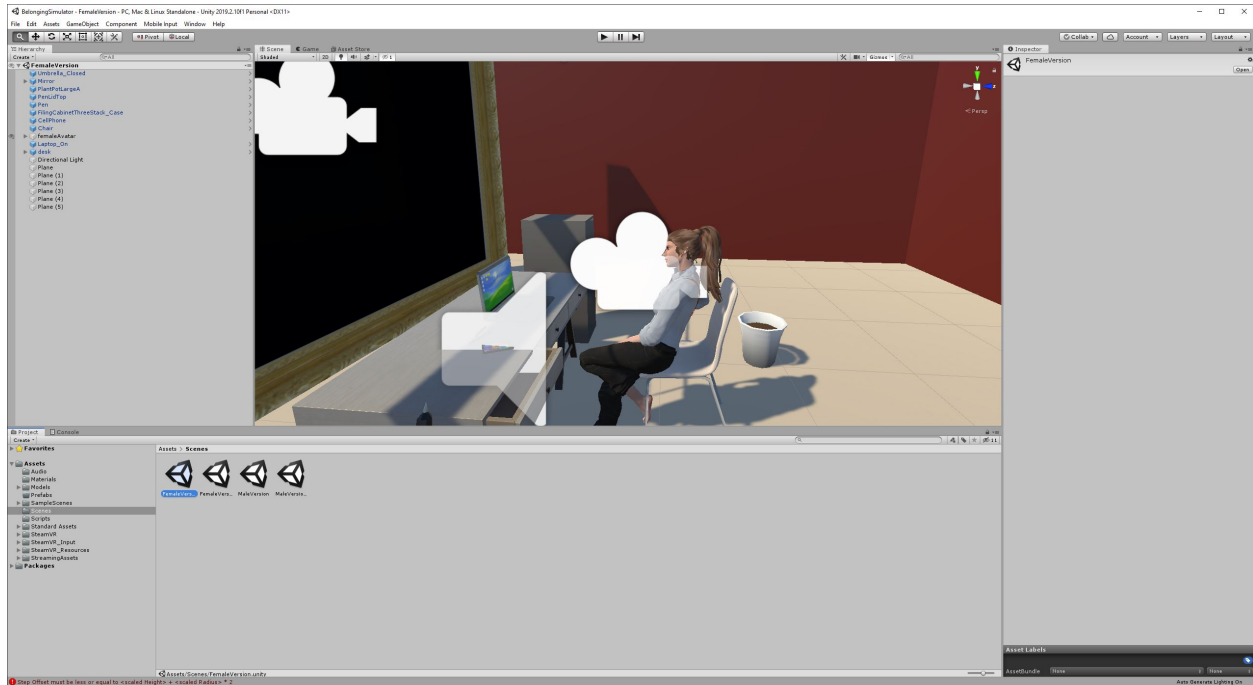
Figure 2.2: Screenshot of the Unity simulated environment: development view - female condition

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.

A transcript of the audio cues is shown in Table 2.2.

Family Background Audio Cue
Hey! So let me tell you. I heard about this CS class for beginners that I'm dying to take. I was wondering if you'd take it with me? I know you've never taken a CS class before, but isn't your dad the head of a tech company, and doesn't your mom do programming at home all the time? Even your grandpa right? Wasn't he like, one of the first people to touch a computer? And you had that friend in high school who was a total programming genius. And I bet that you kind of absorbed so much information from all of these people. Do you want to take it with me? I could really use your help.
Control Audio Cue
Hey! So let me tell you. I am totally thinking about taking this beginners CS class next semester. I know you have never taken one before but you've always been such a smarty in all of your classes. I know you don't have a background in CS, I know you've never touched a computer, I know you're just like me, but it's like super important, right? And my advisor tells me to do it all the time. Would you like to take it with me?

Table 2.2: Transcripts of Pilot Study Audio Cues

2.1.4 Participants

The participants in this study were all students at Colorado State University. 10 participants were recruited (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.

2.1.5 Setup

Prior to every experiment session, the participants were sent a link through email. The link was generated by Google Forms to share the survey that participants were meant to complete once they had finished the experiment.

To start, one of the four scenes, created for each of the four conditions in the experiment, was randomly selected. The Oculus Rift S was connected to the computer and I confirmed that it was working properly. At this stage, I also confirmed that the participant would be inside the game area when entering the simulation.

2.1.6   Procedure

Participants were recruited through word-of-mouth and email correspondence. Class communication tools were used such as Piazza, Slack, and Canvas to advertise the experiment. Through email, a link was provided which led the post-simulation survey with instructions not to open the survey until the experiment was complete. Each participant came to the NUILab [33] located on campus for the experiment. Prior to the start of the experiment, they read and signed a consent form. A pre-written script was read which 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). It was made 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. I emphasized that the participant must respond verbally to the question posed to the avatar by the disembodied agent in the simulation. I 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 I had them verbally confirm that they were within the play area. I 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 they were asked to complete the survey. 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, I 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 using secure methods standard with IRB practices.

