Stereotype Threat in Virtual Learning Environments:
Effects of Avatar Gender and Sexist Behavior on Women’s Math Learning Outcomes

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Citation:
Abstract

Women in math, science, and engineering (MSE) often face stereotype threat: they fear that their performance in MSE will confirm an existing negative stereotype – that women are bad at math – which in turn may impair their learning and performance in math. The current research investigated if sexist non-verbal behavior of a male instructor that is indicative of negative stereotypes about women could activate stereotype threat among women in a virtual classroom. Additionally, the research examined if learners’ avatar representation in VR altered this non-verbal process. Specifically, a 2 (avatar gender: female vs. male) x 2 (instructor behavior: dominant-sexist vs. non-dominant or non-sexist) between-subjects experiment was employed. Data from 76 female college students demonstrated that participants learned less and performed worse when interacting with a sexist male instructor compared to a non-sexist instructor in a virtual classroom. Participants learned and performed equally well when represented by female and male avatars. Our findings extend previous research in physical learning settings, suggesting that dominant-sexist behaviors may give rise to stereotype threat and undermine women’s learning outcomes in virtual classrooms. Implications for gender achievement gaps and stereotype threat are discussed.

Keywords: virtual reality, stereotype threat, social identity, virtual learning, gender
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Gender achievement gaps – the achievement differences between male and female – are pervasive in the United States.\(^1\)\(^2\) The gap that favors males in math, science, and engineering (MSE) domains is particularly subject to intense scrutiny.\(^1\)\(^2\) Researchers believe that a primary psychological cause for women’s underperformance in math is stereotype threat, a form of cognitive burden that stems from concerns of being judged as less capable due to an individual’s social identity.\(^3\) The current study focuses on stereotype threat in virtual learning environments.

“Women are bad at math” is a pervasive negative stereotype. Women majoring in MSE may experience stereotype threat – the fear of being judged as poor in math ability due to this stereotype. While a well-established literature has suggested that stereotype threat hurts female learners’ learning and performance in physical MSE settings,\(^4\)-\(^10\) it is important to examine if gender-based identity and stereotype threat plays out in virtual spaces, given the increasing use of virtual classrooms in math education.\(^11\) Virtual classrooms allow people to use avatars – digital representations of themselves in computer-mediated communication\(^12\) – as they learn. Therefore, it is important to investigate the understudied phenomenon of how avatar embodiment of gender can affect people’s learning and performance in immersive virtual environments (IVE).

The current study aims to investigate (a) the effects of non-verbal behavior of a male instructor avatar on women’s math learning and performance, with dominant-sexist behavior as a threatening cue and (b) how avatar gender may moderate the stereotype threat effect in IVE. The insights obtained through the study will enhance understanding of how stereotype threat
manifests in virtual environments and will suggest avenues for future educational research or areas where intervention may be needed to promote equitable learning environments.

**Effects of Stereotype Threat on Learning and Performance**

Women often face reminders of the negative stereotype that their achievements in MSE will be worse than men; this threat in turn impairs their learning and performance in these fields. Well-established research on stereotype threat suggests that compared to non-stigmatized group members, stigmatized individuals facing a negative group stereotype tend to underperform in a variety of learning-related tasks such as working memory (i.e., temporary storage of information),

- learning (i.e., the ability to encode math rules necessary to solve problems),
- and performance (i.e., the intellectual ability to accurately solve problems).

A variety of situational cues in learning contexts can evoke stereotype threat, such as the salient representations of stereotypically masculine artifacts in the classroom (e.g., a Star Trek poster) and the representation of men in numerical majority of the group. Behavioral cues in social interactions have been shown to elicit stereotype threat as well. For example, women who interacted with a male partner with dominant and sexually interested behavior (i.e., looking at women’s bodies, sitting close to women with open body posture) experienced deficits in an engineering task. Van Loo et al. suggested that simply watching a video of another woman interacting with a sexist man reduced female viewers’ math performance. Further, a field study found that professional female engineers who had negative work-related conversations with male colleagues on a given day experienced greater stereotype threat and burnout later in the same day.

**Stereotype Threat in Immersive Virtual Environment (IVE)**
Virtual environments (VEs) refers to sensory information that leads to perceptions of a synthetic environment as non-synthetic. An immersive virtual environment (IVE) is one that presents a multi-sensory environment which responds to body movements, leading to greater psychological presence. Virtual classrooms allow people to teach and learn a course in an IVE, providing more personalized and richer communication than other online educational technologies. As digital educational programs have been increasingly common in post-secondary education, it is important to understand how IVEs can change the social dynamics and outcomes of learning.

