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Classrooms matter: The design of virtual classrooms influences gender disparities in computer science classes

Sapna Cheryan [a,*], Andrew N. Meltzoff [a,b], Saenam Kim [a]

[a] Department of Psychology, Box 351525, University of Washington, Seattle, WA 98195-1525, United States
[b] Institute for Learning & Brain Sciences, University of Washington, Seattle, WA 98195, United States

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ABSTRACT

Three experiments examined whether the design of virtual learning environments influences undergraduates' enrollment intentions and anticipated success in introductory computer science courses. Changing the design of a virtual classroom – from one that conveys current computer science stereotypes to one that does not – significantly increased women's interest and anticipated success in computer science. Effects occurred even when the learning material, gender of the professor and gender ratio of the classmates were identical, isolating the physical environment as a key determinant of women's choices and expectations. Men's interest and anticipated success were not similarly affected by the environmental changes. Statistical analyses indicated that gender disparities in interest and anticipated success in the stereotypically designed classroom were mediated by women's lower sense of belonging in that environment. Changing the design of virtual learning environments may be a vehicle that universities can use to signal belonging to a wider net of students, and thus increase students' likelihood of enrolling and succeeding in those classes.

1. Introduction

Three-dimensional virtual worlds are an increasing presence in people's lives. Worldwide, over 300 schools own and operate three-dimensional virtual learning environments (3-D VLEs) for educational purposes (Sussman, 2007), including virtual classrooms and labs, offices, and areas for students and teachers to interact with one another (Baker, Wentz, & Woods, 2009; Barbour & Reeves, 2009; Dede, 2009; Jennings & Collins, 2008; Sussman, 2007; Wong, 2006).

Many of the world's top universities are actively supplementing their traditional brick-and-mortar campuses with 3-D VLEs. This is occurring for two principal reasons. First, advances in online technology have enabled the creation of virtual spaces in which students can listen to lectures, ask questions and interact with their professors and peers outside of traditional classroom time (Bailenson et al., 2008; Chittaro & Ranon, 2007; Krämer & Bente, 2010; Petrakou, 2010). Second, 3-D VLEs provide a nimble mechanism for meeting the needs of students while working within the space and financial constraints faced by many universities today (Barbour & Reeves, 2009; Herold, 2009; Lester & King, 2009; Warburton, 2009).

3-D VLEs are afforded almost limitless design possibilities. Virtual worlds are not constrained by the availability of physical materials or even by the laws of physics. As a result, university 3-D VLEs currently vary greatly in their appearance (Herold, 2009; Jennings & Collins, 2008). For instance, some universities have created virtual replicas of their actual campuses – such as Ohio University's red brick buildings (Jennings & Collins, 2008) and MIT's virtual residence hall tours (Foster, 2007) – while other universities have constructed spaces that look entirely different from their actual campuses – such as classrooms with supernatural elements (e.g., floating chairs) (Jennings & Collins, 2008; Lester & King, 2009). Might the design of 3-D VLEs influence students' choices and attitudes toward the school or the specific courses in which they enroll? The current work provides an experimental test of whether 3-D VLEs, through the objects they contain and their overall design, can communicate to students how much they belong in a virtual environment and thereby influence their participation and success in that environment. In this work, we focus specifically on whether the design of 3-D VLEs influences gender disparities in interest in college level computer science courses.

* Corresponding author. Tel.: +1 206 543 5688; fax: +1 206 685 3157.
E-mail address: scheryan@uw.edu (S. Cheryan).

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1.1. Background research: physical environments and education

1.1.1. Real environments and educational outcomes

The way in which schools and universities design their real-world educational environments, such as their classrooms and offices, has important consequences for students' educational outcomes (Küller & Lindsten, 1992; Martin, 2006; Moore & Lackney, 1994; Weinstein, 1977, 1979). One way environments affect students is through identity cues, or structural elements that communicate who belongs in that environment (Cheryan, Plaut, Davies, & Steele, 2009; see also Gosling, Ko, Mannarelli, & Morris, 2002; Mendoza-Denton, Shaw-Taylor, Chen, & Chang, 2009). For instance, Cheryan et al. (2009) found that when a computer science classroom contained objects stereotypically associated with computer science (e.g., Star Trek poster, video games), female undergraduates expressed less interest in computer science than their male peers. However, when the computer science classroom was re-designed to include objects not stereotypically associated with computer science (e.g., art, water bottles), women's interest in computer science increased to the level of men's interest. Stereotypes projected through an environment can thus have important educational consequences, despite the potential inaccuracy of these stereotypes (Borg, 1999).

1.1.2. Identity and ambient belonging

Why do environments with objects stereotypically associated with computer science steer women away? Educational environments, through their layout and objects, influence students' sense of ambient belonging (Cheryan et al., 2009), or feeling of fit in an environment. Not feeling like one belongs in an environment has a detrimental impact on learning (Anderman, 2003; Pittman & Richmond, 2007, 2008). The stereotypical computer science environment was seen as masculine by both women and men (Cheryan et al., 2009). Masculine environments are perceived as incongruous with the female gender role (Barbercheck, 2008; Cheryan et al., 2009; Eagly & Steffen, 1984; Nosek, Banaji, & Greenwald, 2002) and cause women to feel a lower sense of belonging in them (Cheryan et al., 2009; Murphy, Steele, & Gross, 2007; Walton & Cohen, 2007). Conversely, learning environments designed to elicit a greater sense of belonging by underrepresented groups increases these students' interest and anticipated success in those environments (Cheryan et al., 2009; Dasgupta & Asgari, 2004; Murphy et al., 2007; Purdie-Vaughns, Steele, Davies, Ditlmann, & Crosby, 2008). To promote a sense of belonging, it is therefore important to make environments compatible with students' social identities (Cheryan et al., 2009; Murphy et al., 2007; Purdie-Vaughns et al., 2008).