2.2 Initial 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. Eight of the participants agreed to take the CS course with the disembodied agent.

Of the eight 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 The results could have occurred by chance with such a small sample size.

2.3 Preliminary 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.

2.3.1 Implications for Future Work

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 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. The most likely reason for these results is that there was not enough data collected to obtain empirical 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. 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.

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.

2.3.2   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 discussing 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 I could only explore the relationship people who have chosen computer science as a major have with belonging in their field. Graduate students are especially likely to have a high sense of belonging since they have chosen to remain in the field longer than most students. This research is meant to target people with a mostly neutral or negative attitude regarding CS, in order to better understand how to shift these attitudes in a more positive direction. This study assumes the participants involved would make similar choices to the target population but this is not guaranteed or highly likely.

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 were 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.

2.4 Initial Conclusion

This study is only the beginning of this research. The results for this study were inconclusive, but it was useful as a way to obtain feedback from participants.

2.4.1 Lessons Learned and Future Work

Future work will include a much larger pool of younger 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.

Chapter 3

Continuing the Exploration

This chapter describes the final experiment for this thesis, where the pilot study and the final experiment are compared. In addition, apparatus, procedure, and methods for data collection are described. This chapter concludes with the results and analysis of the final experiment.

3.1 Apparatus

All the hardware and materials are described to provide enough information for reproduction by other researchers.

3.1.1 Unreal

Unreal Engine v4.23 [34] was used for development of the final simulated environment. Unreal provided the ability to develop a mirror using assets integrated into the basic architecture of the software. Unreal allowed the use of more detailed assets and had the ability to import avatars that were high quality.

3.1.2 Virtual Environment

The general layout of the simulated environment remained largely the same as it was in the first iteration of the experiment. The avatar was placed seated behind a desk directly facing a mirror on the back wall of a small room. The room had a door, a light and a small painting as decoration. The desk displayed a cell phone used to listen to the audio cues. The mirror on the back wall was made larger in this version of the simulation.

The mirror used needed to not create any distortion and needed to be able to handle the bi-ocular nature of VR. Assets that were designed by other developers were intentionally blurred, projected a duplicate image when using VR, or portrayed a distorted image. Since it was essential
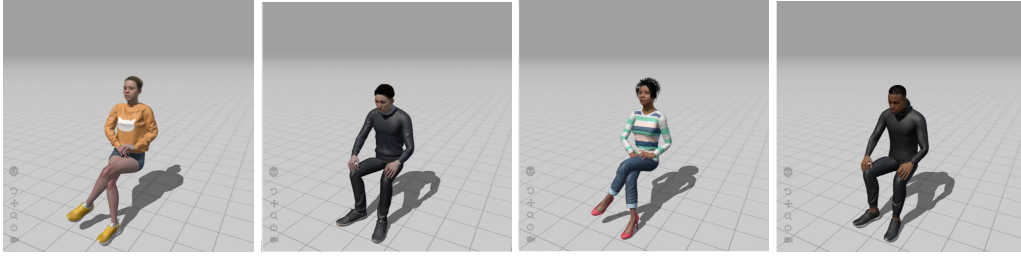
Figure 3.1: Light-Skinned Female **Figure 3.2:** Light-Skinned Male **Figure 3.3:** Dark-Skinned Female **Figure 3.4:** Dark-Skinned Male

that the participants felt somewhat embodied in the avatar the mirror was a crucial part of the simulation. Unreal allowed me to develop exactly the mirror desired very quickly.

3.1.3 Avatars

More diverse avatar options were incorporated into the final simulated environment. Instead of randomly assigning participants a gender of avatar, participants were matched with their preferred gender and ethnicity. This allows participants to feel as embodied by the avatar as possible during the simulation. This change was made because randomizing gender assignment added a layer of complexity to the initial experiment that may have tarnished the results gathered by the original participants. Dark-skinned avatars were added in case participants preferred that look but no participants felt characterized by a dark-skinned avatar. The avatars imported for this experiment were created on Mixamo an Adobe affiliate [35]. The avatars used are shown above. Some animations were added to the avatars based on the feedback received from the pilot study. The participants could see the avatars breathe in the mirror and when they looked down at the avatar's body.

3.1.4 Audio Cues

The audio cues used in the simulation were formatted as voicemail messages. This was done so that participants wouldn't feel the need to respond verbally to the questions asked of them. A female voice was the agent speaking who introduced herself as a worker at the college registration office at Colorado State University. She then prompted the participants embodying avatars, high-

lighting the four factors discussed at length previously. The transcript of the voicemail for each

condition can be found in Figure 3.1.