Prior research suggested that situational cues that trigger stereotype threat in physical settings have a similar effect in virtual environments. Cheryan and colleagues found that viewing a virtual computer science classroom that contained stereotypically masculine objects (e.g., science fiction books, electronics) reduced female students’ intentions to enroll in the class. In a virtual public speaking class, women spoke for a shorter amount of time than men when they were exposed to a picture of a male role model (e.g., Bill Clinton); this gender difference disappeared when a picture of a female role model (e.g., Hillary Clinton) was presented. Given that dominant-sexist behavior by men (i.e., looking at women’s bodies, sitting close to women with open body posture) has been shown to evoke stereotype threat in physical settings, we expected the same social dynamic to hold in IVE, where there is an additional experimental benefit in that the behavior of a virtual male instructor avatar can be entirely programmed and thus controlled.

**H1**: Dominant-sexist behavior from a male instructor will reduce women learners’ math learning and performance in IVE compared to a non-sexist instructor.

**Effects of Avatar Gender Representation**
While IVE provides behavioral cues likely to evoke stereotype threat just as in physical settings, they uniquely afford people the ability to dramatically alter self-presentation and self-identity through an avatar (i.e., digital portrayals of oneself).\(^\text{12}\) The Proteus effect is a prominent theory that suggests the cognitive and behavioral effects of avatar embodiment, which assumes that people think and behave in line with their avatars’ appearances and characteristics, regardless of their own self-identity.\(^\text{24,25}\) For example, participants represented with more attractive and taller avatars in VR were more confident and sociable towards other avatars than those represented with less attractive and shorter avatars.\(^\text{24}\) More specific to gender representation, research has shown that game players using female avatars performed more healing activities whereas players using male avatars engaged in more aggressive combatting activities, regardless of participants’ actual gender.\(^\text{26}\) In a study using a computer screen display, participants who embodied a male avatar and competed against two female avatars performed better on an arithmetic task than participants embodied by a female avatar competing against two male avatars.\(^\text{27}\)

Drawing on the Proteus Effect, avatar gender may moderate stereotype threat effects in virtual MSE learning environments. Female learners represented by male avatars may perceive the male avatar characteristics as relevant to self-concept and internalize the male identity, thereby being less susceptible to the threatening cues associated with the negative stereotype about women during the learning session. Therefore, it is reasonable to predict that women represented by male avatars can learn and perform math tasks more successfully than those using female avatars in virtual classrooms where stereotype threat is induced.

However, Stereotype activation theory provides an alternative perspective on how avatar gender representation may affect stereotype threat effects.\(^\text{28}\) The theory suggests that physical
traits (e.g., race, gender) can automatically activate stereotypes associated with the marginalized social groups. While VR embodiment allows people to alter their digital identities (e.g., a woman can be embodied by a male avatar), altering gender - usually understood to be a relatively stable physical trait – may only make it more salient, which in turn could further trigger stereotyped thoughts about the gender. In support of the activation hypothesis, Groom et al. found that people embodied by a Black avatar (with head-tracking only) showed greater preference for White people than those embodied by a White avatar, regardless of participants’ race.²⁹ Lopez et al. found that male participants embodied by a female avatar (with full-body tracking) in VR exhibited increased implicit gender bias, compared to those embodied by a male avatar.³⁰ Therefore, representation by a male avatar in IVE could simply draw more attention to one’s female identity, especially in a negatively stereotyped scenario when interacting with a dominant-sexist male instructor. If so, body-swapping could trigger greater stereotype threat and further undermine learning or performance among women embodying male avatars.

Given the competing hypotheses, we asked,

RQ1: Will the avatar gender of women learners moderate the effects of instructor behavior on learners’ math learning and performance?

Little research has examined the effects of behaviorally threatening cues in virtual classroom on women’s math learning and it is unclear if VR avatar embodiment can effectively prevent women’s math learning from stereotype threat; the present study will address these gaps in a controlled experiment using a head-tracking IVE system.

Method

Participants
We conducted a priori power analysis to ensure a sufficient sample for this study. A power analysis using a moderate effect size of $d = 0.36$ based on a meta-analysis,$^{31}$ a significance level of .05, powered at 80%, required a total of 78 participants to find an effect.