1.1.3. Virtual environments and educational outcomes

Like real classrooms, virtual classrooms may also influence students' interest and anticipated success by virtue of their design. Hundreds of universities are engaging in massive online construction projects as they build virtual educational spaces to accommodate the growing number of students who learn online (Baker et al., 2009; Barbour & Reeves, 2009; Dede, 2009; Jennings & Collins, 2008; Sussman, 2007; Wong, 2006). It is known that the *quality* of 3-D VLEs affects learning (Baker et al., 2009; Dalgarno & Lee, 2009; de Freitas, Rebolledo-Mendez, Liarokapis, Magoulas, & Poulovassilis, 2010; Petrakou, 2010), but less work has examined how the *design* of virtual environments (i.e., layout, objects) affects students (see Bailenson et al., 2008). The flexibility and ease of designing afforded to 3-D VLEs has resulted in great variation in the choices of the design of virtual university spaces (Herold, 2009; Jennings & Collins, 2008). Understanding how the appearance of 3-D VLEs influences learning is an important step in designing successful virtual classrooms that enable students to thrive.

Fostering a sense of belonging in a virtual environment, through its design, may be important to cultivating students' interest and expected success in that environment (De Lucia, Francese, Passero, & Tortora, 2009; Hrastinski, 2009; Liu, Magjuka, Bonk, & Lee, 2007). When in virtual environments, people often act in accordance with their real-life social identities (e.g., gender, race) (Dotsch & Wigboldus, 2008; Eastwick & Gardner, 2009; McKenna & Bargh, 1998; Palomares & Lee, 2010; Plant, Baylor, Doerr, & Rosenberg-Kima, 2009; Reeves & Nass, 1996). We thus hypothesize that women will be more interested in enrolling in an introductory computer science class taught in a 3-D VLE and anticipate greater success there if the classroom is set up in a more identity-consistent (i.e., less masculine) manner.

1.2. Gender disparities in computer science

In the U.S., the field of computer science has one of the highest gender disparities in participation, with less than 20% of undergraduate degrees in computer science currently granted to women (National Science Foundation, 2009). As a result, women have been deprived of careers in computer science, and society has been deprived of the benefits of diversity among the developers of our modern information age (Margolis & Fisher, 2002). Women, at all levels of schooling, are less likely than men to choose courses necessary to pursue computer science – a disparity that persists even when women and men are matched for quantitative ability and experience (Strenta, Elliott, Adair, Matier, & Scott, 1994). Current stereotypes of computer scientists as "computer nerds" – predominantly male, socially awkward and singularly focused on computers – is one of the factors that deters women from entering the field (Cheryan et al., 2009; Cheryan, Siy, Vichayapai, Kim, & Drury, in press; Cohoon & Aspray, 2006; Diekman, Brown, Johnston, & Clark, 2010; Margolis & Fisher, 2002; Plant et al., 2009; Schott & Selwyn, 2000). Broadening the image of computer science to be more appealing to women is crucial to ensuring their participation (Barker & Aspray, 2006). The current work examines whether re-designing virtual classrooms can be one such way to broaden the image and increase women's participation in computer science.

Making introductory computer science courses more appealing to draw women into them is crucial because most high school and college curricula do not include mandatory computer science requirements (Barker & Aspray, 2006), and a student's decision to forgo even a single feeder course can effectively preclude a technical major (Moses, Howe, & Niesz, 1999). Not taking the first class may block many women from discovering a talent or passion for computer science and influence their educational pathway. Thus, it is important to increase women's interest in enrolling in introductory computer science courses in order to increase their participation in the field. This effort may be assisted by re-designing virtual classrooms in which such classes are taught.

We hypothesize that stereotypes evoked by environments may also influence women's beliefs about their ability to be successful in computer science. Improving women's success beliefs in computer science is crucial to remedying current gender disparities for three reasons. First, in contrast to men, women tend to underestimate their abilities in science and mathematics (Campbell & Hackett, 1986;

Cheryan & Plaut, 2010; Ehrlinger & Dunning, 2003; Sax, 1994) even though they do not underestimate their abilities in other fields (Cheryan & Plaut, 2010; Lundeberg, Fox, & Puncochar, 1994). Second, anticipated success is a known determinant of actual success (Bandura, 1986; Meece, Wigfield, & Eccles, 1990) and interest in choosing to enter the domain (Bandura, 1997; Beyer, Rynes, Perrault, Hay, & Haller, 2003; Eccles, 1994; Eccles, Barber, & Jozefowicz, 1999; Meece et al., 1990). Finally, women in computing also face additional barriers to their success not faced by men, such as stereotypes that women are less skilled at computer science (Koch, Müller, & Sieverding, 2008). Concern about confirming negative stereotypes about one's group, known as stereotype threat, can itself result in performance decrements (Koch et al., 2008; Spencer, Steele, & Quinn, 1999; Steele, 1997; Steele & Aronson, 1995), even among people skilled in the domain (Good, Aronson, & Harder, 2008). Thus, increasing women's beliefs that they can be successful in computer science courses is crucial to remedying gender disparities in computer science. Using virtual environments to communicate a sense of belonging among women may be one way to achieve this.

1.3. *Research questions and hypotheses*

In three behavioral experiments, we manipulate the environment of virtual computer science classrooms to investigate its effect on enrollment intentions, anticipated success and ambient belonging among undergraduates. This research question is important because universities are increasingly using 3-D VLEs to educate, but little research has examined the influence of these designed virtual learning environments on their students. Understanding how the design of 3-D VLEs affects the choices and success of students could be used to attract a larger and more diverse student body. Moreover, this research allows us to examine how fundamental psychological principles that operate in real-world environments translate to virtual environments.