Goal Orientation
Hello, this is the office of registration and advising in the Computer Science department at Colorado State University. We are contacting you because our records indicate that you have not yet declared a major and we would like to encourage you to enroll in an introductory Computer Science course. With a background in Computer Science, you will have many opportunities to contribute new technologies and innovations to your community and the world. If your goal is to help others Computer Science may be right for you. Would you like to enroll?
Self-Efficacy
Hello, this is the office of registration and advising in the Computer Science department at Colorado State University. We are contacting you because our records indicate that you have not yet declared a major and we would like to encourage you to enroll in an introductory Computer Science course. Your transcripts indicate you did not take a Computer Science course in high school but with your high grades and drive to succeed that you make clear in your essay you should have no trouble in Computer Science. Would you like to enroll?
Family Background
Hello, this is the office of registration and advising in the Computer Science department at Colorado State University. We are contacting you because our records indicate that you have not yet declared a major and we would like to encourage you to enroll in an introductory Computer Science course. According to your personal records, your mother and father are both in tech fields. Despite never having taken a Computer Science course before we expect that you would have no trouble adapting to the demands of the course due to your life-long exposure to the material. Would you like to enroll?
Demographics
Hello, this is the office of registration and advising in the Computer Science department at Colorado State University. We are contacting you because our records indicate that you have not yet declared a major and we would like to encourage you to enroll in an introductory Computer Science course. This department strives to be as inclusive as possible and we believe that you will feel a strong sense of community among your peers according to your gender and ethnic profile. Would you like to enroll?

Table 3.1: Transcript of the audio cues from the final experiment

3.2   Survey

The survey each participant filled out took about 10 to 15 minutes to complete. It was developed by the researchers to garner how likely the participant was to enroll their avatar in the CS course offered with only the information highlighted in each condition. The survey questions can be found in Appendix A.2. The consent form was attached to the survey. If the participants consented to participate and they were 18 years or older only then would they get access to the survey. The consent form can also be found in Appendix A.1.

3.3   Final Experiment Procedure

In this section, the entire process of running the experiment is detailed. This was a repeated measures experiment meaning that every participant performed each of the treatments.

3.3.1   Participants

For the final experiment, there was a total of 25 participants. One participant's results had to be discarded due to an error made when filling out the survey (n= 24). The participant pool was comprised of mostly white males (86.4% and 63.6% respectively). The majority of participants were undergraduates in CS fields (59.1%) and between the ages of 18 to 22 (45.5%). 31.8% of participants were between the ages of 23 to 27 and 22.7% were over the age of 28. Nearly all participants were currently in college pursuing a degree. All of the participants had no prior knowledge of the intent of this study when they agreed to volunteer to do the experiment. Several of the participants agreed to do the study in exchange for course credit but the majority were strictly volunteers. Due to the fact that many of the participants were in CS fields they had some exposure to VR but many participants had never experienced a virtual environment before.

3.3.2   Different Versions

This experiment was developed to work in a virtual environment using an Oculus Quest with computer linked cable or any HMD that could connect with a Windows Personal Computer. The

file needed to run the simulated environment was a .EXE file so any computer that could run a .EXE file could be used.

The experimental simulated environment was also able to run on a desktop without a HMD. The experiment was designed to support both options so as to allow more accessibility for potential participants. Very few participants used the desktop version of the experiment (9.1%) making it difficult to determine if there was a significant impact on the overall experience for the participants.

The experiment was designed to be done remotely, if necessary, again, in order to allow for more accessibility to potential participants. The instructions for performing the experiment remotely can be found in Appendix A.3. An introduction to the avatar the participants embodied is also found in Appendix A.3 therefore sections of the instructions were used when the experiment was not being done remotely.

3.3.3   Running the Final Experiment

All potential participants were initially sent an email with instructions describing the requirements for this experiment. It was made clear that only people 18 years or older could participate. It was also noted that all participants could run this experiment remotely or in a lab on campus. Any participants interested were asked to sign up for a specific time slot if they wanted to come into the lab to run the experiment. If a participant requested to do the experiment remotely, they were sent an email with links to the consent form Appendix A.1 and survey Appendix A.2, as well as a link to the files necessary to run the simulation and instructions Appendix A.3.

Participants who ran the simulation remotely were instructed to read the instructions provided completely before moving forward. They were then instructed to download the simulated environment which contained the avatar that best represented their gender and racial identity (i.e. Light_Skinned_Male_VR). The folders that contained all necessary files for running the simulation could be found on Microsoft OneDrive. Once the files were downloaded (20 minute download time at low processing power) the participant was instructed to find the executable file called *project2.exe* and answer the first question on the survey. They then opened the executable file and

then put on their personal HMD if they had access. If they did not have access to a HMD they opened the executable file and used their mouse to look around the simulated environment. All participants were then asked to select and remember any number between 1 and 4 on their keyboard. The number key triggered one of the four audio cues. Once the audio cue completed playing they were asked to remember the four digit number that appeared over the top of the cellphone in the simulation. Once they had the number memorized they could remove the HMD and/or go back to the survey. They then filled out the next three questions on the survey asking them which condition they had just completed, what the condition was highlighting as a means of determining if the participant was listening closely, and how likely they were to enroll in the CS course discussed in the audio cue. Remote participants were also asked to provide the four digit number to ensure completion of each condition.