A total of 89 female undergraduate students enrolled at a private university took part in the study in exchange for either course credit or $15. Only female students were recruited because the present research examined the effects of avatar gender on math learning outcomes, and females were overall more likely to suffer from stereotype threat than males on math achievement.$^4$ Our final sample size after exclusions ($N = 76)^a$ almost met the threshold from the power analysis. 42.1% of the participants ($n = 32$) majored in MSE and 57.9% ($n = 44$) in non-MSE disciplines. All participants indicated no prior knowledge of modular arithmetic (MA) math.

**Design and Procedure**

This study obtained the approval of the university Institutional Review Board. A 2 (avatar gender: female vs. male) x 2 (instructor behavior: sexist vs. non-sexist) between-subjects experimental design was employed.

**Manipulations.** Participants were randomly assigned to be represented by either a college-aged White female or male avatar. Participants were then randomly assigned to interact with a male avatar instructor whose non-verbal behavior toward the participants’ avatar was either dominant and sexist or non-dominant and nonsexist. The dominant behavior aimed to elicit stereotype threat, which involved sitting with open body posture (i.e., shoulders leaned back, legs apart) relatively close to the participant’s avatar and alternating between making direct eye contact with the participant and glancing at the participant’s avatar’s body. In contrast, non-dominant behavior involved sitting further from the participant’s avatar with a closed body
posture (i.e., legs crossed, body turned slightly away) and alternating between eye contact with the participant and looking at the ground.

**Procedure.** Upon arriving at the experiment site, participants were told that the study examined how people would learn in virtual reality and that they would learn a novel type of math called modular arithmetic (MA) from an avatar instructor controlled by a graduate student in another room whom they had not met before. In reality, the avatar instructor was programmed and animated to provide identical pedagogical content to all participants. The virtual classroom contained a projector screen that displayed slides for the math lesson and a video monitor that showed the participant’s avatar in real time (see Figure 1). Both the video monitor and the avatar instructor were in the participant’s field of vision throughout the entire learning period.

![Figure 1](image)

*Figure 1. Sample images of a virtual classroom used in the study.*

*Note.* Participants were represented by (A) a male or female avatar in a virtual classroom that contained (B) a projector screen that displayed instructional slides for the MA math learning task. Participants interacted with (C) a non-sexist tutor with neutral body posture or (D) a sexist tutor who sat closer to them with sexually dominant body posture.
Participants then put on the virtual reality head-mounted display equipment (HMD) and learned a virtual math course for approximately 10 minutes with an avatar instructor. The avatar instructor explained the math learning objectives through slides on the projection screen and occasionally provided additional pre-recorded explanations throughout the lesson. Upon finishing the experiment, participants left the virtual classroom and completed a questionnaire measuring math learning and performance on a desktop computer.

Materials and Measures

We adopted a MA learning task from Rydell et al. to examine both math learning and performance. MA is a mathematical task where participants learn a modulus function, which consists of an equation with three parameters: \( a = b \mod n \). The modulus function is solved by a series of arithmetic operations: \((a - b) / n\). If the answer to the modulus function is an integer value, then the modulus function is true (e.g., \( 17 = 5 \mod 6 \)). Conversely, if the answer is not an integer value, then the modulus function is false (e.g., \( 19 = 7 \mod 7 \)).

MA learning. Participants were asked to complete a questionnaire on a lab computer after leaving the virtual classroom, where they first provided a step-by-step explanation of how to solve a MA problem. The explanations were independently rated by two condition-blind coders on a Likert-type scale from 1= Very poor to 5 = Excellent. The MA explanation score was the average of two independent ratings for each participant (\( M = 3.13, SD = 1.83 \), Krippendorff’s alpha = .89).

MA performance. Participants were asked to solve 54 MA problems. The number of problems correctly solved was used to measure math performance (min = 25, max = 54, \( M = 47.37, SD = 8.80 \)). Accuracy score was positively correlated with explanation score (\( r = .77, p < .05 \)).
Data Analysis and Results

Data Analysis

Because the current study aimed to examine effects of stereotype threat and avatar gender representation on both math learning and performance and these two measures were closely associated, we examined the effects on performance by statistically controlling for learning score. We conducted a two-way ANOVA (avatar gender X instructor behavior) to examine the effects on MA learning, and conducted a two-way ANCOVA for MA performance, including participants’ MA learning score as a covariate. To avoid violating the assumption of normality for both tests, we performed square root transformation for both MA explanation and accuracy scores to address the negative skewness. For ease of interpretation, we reported the untransformed means and standard error.