In Experiment 1, male and female undergraduates indicated their interest in enrolling in two introductory computer science classes, one with a virtual classroom environment that fits current computer science stereotypes and the other with a virtual classroom environment that does not fit these stereotypes. In Experiment 2, male and female undergraduates indicated their interest in enrolling in an online computer science course that they were told was actually offered at their university. The second experiment also assessed whether the classroom environment influences anticipated success. Experiment 3 compared the two classrooms to a "standard" classroom (without either set of objects) to investigate whether the stereotypical or non-stereotypical classroom (or both) drives the effects. If, for instance, the non-stereotypical classroom has an effect on women compared to a standard classroom, it would suggest to the designers of 3-D VLEs that they should add these elements to their virtual classrooms to improve the educational outcomes of female students.

Our specific hypotheses were three-fold. We predicted that a 3-D VLE that does not project current masculine computer science stereotypes compared to one that projects these stereotypes will: (a) encourage women to enroll in that class; (b) encourage women to anticipate better course performance; and (c) cause women to feel a greater ambient belonging in that environment. We further predicted that these environments will not have a similar effect on men.

2. Experiment 1

In the first experiment, female and male undergraduates indicated their intentions to enroll in a choice of two introductory computer science courses, in a process that mimicked college course registration, where students learn about and try classes before selecting one. The two classes were described as identical in curriculum (computer science), gender of the professor (male) and gender ratio of the students (50% female). The only difference was the design of the virtual classroom environment. Participants saw the classrooms in Second Life (http://www.secondlife.com), a 3-D VLE commonly used by universities (Graves, 2008). Because we are interested in recruitment, we did not include students who were already computer science majors.

2.1. *Method*

2.1.1. *Participants*

Sixty-three non-computer science majors at the University of Washington participated in exchange for extra course credit in one of three psychology classes. Three participants were eliminated from analysis due to procedural errors (i.e., seeing questions before seeing rooms, not following instructions), and one was eliminated for technical difficulties (i.e., room not loading properly). Of the 59 remaining participants, 25 were male. Participants' self-reported race/ethnicity included 23 Whites, 3 Latinos, 26 Asian Americans, 1 African American and 6 mixed race or other. Participants were mostly freshmen (66.1%) and sophomores (25.4%), with the remaining being juniors (3.4%) and seniors (5.1%). Participants reported a variety of majors, most commonly business (18.6%), biology (8.5%) and psychology (8.5%). (Results remained the same when we re-analyzed the data dropping psychology majors; all 59 participants are included in the analyses reported below.)

2.1.2. *Virtual environments*

Two classrooms were created in Second Life (see Fig. 1). Each contained 12 students' desks and chairs, one professor's desk and chair, a bulletin board, a shelf and a whiteboard labeled with "Welcome to Introduction to Computer Science." The classrooms differed only in their objects. One classroom contained objects stereotypically associated with computer science and the other did not. The stereotypical objects were generated by undergraduates who were surveyed about what objects they expected to find in stereotypical computer science environments (Cheryan et al., 2009). Specifically, the objects stereotypically associated with computer science were: science fiction books, computer parts, electronics, software, technology magazines, video games, computer books and Star Wars and Star Trek items. The objects not stereotypically associated with computer science were: water bottles, a coffee maker, art pictures, nature pictures, lamps, pens, general magazines and plants.

2.1.2.1. Pretest. To pretest the environments, a separate sample of 70 undergraduates (48 females) rated the two classrooms for how much each looked like a stereotypical computer science environment, on a scale from 1 (*not at all*) to 7 (*extremely*), and how masculine or feminine

Fig. 1. Stereotypical classroom, with science fiction items, video games, etc. (left), and non-stereotypical classroom, with nature posters, water bottles, etc. (right), in Second Life.

each was, on a scale from 1 (*very masculine*) to 7 (*very feminine*) (reversed during data analysis for ease of interpretation such that higher scores correspond to greater perceived masculinity). We conducted several pretest analyses of our stimuli using analyses of variance (ANOVA) models. As predicted, a 2 (Classroom) × 2 (Gender) ANOVA on the stereotype ratings revealed a main effect of Classroom, $F(1, 66) = 33.91$, $p < .001$, $d = .99$, with the stereotypical classroom being rated as significantly more stereotypical ($M = 4.56$, $SD = 1.86$) than the non-stereotypical classroom ($M = 2.44$, $SD = 1.54$). There was no main effect of Gender, $F(1, 66) = 1.03$, *ns*, and no Classroom × Gender interaction, $F(1, 66) = 1.59$, *ns*, indicating that men and women did not significantly differ in the extent to which they associated the rooms with the stereotype. A 2 (Classroom) × 2 (Gender) ANOVA on masculinity/femininity also revealed a main effect of Classroom, $F(1, 67) = 199.50$, $p < .001$, $d = 2.66$. The stereotypical classroom was rated as significantly more masculine ($M = 5.83$, $SD = 1.00$) than the non-stereotypical classroom ($M = 2.88$, $SD = 1.09$). There was no significant effect of Gender, $F(1, 67) < 1$, *ns*, and no Classroom × Gender interaction, $F(1, 67) = 1.23$, *ns*. Compared to the midpoint of 4, the stereotypical room was rated as masculine, $t(69) = 15.42$, $p < .001$, $d = 1.84$, while the non-stereotypical classroom was rated as feminine, $t(68) = 8.49$, $p < .001$, $d = 1.02$.

2.1.3. Materials and procedure

Before starting the experiment, participants learned how to move through the virtual environment by completing an orientation maze in Second Life. Once they could finish the maze in 30 seconds, they were permitted to move onto the experiment. Participants navigated in Second Life using "mouselook" view, which enables first-person navigation.

Instructions were delivered on the computer. Participants were tested in individual, private experiment rooms. Experimenters were not in the experiment rooms when participants viewed the classrooms or during data collection. Participants were told to imagine they were considering taking a year-long intensive computer programming class and were told about two different hypothetical classes. Both classes were stated as identical in subject matter, homework requirements and gender of the professor (male) and students (50% female).