All participants entered the simulation four separate times to experience each audio cue. The remote participants were asked to randomly select the triggering keys to avoid ordering effects. After they had listened to all audio cues they were asked to complete the remaining questions on the survey before they finished the experiment.

Participants who signed up to run the experiment in-person had a very similar experience. After signing the consent form they were asked to answer the first question on the survey which acted as a control question to see how likely the participant was to enroll in an introductory CS course without any treatment. They were then instructed to read the first section of the instructions provided Appendix A.3 as well as the section introducing the avatar they would be embodying. This section reads as follows:

"In the simulation you will be embodying a first-year undergraduate student who has yet to declare a major. This person has not taken any computer science courses in the past. You should take everything suggested in audio cues as fact."

The participants then put on an Oculus Quest with computer link cable. A researcher used a bluetooth keyboard to open the simulation executable and randomly select an audio cue to play. The participant was instructed to remove their HMD and answer the questions associated with

the condition they just completed. The participants were told which condition they had just been through. When the participants performed the experiment in-person they were not required to remember a four digit code after each condition. Participants went through the simulation four times in order to complete all four conditions. After they had completed all conditions and filled out the entire survey they submitted the survey and their part was finished.

3.4   Methods for Evaluation

The assumptions of normality and residual variance were satisfactory (Appendix A.4). Analysis was completed using a linear mixed-effects model. A linear mixed-effects model accounted for the within subjects design of the experiment. This model accounts for a participant's data points correlating with one another since they come from the same participant as well as the variability at the subject-to-subject level. The fixed effects for this model were the various audio cues because this study was interested in the effect of the audio cues on participant response, and if the effect varied depending on the highlighted factor in a given cue. The marginal sum of squares obtained by deleting one term from the model at a time was used when running an analysis of variance (ANOVA test) comparing the means between conditions.

The proportion of responses on each condition were examined first. The proportions were considered to determine if there was a definite direction in response for each condition. The chi-squared goodness of fit test was used to obtain data on the proportion of responses for each of the five levels used in this Likert scale per condition.

3.5   Results

According to the chi-squared goodness of fit test there was a difference in response proportion for all conditions except the condition that highlighted self-efficacy (p=0.09; Table 3.2) labelled as Ability in all graphs and plots moving forward. This result suggests that participants showed no preference for a single response when being asked about self-efficacy. It is also worth noting that the response proportion for the family background condition labelled Family in all plots and
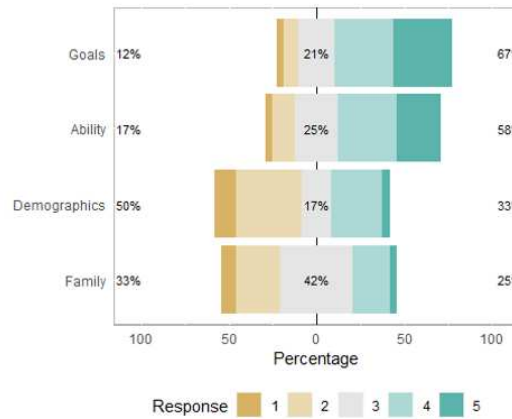
Figure 3.5: A bar graph of likert scale responses from participants concerning their interest in taking a CS course

graphs moving forward had a much higher proportion of responses in the 'not likely or unlikely' category.

Table 3.2: Proportions for each condition

Condition	not at all	unlikely	not likely or un-likely	moderately likely	entirely likely	p Values
Demographics	0.1250	0.3750	0.1666	0.2916	0.0416	**0.0311**
Ability	0.0416	0.1250	0.2500	0.3333	0.2500	0.0908
Family	0.0833	0.2500	0.4166	0.2083	0.0416	**0.0102**
Goals	0.0416	0.0833	0.2083	0.3333	0.3333	**0.0249**