Results

MA learning. The main effect of instructor behavior was significant, $F(1, 72) = 3.98, p = .05, \eta^2 = .05$, suggesting that women performed worse on MA explanations when learning from a dominant-sexist instructor ($M = 2.75, SE = 0.29$) than from a non-dominant instructor ($M = 3.55, SE = .30$). However, neither the main effect of avatar gender, $F(1, 72) = .31, p = .58, \eta^2 < .005$, nor the interaction effect between avatar gender and instructor behavior was significant, $F(1, 72) = .05, p = .83, \eta^2 < .005$ (Figure 2).
Figure 2. Effects of avatar gender and avatar tutor behavior on MA learning scores.

Note: Bars represent estimated marginal means by conditions. Error bars denote 95% confidence interval.

**MA performance.** Controlling for MA learning score, the main effect of instructor behavior was significant, $F(1, 71) = 13.62, p < .001, \eta^2 = .08$, suggesting that women correctly solved fewer MA problems when learning from a dominant-sexist instructor ($M = 45.10, SE = 1.36$) than from a non-dominant instructor ($M = 49.92, SE = 1.44$). Non-significant results were observed for the main effect of avatar gender, $F(1, 71) = .07, p = .79, \eta^2 < .005$, and the interaction effect between avatar gender and instructor behavior, $F(1,71) = .32, p = .58, \eta^2 < .005$ (Figure 3).
Figure 3. Effects of avatar gender and avatar tutor behavior on MA performance scores.

*Note:* Bars represent estimated marginal means by conditions. Error bars denote 95% confidence interval.

**Discussion**

The present study found that interacting with a male instructor with dominant and sexist non-verbal behavior undermined women’s math learning and performance on a math task, which suggests that behavioral cues in social interaction can evoke stereotype threat in IVE. However, avatar gender did not significantly impact women’s math learning and performance when interacting with a dominant and sexist instructor, suggesting that it did not affect women’s experiences of stereotype threat. This is inconsistent with both the *Proteus effect* and the *stereotype activation theory*. 
The present study has several theoretical and practical implications. First, this study parallels the move of situational cues from offline settings to virtual classrooms.\textsuperscript{21,22} It extends previous research\textsuperscript{16} showing that non-verbal behavior as evaluative of a negatively stereotyped ability (here, dominant-sexist behavior) can undermine women’s learning in IVE as it can do in physical classroom. Therefore, other threatening cues such as negative conversations and facial expressions in offline interactions\textsuperscript{17,18} may also trigger stereotypes about women in IVEs and therefore cause women to underperform in math compared to men. Future research could examine this possibility in virtual classrooms and other forms of educational technologies. This finding also has implications for less immersive but more pervasive educational technologies, such as course website interfaces,\textsuperscript{32} Massive Open Online Courses (MOOCs),\textsuperscript{33} and online games.\textsuperscript{34} Educational practitioners on these platforms should closely monitor and remove non-verbal cues, such as in lecture videos, that are likely to trigger stereotype threat.

Second, recall that the \textit{Proteus effect}\textsuperscript{24} suggests that people tend to behave consistently with their digital self-representation whereas the \textit{stereotype activation theory} predicts that people conform to stereotypes of their own self-identity when stereotypes are activated.\textsuperscript{28} Our findings supported neither hypothesis, demonstrating, instead, that avatar gender did not intensify or alleviate the stereotype threat effect on math learning-related tasks. Drawing on prior work also showing the null result of avatar gender,\textsuperscript{35-37} it is possible that self-identified gender is more salient to individuals than the gender of an assigned avatar during the avatar-based learning task. The lack of self-relevance to the avatar gender may not sufficiently activate stereotypical thoughts about women’s underperformance in math, and thus may inhibit the avatar gender effects, especially during the post-use assessment tasks.\textsuperscript{35,36} Further, unlike prior research that used Implicit Association Tests as indicators of gender/race bias,\textsuperscript{29,30} participants in our study
engaged in a cognitively demanding task of learning and applying a math rule. They may not have been able to devote cognitive resources to internalizing the identity of their assigned avatars, thus mitigating potential differences in stereotype activation from female versus male avatar representation. Lastly, the null result of avatar gender may be due to a low statistical power based on a relatively small number of participants in this study ($N = 76$). Future research should explore potential factors that may impact the effects of avatar gender on stereotype threats and math learning-related tasks, including self-relevance and the difficulty of math tasks, to better understand whether and when avatar embodiment can affect gender-based stereotypical thoughts using a larger sample.