Before seeing the rooms, participants were told, "You decide to attend the first day of both classes. You arrive early, which gives you a chance to look around the classrooms." Participants navigated into the stereotypical classroom and then the non-stereotypical classroom to look around. Before and after participants had "walked through" the classrooms virtually, they were tested on their knowledge of the classes to ensure that they knew that there were two classes and both had the same gender ratio. If a question was answered incorrectly, participants were presented with the relevant instruction screen and then asked to answer the question again. A large majority of participants (78.0%) answered both questions correctly on the first try, and all participants answered the questions correctly before continuing.

After seeing the virtual classrooms, *enrollment intentions* were assessed with a single-item measure asking how much they would want to join each class. *Ambient belonging* in the class was assessed by averaging the following four questions for analysis: (a) how much participants belong in the class, (b) how much they fit into the environment, (c) how similar they are to students in the class and (d) how much they fit with students in the class (Cheryan et al., 2009) (stereotypical $\alpha = .93$, non-stereotypical $\alpha = .94$). Enrollment intentions and ambient belonging questions were assessed on continuous scales from 1 (*not at all*) to 7 (*extremely*). In addition, participants indicated their dichotomous choice of class and why they chose that class (open-ended question). Demographic information (e.g., gender, major) was assessed at the end of the experiment.

2.2. Results

2.2.1. Course enrollment intentions

The design of the virtual classroom environment significantly influenced women's academic choices. A minority of women (17.6%; 6 of 34) but a majority of men (60.0%; 15 of 25) chose to take computer science in the stereotypical classroom, resulting in a significant 2 (Classroom) × 2 (Gender) contingency table, $\chi^2(1) = 11.27$, $p = .001$. On the continuous measure of enrollment intentions, a 2 (Classroom) × 2 (Gender) mixed-model ANOVA showed no significant main effects of Classroom, $F(1, 57) = 2.35$, *ns*, and a marginal main effect of Gender, $F(1, 57) = 3.27$, $p = .08$. As predicted, there was a Classroom × Gender interaction, $F(1, 57) = 11.93$, $p = .001$ (Fig. 2). Women expressed greater intentions to enroll in the non-stereotypical class ($M = 4.97$, $SD = 1.64$) than in the stereotypical class ($M = 3.21$, $SD = 1.65$), $F(1, 57) = 14.67$, $p < .001$, $d = .89$, while men expressed the same intentions to enroll in the two classes ($M = 4.12$, $SD = 1.39$ vs. $M = 4.80$, $SD = 1.44$), $F(1, 57) = 1.60$, *ns*.

2.2.2. Ambient belonging in the virtual classroom

A 2 (Classroom) × 2 (Gender) mixed-model ANOVA on ambient belonging revealed no main effect of Gender, $F(1, 57) < 1$, *ns*, but a significant main effect of Classroom, $F(1, 57) = 5.27$, $p < .05$, $d = .47$ (Fig. 2). The non-stereotypical classroom elicited significantly higher ambient belonging ($M = 4.39$, $SD = 1.32$) than the stereotypical classroom ($M = 3.54$, $SD = 1.53$). This main effect was qualified by

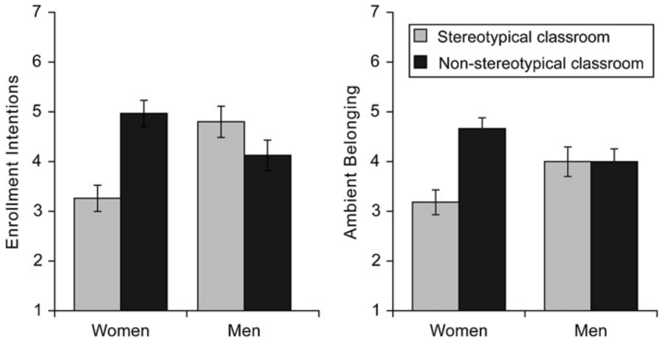

Fig. 2. Course enrollment intentions and ambient belonging for a computer science class in Experiment 1 when the classroom had objects that were stereotypical or not stereotypical of computer science. Error bars = *SEM*.

a Classroom × Gender interaction, $F(1, 57) = 5.27$, $p < .05$. Women felt significantly lower ambient belonging in the stereotypical classroom ($M = 3.20$, $SD = 1.62$) than in the non-stereotypical classroom ($M = 4.68$, $SD = 1.37$), $F(1, 57) = 12.43$, $p = .001$, $d = .81$, while men reported an equal sense of belonging in the two classrooms ($M = 4.00$, $SD = 1.30$ vs. $M = 4.00$, $SD = 1.17$), $F(1, 57) < 1$, *ns*.

2.2.3. Do feelings of ambient belonging explain gender differences in enrollment intentions?

To examine whether ambient belonging mediates the gender disparity in enrollment intentions in the stereotypical class, we conducted a standard mediation analysis (Baron & Kenny, 1986; Kenny, Kashy, & Bolger, 1998), employing 1000 bootstrap resamples using an SPSS macro provided by Preacher and Hayes (2004). Women had lower intentions to enroll in the stereotypical class than men, $b = -1.59$, $SE = .41$, $p < .001$ (Step 1). Relative to men, women also reported less ambient belonging, $b = -.80$, $SE = .39$, $p < .05$ (Step 2). Upon controlling for participant gender, belonging significantly predicted intentions to enroll in the stereotypical class, $b = .87$, $SE = .08$, $p < .001$ (Step 3), and the relationship between gender and enrollment intentions was attenuated when ambient belonging was controlled for, $b = -.90$, $SE = .24$, $p < .001$ (Step 4). The Sobel test indicated that ambient belonging was a significant mediator of the relationship between gender and enrollment intentions in the class, $Z = -2.00$, $p < .05$. Gender disparities in enrollment intentions in the stereotypical class could thus be accounted for by women's perceived lack of ambient belonging in the class.

2.3. Discussion

The results of this first experiment demonstrate that re-designing virtual learning spaces may help to remedy the underrepresentation of women in computer science and other technical fields. Women expressed greater intentions to enroll in the computer science class when it had a non-stereotypical rather than a stereotypical environment. Men, in contrast, were equally interested in both environments. The stereotypical classroom caused women to experience less ambient belonging in that class than the non-stereotypical classroom, which in turn, predicted their lower interest in that class.