Participants strongly favored the condition of the experiment which emphasized goal orientation Figure 3.5. Participants appear to favor the condition which emphasized self-efficacy, but Table 3.2 reflects that response to the self-efficacy condition were widely spread among participants. Participants indicated a substantial decline in interest in the course when the emphasis was on their race and ethnic background. Family background had a neutral response among participants which Figure 3.5 shows most clearly with 40% of participants responding with 'not likely or unlikely'.
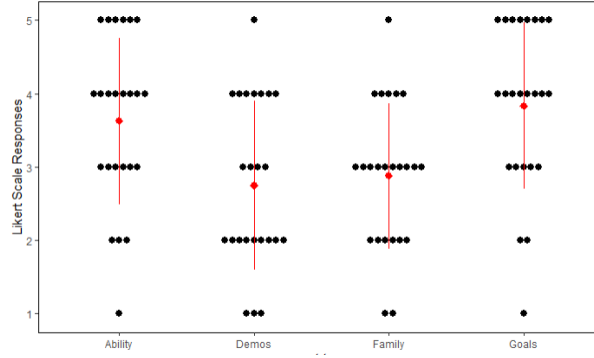
Figure 3.6: A dot plot of likert scale responses from participants concerning their interest in taking a CS course including the mean and standard deviation for each treatment

The averages and standard deviations of the responses compared to one another can be seen in Figure 3.6. From this plot, it is evident that there were more favorable average responses toward self-efficacy and goal orientation labelled Goals in the plots and charts in this section.

Finally, since there was a substantial difference in responses between conditions across participants as shown by an ANOVA test ($F = 9.484$, $p < 0.0001$) there was enough evidence to contrast each condition. The results of those contrasts are shown in Table 3.3. There was a difference in means between most conditions except self-efficacy compared to goal orientation and demographics compared to family background.

Table 3.3: Summary table of contrasts between treatments

Contrast	Estimates	SE	DF	T Ratios	P Values
Ability - Demos	0.875	0.247	69	3.539	**0.0040**
Ability - Family	0.750	0.247	69	3.033	**0.0175**
Ability - Goals	-0.208	0.247	69	-0.843	0.8340
Demos - Family	-0.125	0.247	69	-0.506	0.9575
Demos - Goals	-1.083	0.247	69	-4.381	**0.0002**
Family - Goals	-0.958	0.247	69	-3.876	**0.0013**

3.6 Discussion

There are two major takeaways from the proportions test comparing the responses for each condition. The responses for self-efficacy were too variable among respondents making any interpretation of the results extracted concerning self-efficacy tenuous. The results of the proportions test in regard to family background indicate that most respondents were unaffected by the family background condition. This result is quite interesting considering it does not conform with the data previously collected by past work by other researchers [10].

The demographic characteristic condition and the goal orientation condition are significantly differences ($p = 0.0002$). This suggests that there is a difference in attitude toward enrollment depending on which factor of belonging is emphasized.

Figures 3.5 and 3.6 indicate that participants were fairly negatively affected by the emphasis on demographic characteristics. It is true that a person's beliefs do not always align with their behavior. This phenomenon is referred to as cognitive dissonance. This research is not suggesting that people would not feel a stronger sense of belonging if they were surrounded by others that reflect their demographic identity. This **research does indicate** that when a person is told that they will find a similar demographic community in CS it does not encourage them to want to attend. It may also be worth noting that the majority of participants in this study represent the demographic balance in the CS community as it is now, which is dominantly white males.

The fact that so many of the participants showed such strong favor to goal orientation is in alignment with the work done by Colleen Lewis et al. [9], research that was a major inspiration for the work done for this project. These results indicate that when choosing a program of study, knowing the copious amount of opportunities in that field is extremely important to people.

3.6.1 Feedback

While the majority of participants were in a field related to CS and gave high scores to the initial question of "How likely are you to enroll in a CS course?" their responses were much more varied after being put in the simulation. This phenomenon might be due to the simulated

environment having the desired effect. The simulated environment allowed participants to have a depersonalized experience and answer the survey questions as the avatar rather than as themselves.

There are certainly alternative explanations for this phenomenon. The participants may have experienced researcher bias which is a bias that occurs when participants want the researcher to be pleased with their performance on the experiment so they aren't completely truthful about their responses. The participants could have recognized that the simulation was meant to have an effect on them therefore they answered the next survey questions as if it had an impact when it did not.

Participants also noted in survey feedback that they would have liked to see even more movement in the avatar to increase the embodying effect. In order to accomplish this, a change in the type of HMD may be advisable in future work. The feedback on the survey was largely positive though, one participant mentioning that they could empathize with the avatar more being embodied in it.

Chapter 4

Conclusion and Future Work

In the final chapter, some major insights are discussed that were discovered during the process of developing this project. Improvements that could have been made to the various elements of the final experiment are explored. And some ideas for future work are looked at in detail.

4.1 Future Work

The work done in this project is highly nuanced since the alterations between conditions are very minor, but it has a clear direction forward. Since the results of this project seem to indicate that there is a preference for what will encourage students to enroll in CS courses the same study should likely be repeated with more participants. Not only should their be more participants, but the participants should include more diverse voices. The majority of participants were CS majors already, and none of the participants were undeclared. The participant's major did not seem to have a large impact on the way they responded but there was not enough data to make a claim about the impact of major in one way or the other.