The current study has limitations. First, the present study did not collect data on participants’ race, which may limit interpretation and generalization of the findings. Since the avatars of both the male instructor and the learner were programmed as White, it is possible that non-White participants may perceive greater level of disconnection with the avatar than White participants. Second, although participants were able to see their avatar representations’ gender during the virtual math course, they were not visually reminded of their avatars’ gender during the assessment tasks (i.e., learning and performance) outside of VR. Therefore, their associations and attachments with their assigned avatars’ gender may diminish after avatar use, leading to the null effect of avatar gender. Future research could program the assessment tasks in VR settings, as opposed to on a desktop computer afterwards, in order to provide clear evidence that the effect is on both learning and performance. Third, although the present study considered several key individual differences (i.e., math identification, MSE background, sense of avatar presence), some factors remained unexamined, such as gender identification$^{38}$ (i.e., perceived importance of being a woman to one’s self-concept) and gender stereotypical beliefs$^{36}$ (i.e., the extent to which
people internalize related gender stereotypes in immediate tasks). Future research should consider these variables that may reinforce or mitigate the effects of stereotype threats among female learners.

**Conclusion**

Virtual learning environments offer an exciting range of opportunities to explore interpersonal dynamics including how they contribute to stereotype threat. The present experiment extends past research on stereotype threat from in-person settings to immersive virtual environments, highlighting the potential harm of non-verbal behavioral cues on women’s learning and performance in math through evoked stereotype threat. The results show that interventions will be necessary to overcome stereotype threat in virtual learning environments. Avatar designers must be mindful of these findings when creating “stock” animations to be used in video games, IVEs, and other virtual learning forums.

**Author Disclosure Statement**

No competing financial interests exist.
References


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Notes

a. Of the 89 total participants, 13 were excluded from analysis due to technical issues with the virtual reality equipment during their experimental trial \((n=7)\), because they failed the avatar gender manipulation check \((n=1)\), because they guessed one of the manipulations \((n=1)\), or because they did not complete the trial (nausea \([n=1]\), nearsightedness \([n=1]\) or dyslexia \([n=1]\) preventing them from clearly viewing the math lesson in the virtual environment; cheating on the modular arithmetic explanation task \([n=1]\)). Thus, the analyses reflect data from 76 participants.

b. The head mounted display used was a nVisor SX with dual 1,280 horizontal x 1,024 vertical pixel resolution panels. HMDs consist of optical projection goggles fitted with a motion-tracking system that synchronizes with a server to continuously update the user’s virtual field of vision during head movement through physical space. Participants were led through a series of tracking exercises for 90 seconds and then were asked to track their physical movements on the video monitor in the virtual classroom. These procedures aimed to make participants aware of the presentation of their own avatar’s gender identity and pay attention repeatedly but covertly to their virtual identity.

c. Given the potential roles of individuals’ virtual experience and the level of self-relevance of learning math indicated in prior literature,\(^{33}\) we measured individuals’ sense of presence in the virtual environment, math identification and educational background as covariates. Presence was a three-dimensional construct involving self, social, and spatial presence.\(^{23}\) Participants rated the extent to which they felt that 1) they authentically embodied their virtual self (i.e., self-presence), 2) the virtual instructor was present (i.e., social presence), and 3) they were actually inside the classroom (i.e., spatial presence) on 5-point Likert scales.
The items were averaged into an index of presence ($M = 3.10$, $SE = .76$, Cronbach’s alpha = .65). Math identification was a single-item scale assessing the importance for participants to do well in math. The scale was measured on a 5-point Likert scale from 1 = *Not at all important* to 7 = *Exceptionally important* ($M = 4.78$, $SD = .89$).

d. In preliminary analyses, a series of t-tests revealed that participants majoring in MSE ($M = 5.09$, $SD = .85$) reported higher level of math identification than those majoring in non-MSE ($M = 4.55$, $SD = .70$), $t(58) = 2.98$, $p < .05$. Participants represented by female avatar ($M = 3.35$, $SD = .77$) reported higher level of presence in IVE than those represented by male avatar ($M = 2.89$, $SD = 0.70$), $t(72) = 2.85$, $p < .05$. ANCOVAs were then conducted to predict MA learning and performance with educational background (1 = MSE, 0 = non-MSE), math identification and level of IVE presence as possible covariates, but neither was significant ($F$’s $< 1$). Controlling for these covariates, findings in the main analyses remained. Therefore, we removed covariates from the main analyses.
Supplementary Material

Participants

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Virtual Reality Equipment and Procedure

The head mounted display used was a nVisor SX with dual 1,280 horizontal x 1,024 vertical pixel resolution panels. HMDs consist of optical projection goggles fitted with a motion-tracking system that synchronizes with a server to continuously update the user’s virtual field of vision during head movement through physical space.

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