The lack of ambient belonging in the stereotypical room was perhaps best illustrated in the open-ended responses we received to the question of why participants chose the classroom that they did. One female participant stated, "I would feel a bit uncomfortable in Classroom A [stereotypical classroom] because I cannot relate to any of the things in the room… Classroom B [non-stereotypical classroom] seems a lot more serene and welcoming." A second female participant noted how she felt more similar to the people in the non-stereotypical room because "I really don't like video games or action movies or computer science type activities. I would join Class B [non-stereotypical classroom] because…a lot of people in that class…are healthy people and I might get along with them." For these women, the stereotypical objects compromised their feelings of belonging with the environment and the people they imagined to be in that environment, even if the subject matter of computer science was interesting to them.

One potential limitation of the current study was that the stereotypical room was presented first, thereby confounding stereotypicality with order of presentation. A second potential limitation was that the class was described as a "year-long" computer science class when most college classes are shorter in duration. To address these two limitations, we repeated the experiment on a separate sample of female undergraduates ($N = 28$), with two changes. First, we counterbalanced room presentation such that participants were randomly assigned to which room they saw first. Second, we removed the "year-long intensive" qualifier and referred to it only as a "computer programming class." The results replicated. Consistent with Experiment 1, the majority (75.0%) of women preferred the non-stereotypical room. Women also expressed more interest in joining the non-stereotypical class ($M = 5.04$, $SD = 1.50$ vs. $M = 3.50$, $SD = 1.75$), $t(27) = 2.78$, $p = .01$, $d = .75$, and felt a greater sense of ambient belonging there ($M = 5.04$, $SD = 1.01$ vs. $M = 2.98$, $SD = 1.20$), $t(27) = 5.97$, $p < .001$, $d = 1.59$. Women were thus drawn more to the non-stereotypical than the stereotypical classroom, even when it was not specified as year-long. In the next experiment, male and female undergraduates were told about a virtual class that they believed would actually be sponsored by their university to examine how virtual classroom design affects actual enrollment intentions, anticipated success and ambient belonging.

3. Experiment 2

We assessed whether stereotypical and non-stereotypical classrooms influence actual choices of college courses by telling participants they would evaluate a class that is offered at their university. In addition, we examined whether stereotypical and non-stereotypical classrooms influence women's anticipated success in the course. Male and female undergraduates were told that the university had implemented virtual online courses and was seeking feedback regarding students' likelihood and willingness to take one of their courses – Introduction to Computer Science – in a virtual environment.

3.1. Method

3.1.1. Participants

Sixty-five non-computer science majors from the University of Washington participated in exchange for extra credit in one of three psychology classes. Three were eliminated due to technical errors (i.e., rooms set up incorrectly), leaving 62 participants (28 males). Based on self-report, there were 31 Whites, 3 Latinos, 20 Asian Americans 1 African American and 7 who designated mixed race or other race. Participants were mostly freshmen (45.2%) and sophomores (33.9%), with the remaining being juniors (12.9%) and seniors (8.1%). The most common majors among participants were psychology (14.5%), business (12.9%) communication (6.4%) and economics (6.4%). Eliminating the psychology majors from analyses did not change results.

3.1.2. Materials and procedure

Using Second Life, each participant was shown two online classrooms in which the computer science class was offered. Rooms were identical to the previous experiment, and order of room presentation was counterbalanced by randomly assigning participants to see either the stereotypical or the non-stereotypical room first.

Dependent measures were the same as in the previous experiment, except that enrollment intentions were measured with three questions that were averaged for analysis: how interested participants are in taking each class during their undergraduate years, how much they want to take each class during their undergraduate years, and how likely they would be to take each class during their undergraduate years, each on a scale from 1 (*not at all*) to 7 (*extremely*) (stereotypical $\alpha = .95$; non-stereotypical $\alpha = .91$). Anticipated success was also assessed in this experiment, with a single-item measure asking students how well they expected to do in the classes (adapted from Wigfield & Eccles, 2000), on a scale from 1 (*not at all*) to 7 (*extremely*). Finally, we again measured masculinity/femininity of the environments using the same questions as the pretest to Experiment 1.

3.2. Results

3.2.1. Order effects

Order of room presentation did not influence any dependent measures, all $F(1, 58)$'s < 2.1, *ns*.

3.2.2. Perceived masculinity of environments

A 2 (Classroom) $\times$ 2 (Gender) mixed-model ANOVA on masculinity/femininity again revealed a main effect of Classroom, $F(1, 60) = 105.57$, $p < .001$, $d = 1.86$. The stereotypical classroom was rated as significantly more masculine ($M = 5.48$, $SD = 1.21$) than the non-stereotypical classroom ($M = 3.06$, $SD = 1.07$). There was a marginal effect of Gender, $F(1, 60) = 3.24$, $p = .08$, $d = .26$, such that women rated the environments as more masculine ($M = 4.41$, $SD = .90$) than did men ($M = 4.11$, $SD = 1.33$). There was no Classroom $\times$ Gender interaction, $F(1, 60) = 2.72$, *ns*. Compared to the midpoint of 4, the stereotypical room was rated as masculine, $t(61) = 9.65$, $p < .001$, $d = 1.23$, and the non-stereotypical classroom was rated as feminine, $t(61) = 6.89$, $p < .001$, $d = .88$.