If the results of this study remain similar upon repetition with a larger and more diverse sample then there may be evidence enough to begin working on actionable initiatives that are considerate of the data gathered.

There are also plenty of improvements that could be made to this experiment design. The four factors that were highlighted in the final experiment were supported with evidence that suggested that they were important to a student's sense of belonging, but there could easily be more factors that were not investigated in this project and deserve to be. There was some feedback from participants saying that they could have felt more embodied in the avatar if it were capable of moving with them. For this project, a more focused virtual environment rather than an interactive one was chosen, but it is possible that the results would have been less biased with more avatar control. The

virtual environment itself was somewhat sparse, so improvements to the space that would make it feel more immersive would also likely lead to a more embodying experience.

4.2 Conclusion

Despite the promising outcomes achieved by this study there were many areas of this research that could be improved upon. In many ways it was a pioneering effort into the world of uniting VR and psychology. Research into the power of VR to create psychologically "sterile" environments, where subjects can lose themselves but still draw conclusions about what they are experiencing is difficult to find. In psychology, it is vital that subjects are in a controlled environment when results are being collected and VR allows researchers to control the environment in ways that were impossible in the past.

This work is a deep examination into the minds of people. It is a chaotic area of research, that is constantly susceptible to change and modification. The results of this study will almost certainly change over time, but it is critical that education researchers persistently try to maintain an edge on what goes through a student's mind, especially when making major decisions for their future.

The research done in this project unfortunately did not encompass an extremely diverse set of people. It is important that the conclusions drawn from this project be reexamined on the population it was designed to help address the needs of. Researchers have a responsibility to aid in bringing students into universities that belong there. Whether a student belongs in CS because their goals require a technology background, they have the confidence to succeed in the field, because of their family, or because their demographic characteristics give them a unique opportunity to provide insights that would not have been explored without their presence. People of all backgrounds are necessary for the future of this field.

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Appendix A

A.1 Consent Form

Exploring Belonging in Computer Science

Carefully read and agree to the terms laid out in the consent form below. You may NOT participate in this experiment without first providing consent.

* Required

Exploring Belonging in Computer Science

Primary Investigator
Francisco Ortega, PhD., Dept. of Computer Science, CSU, f.ortega@cs.colostate.edu
Student Investigator
Vidya Gaddy, BS., Dept of Computer Science, CSU gaddvi@colostate.edu

Project Purpose and Procedures

This experiment is designed to investigate how people interact with and respond to a simulation within a virtual environment created by a virtual reality headset or a typical 2D display. There is a moderate risk of motion sickness. Please do not move around while in the simulation.
The purpose of this experiment is to gather information that can help improve students' sense of belonging in Computer Science. You are being asked to complete a simulation and survey to assist us in that regard. We expect it will take you approximately 5-10 minutes to complete the simulation and survey.

Confidentiality

The identities of all people who participate will remain anonymous and will be kept confidential. Identifiable data will be stored securely in a locked metal filing cabinet or in a password protected computer account. All data from individual participants will be coded so that their anonymity will be protected in any reports, research papers, thesis documents, and presentations that result from this work.

Remuneration/Compensation

We are very grateful for your participation. However, you will not receive compensation of any kind for participating in this project.

Contact Information About the Project

If you have any questions or require further information about the project you may contact Vidya Gaddy gaddvi@colostate.edu.

Consent

We intend for your participation in this project to be pleasant and stress-free. Your participation is entirely voluntary and you may refuse to participate or withdraw from the study at any time.

A.2 Belonging in CS Experiment Survey

Exploring Belonging in Computer Science

* Required

Simulation Response Survey

Please answer the questions for this survey as you complete each experimental condition.
Follow the instructions for completing this survey as given in the README file.
When you see "###" please begin the next condition of the experiment prior to answering the survey questions
Do not submit this survey until you have gone through all 4 conditions!

On a scale of 1-5 (1-not at all, 5-entirely): How likely are you to agree to enroll in an introductory Computer Science course? *

1	2	3	4	5
○	○	○	○	○

DO NOT CONTINUE THIS SURVEY UNTIL AFTER YOU BEGIN RUNNING THE SIMULATION

Which condition did you just complete? *

○ Condition 1

○ Condition 2

○ Condition 3

○ Condition 4

What was the subject of the voicemail recording? *

○ Personal Ability

○ Family Background

○ Personal goals

○ Personal characteristics

On a scale of 1-5 (1-not at all, 5-entirely): How likely are you to agree to enroll in the Computer Science course being offered? *