3.2.3. Course enrollment intentions

Consistent with the previous experiment, the classroom environment influenced enrollment intentions. A 2 (Classroom) $\times$ 2 (Gender) mixed-model ANOVA on enrollment intentions revealed no main effect of Gender, $F(1, 60) < 1$, *ns*, but a main effect of Classroom, $F(1, 60) = 7.03$, $p = .01$, $d = .50$ (Fig. 3). Students were more interested in enrolling in the non-stereotypical class ($M = 3.83$, $SD = 1.49$) than in the stereotypical class ($M = 3.09$, $SD = 1.68$). A Classroom $\times$ Gender interaction qualified this main effect, $F(1, 60) = 5.62$, $p < .05$. Women expressed lower intentions to enroll in the stereotypical class ($M = 2.73$, $SD = 1.70$) than the non-stereotypical class ($M = 4.01$, $SD = 1.53$), $F(1, 60) = 13.96$, $p < .001$, $d = 1.02$. In contrast, men expressed equal intentions to enroll in the two classes ($M = 3.54$, $SD = 1.56$ vs. $M = 3.61$, $SD = 1.45$), $F(1, 60) < 1$, ns.

3.2.4. Anticipated success

As predicted, classroom environment also affected how well students expected to perform in the class. A 2 (Classroom) $\times$ 2 (Gender) mixed-model ANOVA on anticipated success revealed no main effect of Classroom, $F(1, 60) = 1.59$, *ns*, but a main effect of Gender, $F(1, 60) = 4.70$, $p < .05$,

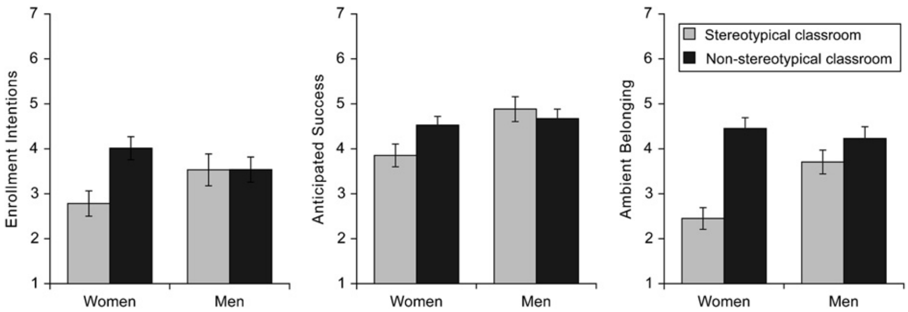

Fig. 3. Course enrollment intentions, anticipated success, and ambient belonging in Experiment 2 when the classroom had objects that were stereotypical or not stereotypical of computer science. Error bars = *SEM*.

$d = .57$ (Fig. 3). Women expected less success in these classes ($M = 4.19$, $SD = 1.21$) than men did ($M = 4.77$, $SD = .80$). This main effect was qualified by a Classroom × Gender interaction, $F(1, 60) = 4.69$, $p < .05$. Women expected less success in the class with the stereotypical environment ($M = 3.85$, $SD = 1.64$) compared to the class with the non-stereotypical environment ($M = 4.53$, $SD = 1.13$), $F(1, 60) = 6.50$, $p = .01$, $d = .70$. Men expected to perform equally well in the two classes ($M = 4.86$, $SD = 1.21$ vs. $M = 4.68$, $SD = 1.09$), $F(1, 60) < 1$, *ns*. Seen another way, women reported less success than men in the stereotypical classroom, $F(1, 60) = 7.28$, $p < .01$, $d = .48$, whereas women anticipated the same amount of success as men in the non-stereotypical classroom, $F(1, 60) < 1$, *ns*.

3.2.5. Ambient belonging in the virtual classroom

A 2 (Classroom) × 2 (Gender) ANOVA on ambient belonging revealed main effects of Classroom, $F(1, 60) = 25.26$, $p < .001$, $d = .90$, and Gender, $F(1, 60) = 4.21$, $p < .05$, $d = .53$ (Fig. 3). Students felt greater ambient belonging in the non-stereotypical classroom ($M = 4.35$, $SD = 1.37$) than they did in the stereotypical classroom ($M = 3.01$, $SD = 1.53$). Also, women felt less ambient belonging in the classrooms ($M = 3.45$, $SD = 1.05$) than men did ($M = 3.96$, $SD = .88$). Both of these main effects were qualified by the predicted Classroom × Gender interaction, $F(1, 60) = 9.06$, $p < .01$. Women felt significantly less ambient belonging in the stereotypical classroom ($M = 2.43$, $SD = 1.54$) than in the non-stereotypical classroom ($M = 4.46$, $SD = 1.52$), $F(1, 60) = 35.75$, $p < .001$, $d = 1.29$, whereas men felt a similar amount of ambient belonging in the two classrooms ($M = 3.71$, $SD = 1.22$ vs. $M = 4.21$, $SD = 1.18$), $F(1, 60) < 2$, *ns*.

3.2.6. Do feelings of ambient belonging mediate gender differences in enrollment intentions and anticipated success?

To examine whether ambient belonging explained the gender disparity in enrollment intentions in the class taught in the stereotypical classroom, we conducted the same standard mediation analysis as in Experiment 1. Women had lower intentions to enroll in the stereotypical class than men, $b = -.81$, $SE = .42$, $p = .06$ (Step 1). Relative to men, women also reported less ambient belonging in that class, $b = -1.27$, $SE = .36$, $p < .001$ (Step 2). Upon controlling for participant gender, belonging significantly predicted enrollment intentions in the stereotypical class, $b = .82$, $SE = .11$, $p < .001$ (Step 3), and the relationship between gender and enrollment intentions was no longer significant when ambient belonging was controlled for, $b = .23$, $SE = .33$, *ns* (Step 4). The Sobel test indicated that ambient belonging was a significant mediator of the relationship between gender and enrollment intentions in the stereotypical class, $Z = -3.19$, $p = .001$. Gender disparities in enrollment intentions in the stereotypical class were thus mediated by women's perceived lack of ambient belonging in the class.

A second mediation analysis examined anticipated success. Women expected less success in the stereotypical class than men, $b = -1.00$, $SE = .37$, $p < .01$ (Step 1). Relative to men, women also reported less ambient belonging in that class, $b = -1.27$, $SE = .36$, $p < .001$ (Step 2). Upon controlling for participant gender, ambient belonging significantly predicted anticipated success in the stereotypical class, $b = .39$, $SE = .13$, $p < .01$ (Step 3), and the relationship between gender and anticipated success was no longer significant when ambient belonging was controlled for, $b = -.50$, $SE = .38$, *ns* (Step 4). The Sobel test indicated that ambient belonging was a significant mediator of the relationship between gender and anticipated success, $Z = -2.30$, $p < .05$. Gender disparities in anticipated success in the stereotypical class could also be accounted for by women's perceived lack of ambient belonging.

3.3. Discussion

The design of the virtual classroom significantly influenced women's, but not men's, intentions to enroll in an introductory computer science class offered by their university and how well they anticipated doing in it. When the virtual classroom contained objects associated with current computer science stereotypes, women expressed less interest in enrolling in it than when the classroom contained objects not stereotypically associated with computer science. The stereotypical classroom also caused women to expect worse performance in that class. Because expectations for success are known to predict actual success (Wigfield & Eccles, 2000), interventions that raise students' expectations for how they will perform are important to ensuring they achieve success. Feelings of ambient belonging mediated both gender differences in intentions to enroll in the stereotypical class and gender differences in anticipated success in the stereotypical class. That these effects were observed for a class that women thought was actually at their university suggests that existing and future 3-D VLEs could make concrete changes to their environments to increase the participation and promote the successes of underrepresented students.

4. Experiment 3

We compared both the stereotypical and non-stereotypical classrooms to a classroom that did not have either set of objects. This allowed us to determine whether the stereotypical environment deters women, the non-stereotypical environment attracts women or both. On an applied level, to impact educational practices and the design of learning environments, knowing which classroom(s) are driving women's enrollment patterns enables recommendations about whether 3-D VLE designers should focus on eliminating stereotypical design elements or incorporating non-stereotypical design elements into their classrooms. Because the focus of this study was on which environments deter or attract women, we included only female participants in this study.

4.1. Method

4.1.1. Participants

Thirty-five female non-computer science majors from the University of Washington participated in exchange for extra credit in one of three psychology classes. One participant was eliminated due to a technical error (i.e., rooms set up incorrectly), leaving 34 participants. Based on self-report, there were 10 Whites, 2 Latinos, 18 Asian Americans and 4 who designated mixed race or other race. Participants were mostly freshmen (67.6%), with the remaining being sophomores (11.8%), juniors (11.8%) and seniors (8.8%). The most common majors among participants were psychology (14.7%), biology (14.7%), nursing (8.8%) and biochemistry (8.8%). Eliminating the psychology majors from analyses did not change results.

4.1.2. Materials and procedure

Procedures were identical to Experiment 1 except that participants saw three instead of two rooms. Order of room presentation was counterbalanced such that all six orders (e.g., control/stereotypical/non-stereotypical, stereotypical/control/non-stereotypical) were used, and participants were randomly assigned to one of the test orders. The stereotypical and non-stereotypical rooms were identical to the previous experiments, and the third "neutral" or control room did not have any stereotypical or non-stereotypical objects (but did have all the standard educational objects in common, e.g., desks/chairs, whiteboard). Dependent measures were the same as in the previous experiment, except that enrollment intentions were assessed with two questions: how much participants would want to take the class and how likely they would be to choose the class (stereotypical $r = .94$, $p < .001$; non-stereotypical $r = .82$, $p < .001$; control $r = .81$, $p < .001$).

4.2. Results

4.2.1. Course enrollment intentions

A repeated-measures ANOVA on enrollment intentions revealed a main effect of Classroom, $F(2, 66) = 13.11$, $p < .001$ (Fig. 4). Within-subject contrasts revealed that women were significantly more interested in enrolling in the non-stereotypical class ($M = 4.75$, $SD = 1.38$) over both the stereotypical class ($M = 3.54$, $SD = 1.81$), $F(1, 33) = 8.68$, $p < .01$, $d = .72$, and the control class ($M = 2.76$, $SD = 1.34$), $F(1, 33) = 42.22$, $p < .001$, $d = 1.58$. Women were also marginally less interested in the control class compared to the stereotypical class, $F(1, 33) = 3.08$, $p = .09$, $d = .43$.

4.2.2. Anticipated success

A repeated-measures ANOVA on anticipated success revealed a main effect of Classroom, $F(2, 64) = 5.34$, $p < .01$ (Fig. 4). Within-subjects contrasts revealed that women anticipated performing better in the non-stereotypical class ($M = 4.27$, $SD = 1.18$) than both the stereotypical class ($M = 3.76$, $SD = 1.20$), $F(1, 32) = 6.06$, $p < .05$, $d = .61$, and the control class ($M = 3.64$, $SD = 1.22$), $F(1, 32) = 12.71$, $p = .001$, $d = .87$. The stereotypical and control class did not differ from one another in anticipated success, $F(1, 32) < 1$, *ns*.

4.2.3. Ambient belonging in the virtual classroom

A repeated-measures ANOVA on ambient belonging revealed a main effect of Classroom, $F(2, 64) = 17.11$, $p < .001$ (Fig. 4). Women anticipated more ambient belonging in the non-stereotypical class ($M = 4.36$, $SD = 1.15$) than both the stereotypical class ($M = 2.98$, $SD = 1.30$), $F(1, 32) = 21.07$, $p < .001$, $d = 1.13$, and the control class ($M = 3.05$, $SD = 1.13$), $F(1, 32) = 41.67$, $p < .001$, $d = 1.58$. The stereotypical and control class did not differ from one another in ambient belonging, $F(1, 32) < 1$, *ns*.

4.3. Discussion

Compared to a neutral virtual classroom, a virtual classroom that added non-stereotypical objects significantly *increased* women's interest, ambient belonging and anticipated success. These results suggest that adding non-stereotypical objects to current and future 3-D VLEs may be one way to increase the participation of women in computer science and other technical fields. More broadly, this experiment suggests that 3-D VLEs can be designed in such as way to signal a sense of ambient belonging to underrepresented students and thereby increase their participation and success.