○ 1

○ 2

○ 3

○ 4

○ 5

Which condition did you just complete? *

○ Condition 1

○ Condition 2

○ Condition 3

○ Condition 4

What was the subject of the voicemail recording? *

○ Personal Ability

○ Personal goals

○ Personal characteristics

○ Family Background

On a scale of 1-5 (1-not at all, 5-entirely): How likely are you to agree to enroll in the Computer Science course being offered? *

○ 1

○ 2

○ 3

○ 4

○ 5

Which condition did you just complete? *

○ Condition 1

○ Condition 2

○ Condition 3

○ Condition 4

What was the subject of the voicemail recording? *

○ Personal goals

○ Personal characteristics

○ Personal Ability

○ Family Background

On a scale of 1-5 (1-not at all, 5-entirely): How likely are you to agree to enroll in the Computer Science course being offered? *

○ 1

○ 2

○ 3

○ 4

○ 5

Which condition did you just complete? *

○ Condition 1

○ Condition 2

○ Condition 3

○ Condition 4

What was the subject of the voicemail recording? *

○ Personal Ability

○ Personal goals

○ Personal characteristics

○ Family Background

On a scale of 1-5 (1-not at all, 5-entirely): How likely are you to agree to enroll in the Computer Science course being offered? *

○ 1

○ 2

○ 3

○ 4

○ 5

On a scale of 1-5 (1-not at all, 5-entirely): Did you feel connected with the avatar in the simulation during any of the conditions? *

○ 1

○ 2

○ 3

○ 4

○ 5

Which version of the experiment did you complete? *

○ Virtual Reality version

○ Desktop version

What is your age?

○ 18-22

○ 23-27

○ 28 +

○ Prefer not to say

What is your academic status?

Choose ▼

What is your major? (if applicable)

Your answer

What academic year are you currently in?

Choose ▾

What is your gender?

○ Female

○ Male

○ Non-binary

○ Other

○ Prefer not to say

What is your ethnicity/race?

Choose ▾

Do you have any feedback about the simulation or comments about the experiment as a whole that you would like to express?

Your answer

Please enter the time of submission *

Time

___ : ___   AM   ▼

Please enter the date of submission *

Date

mm/dd/yyyy 🗓

Back   Submit

A.3 Remote Experiment Instructions

Introduction:

This experiment will consist of 4 short 30 second simulations.

If you have NOT completed the consent form, please follow the link below:

https://forms.gle/6oS8Bx23WWUD1nuw8

Please read this document fully before running the simulation and filling out the survey.

Desktop Version:

If you do not have access to a VR headset but you do have a Windows compatible computer, please open the Belonging_Experiment folder and select the folder name that best reflects your personal gender and ethnic identity (I.e. Light_Skinned_Female1). Do not open the folders ending in "_vr".

Download the folder and all its contents (select the folder do not open it, download button will appear in the top left corner of the screen), it should be in a zip format. Unzip the folder in a location of your choice. (It may take a while to download the zip file)

Once you have successfully unzipped the file navigate to <X_Skinned_X1>/WindowsNoEditor on your personal computer. Before clicking **MyProject2.exe** please review the simulation instructions listed below

VR Version:

If you have access to a VR headset on a Windows-64 computer, please open the Belonging_Experiment folder and select the folder name that best reflects your personal gender and ethnic identity (I.e. Light_Skinned_Female_vr). Do not open the folders ending in "1".

Download the folder and all its contents (select the folder do not open it, download button will appear in the top left corner of the screen), it should be in a zip format. Unzip the folder in a location of your choice. (It may take a while to download the zip file)

Once you have successfully unzipped the file navigate to <X_Skinned_X_vr>/WindowsNoEditor on your personal computer. Before clicking **MyProject2.exe** please review the simulation instructions listed below

Simulation Instructions:

In the simulation you will be embodying a first-year undergraduate student who has yet to declare a major. This person has not taken any computer science courses in the past. You should take everything suggested in audio cues as fact.

You may get a warning message when opening the MyProject2.exe file click **'more info'** then **'run anyway'** at the bottom of the message.

The simulation might automatically enter full screen mode you may press **ESC** on your keyboard at any time to **exit the simulation**

Desktop:

You will need to use your keyboard while in the simulation!

Press a number key on your keyboard while in the simulation to hear an audio cue unique to that key. Do not press more than one number at a time. If you do hit more than one press the **ESC** key and begin the simulation again.

Numbers 1-4 correspond to a condition of the experiment (i.e. key 1 = condition 1 on the survey). TRY TO REMEMBER THE NUMBER YOU PRESS DURING EACH TRAIL. This will be important when filling out the survey.

While in the simulation choose at random any key 1-4.

Make sure your audio is turned up and coming through headphones if possible

Please listen carefully to the audio cue. **They will sound very similar.**

Each audio cue should be considered independently

Once you hear the message get deleted you must press **ESC** and complete the section of the experiment survey beginning with ###.