As shown in the pretest data in Experiment 1, the stereotypical room fit undergraduates' current stereotypes of computer science. Being exposed to the stereotypical classroom may not have communicated anything about computer science to women that they did not already believe. In addition, the neutral classroom may have seemed less interesting or engaging compared to classrooms with décor. However, the non-stereotypical room exposed students to an image of computer science that was radically *different* from their dominant representation. In other words, a computer science class in a neutral classroom may not do anything to attract women, whereas a classroom that projects a broader image of computer science may allow women to feel a sense of belonging in computer science. Thus, changing current virtual learning environments by adding cues that signal a sense of belonging to underrepresented groups may be a vehicle for attracting them to computer science courses and improving their chances at succeeding in them.

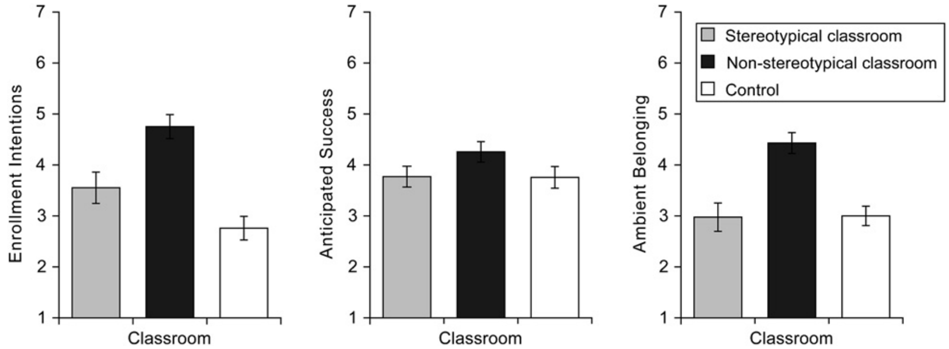

Fig. 4. Women's course enrollment intentions, anticipated success, and ambient belonging in Experiment 3 when the classroom had objects that were stereotypical or not stereotypical of computer science or had no such objects. Error bars = *SEM*.

5. Conclusions

This work demonstrates that students' enrollment decisions, anticipated success and sense of belonging are significantly shaped by the design of the virtual educational environment. When a computer science virtual classroom reflected current masculine stereotypes of the field, women's intentions to enroll in the class and their anticipated performance was lower than their male peers. However, when a virtual classroom environment defied current stereotypes, women's intentions to enroll in the class and their anticipated performance increased to the level of their male peers. This simple design change had a profound effect. The implication is that the physical design of learning environments, such as classrooms, computer labs and university departments, can project identity-based messages about who does not belong and thereby deter some populations from entering the field and believing they can achieve success there.

The non-stereotypical virtual classroom environment increased women's interest, anticipated success, and sense of belonging in computer science over a neutral classroom that had no stereotypical or non-stereotypical objects in it. The non-stereotypical objects used in our experiments were not of the extreme feminine variety, which may explain why men were not deterred from that environment relative to the stereotypical environment. Yet women still inferred a sense of belonging from them. Future research could investigate whether explicitly feminine environments are beneficial to women or may backfire.

What are the psychological mechanisms that underlie the observed effects of virtual environments on choices and expectations? Results suggest that the physical virtual environment signaled to prospective students how much they belonged in the class. Women were less likely to feel that they belonged in the stereotypical classroom than men, and it was this lack of ambient belonging that best explained their lower intentions to enroll in that class and their expectations that they would be less successful there. However, when the classroom was re-designed so that it did not project current masculine stereotypes, women's sense of ambient belonging in the class was the same as men's. Feeling a lack of belonging – a factor that is distinct from abilities or talent – can thus be communicated by even a brief exposure to a virtual environment and can have consequences for educational choices, interest and expectations. Effects held when gender of teacher and gender proportion of students was identical, suggesting that students base their sense of belonging in a class on more than gender composition in the classroom. Future studies could vary pedagogical agents to examine how characteristics of teachers – for instance, their teaching styles and personalities (as conveyed by appearance, movements, voice) – influence students' sense of belonging. Students' choices and learning may be influenced both by the physical virtual environment and also the degree to which the social agents in that environment are interpreted to be "Like Me," a factor shown to powerfully influence learning (Meltzoff, 2007; Meltzoff, Kuhl, Movellan, & Sejnowski, 2009).

5.1. Implications for practice

How might universities design their virtual environments to improve students' learning? The design of 3-D VLEs may be used to decrease gender disparities in computer science by designing virtual environments that communicate a greater sense of belonging to women. In addition, because work done in one academic field can often be relevant to other fields (Clement, 2004), this work will also be relevant to other male-dominated domains (e.g., math, science) that might similarly be interested in increasing their diversity. The non-stereotypical virtual classroom in our experiment was preferentially chosen by women over a classroom that fit the current stereotypes and even over a more neutral-looking virtual classroom (i.e., one with minimal décor). If recruiting more women into a class and ensuring their success is a goal, as it is for many for science, technology, engineering and mathematics (STEM) classes, making the classroom environment (both virtual and real) welcoming by incorporating non-stereotypical elements into the design may be one way to achieve that goal.

More broadly, this work may have implications for 3-D VLEs beyond STEM. The current work demonstrates that students' beliefs about classes and their own capabilities for success are influenced by what they see when they enter a virtual classroom. Universities should consider the social messages conveyed by existing and future virtual spaces. Designing 3-D VLEs that allow students who are underrepresented feel a sense of belonging in the classroom environment, by adding design elements that are compatible with their identities, could have positive effects on their learning. Changing the environments of 3-D VLEs may be a vehicle that universities can use to signal belonging to a wider net of students, and thus increase students' likelihood of enrolling and achieving success in those classes. Because designing virtual educational spaces affords a great deal of ease and flexibility compared to designing actual educational spaces, adding cues that make underrepresented groups feel they belong in a learning environment is a realistic, concrete and achievable tool for counteracting the pernicious effect of stereotypes and reducing educational disparities.

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