After answering the questions concerning the condition you just went through open MyProject2.exe again and press any key 1-4 which you have not yet pressed.

After completing all four conditions please answer the remaining questions on the experiment survey and submit.

Begin the Simulation:

Open the MyProject2.exe

You may now press any key 1-4 and listen to the audio cue.

Press ESC and return to the survey after each trial and answer all questions until you see ###

Repeat these steps until you have heard all 4 audio cues.

VR:

You will need to use your keyboard while in the simulation!

Press a number key on your keyboard while in the simulation to hear an audio cue unique to that key. Do not press more than one number at a time. If you do hit more than one press the **ESC** key and begin the simulation again.

Numbers 1-4 correspond to a condition of the experiment (i.e. key 1 = condition 1 on the survey). TRY TO REMEMBER THE NUMBER YOU PRESS DURING EACH TRAIL. This will be important when filling out the survey.

While in the simulation choose at random any key 1-4.

Make sure your audio is turned up and coming through your VR device

Please listen carefully to the audio cue. **They will sound very similar.**

Each audio cue should be considered independently

Once you hear the message get deleted you must remove your headset and complete the section of the experiment survey beginning with ###.

After answering the questions concerning the condition you just went through open MyProject2.exe again and press any key 1-4 which you have not yet pressed.

After completing all four conditions please answer the remaining questions on the experiment survey and submit.

Begin the Simulation:

Place your headset on your head making sure all environment settings are correct. Lift the headset and open the MyProject2.exe

Situate yourself so you are comfortably sitting with your head aligned with the head of the person in the simulation.

You may now press any key 1-4 and listen to the audio cue.

Remove your headset press ESC and return to the survey after each trial and answer all questions until you see ###

Repeat these steps until you have heard all 4 audio cues.

Conclusion, Questions and Concerns

After you have completed and submitted the survey feel free to remove the simulation folder and all contents from your machine.

Thank you SO MUCH for your participation!

If you have any technical difficulties or questions concerning this experiment, feel free to contact gaddvi@colostate.edu
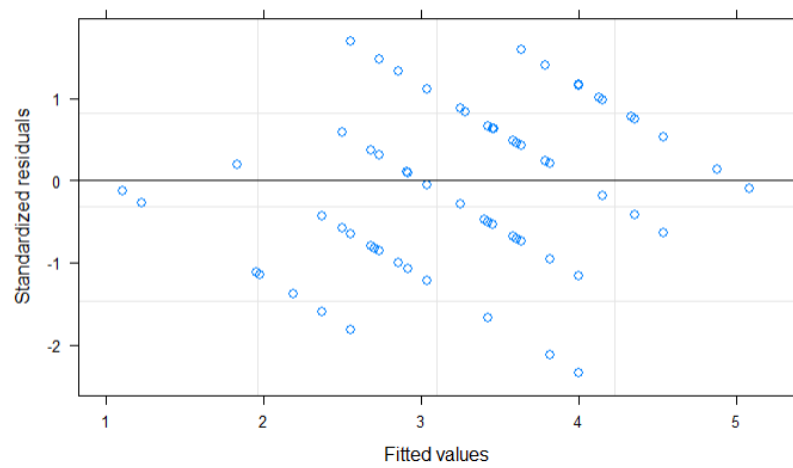
A.4   Normality and Variance Plots
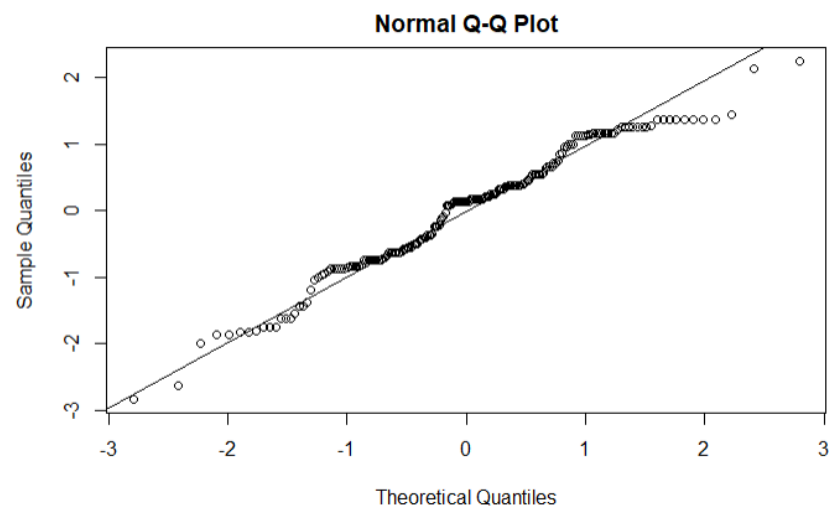

Figure A.1: Plot of the residual values in the data

Figure A.2: QQPlot that indicates normality of residuals