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“I'm a Computer Scientist!”: Virtual Reality Experience Influences Stereotype Threat and STEM Motivation Among Undergraduate Women

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Abstract

Women are less likely to choose physical Science, Technology, Engineering, and Math (pSTEM) majors, partly because a lack of role models makes it hard for women to imagine themselves as successful in those fields. Possible self-interventions can help people imagine themselves having a successful future. Using social cognitive theory and expectancy-value framework, the current study explored virtual reality (VR; HTC Vive) as a space for a possible self-intervention to decrease stereotype threat and increase pSTEM motivation. Participants were 79 undergraduate women in California (46% Asian, 32% Latina, 14% white) who were randomly assigned to embody a future self either highly successful in pSTEM or highly successful in humanities. Following the virtual experience, women in the pSTEM condition differed significantly from women in the humanities condition regarding pSTEM value beliefs, anticipated stereotype threat, course motivation, and women-pSTEM implicit associations, after controlling for prior pSTEM-self implicit associations. However, this difference only occurred among women who identified with the experience. While women with high identification demonstrated an effect in the desired direction, women with low identification demonstrated reactance in the opposite direction. This speaks to the usefulness of identification as a moderator and implies that virtual reality might be a useful tool for future self-interventions among students.

Keywords Social identity · Possible selves · Expectancy-value beliefs · Identification · Virtual reality intervention · STEM confidence

Introduction

Women are underrepresented in math, physical sciences, engineering, and computer science fields (pSTEM), which are some of the highest paid and growing careers in the USA (Eccles and Wang 2016; Leaper 2015b; NSF 2015). Additionally, they are less likely to choose pSTEM-related majors (Eccles and Wang 2016). The dearth of women in pSTEM domains is due to a variety of factors, including stereotypes, stereotype threat, and lower confidence and interest on average among women when compared to men (e.g., Eccles and Wang 2016; Leaper 2015a; Wang and Degol 2013). Because of this, it is important to explore ways to reduce stereotypes and related threat and increase pSTEM motivation among women. The current study explored virtual reality (VR) as a potential space for a targeted intervention to decrease stereotypes and increase motivation among emerging adult women. Specifically, we investigated implicit associations between pSTEM and women and pSTEM and the self, anticipated stereotype threat in pSTEM situations, and three different forms of pSTEM motivation (expectancy beliefs, value beliefs, and career motivation).

Prior studies have found that closing your eyes and imagining yourself as successful in the future is related to significantly higher optimism (Meevissen et al. 2011) and belief that you will succeed in your goals (Peters et al. 2010). Possible self-interventions like these aim to help individuals imagine a more positive future for themselves, including success in particular domains such as school. For example, one study among low-income and minority adolescents found that a multi-session possible self-intervention was related to increases in positive outcomes such as academic initiative and higher grades (Oyserman et al. 2006). Although prior possible self-interventions have relied on imagination or writing (Loveday

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et al. 2018), it is reasonable that they could be supported by a virtual environment. It is possible that exploring a virtual reality office as your future self who is highly successful in pSTEM may lead to decreased stereotypes and related threat and increased pSTEM motivation. Using immersive technology like VR to increase academic motivation may be more appealing to students (Marino et al. 2013) and thus potentially more effective than other forms of media. Prior studies have found games and other forms of virtual media to be successful in increasing STEM motivation in students (e.g., Gilliam et al. 2017; Miller et al. 2011).

Studies intersecting psychology and computer science have found that people in virtual contexts take on the attributes and behaviors related to the avatar they are embodying (Yee et al. 2009). For example, Fox and Bailenson (2009) found that participants who watched a virtual version of themselves exercising increased their own physical activity. Environmental factors may also influence participants (Ahn 2015; Ahn et al. 2015; Peña and Blackburn 2013). For example, a study found that people interacting in a virtual library were more formal in their speech and interactions than those who met in a virtual café (Peña and Blackburn 2013). Based on these prior findings, it is plausible that VR could also influence women's academic motivation and self-concepts, such as future pSTEM course interest. However, media effects are often conditional (Valkenburg and Peter 2013) and identification with a model is often necessary for successful modeling (Bandura 2001; Bussey and Bandura 1999). As a result, the VR space might only positively influence the STEM motivation of women who identify with their future self in the virtual reality space. People who do not identify with a scenario may experience reactance, or rejection of media that has a persuasive intent (Scherr and Müller 2017).

Literature Review

pSTEM Motivation

Expectancy-value theory (e.g., Eccles 2011; Eccles and Wigfield 1995) posits that motivation can be divided into expectancy beliefs (e.g., confidence) and value beliefs (e.g., interest). Expectancy beliefs include a person's confidence in how well they expect to currently do in pSTEM (both tasks and courses), as well as their beliefs about how they would do in the future. Value beliefs include how fun and interesting a person views pSTEM, as well as how useful they view pSTEM for their current and future goals. People are most motivated in a subject if both their expectancy and value beliefs are high (Eccles 2011; Eccles and Wigfield 2002).

In general, women and girls tend to have lower expectancy and value beliefs about math than men and boys (Eccles and Wang 2016), despite their similar performance on tests (Else-Quest et al. 2010). Several longitudinal studies have found that math expectancy and value beliefs predict later math achievement and motivation, such as advanced coursework and career aspirations (Ball et al. 2017; Guo et al. 2015; Schoon and Eccles 2014). These findings indicate that expectancy and value beliefs are important motivational factors to consider when examining gender and pSTEM. In addition to expectancy and value beliefs, it is important to explore direct intent to take pSTEM courses, given that intentions can lead to outcomes.

Factors That Influence Motivation

According to Eccles' model, motivation is shaped by both individual and environmental factors (Eccles 2011). When considering women's motivation in pSTEM, implicit associations and stereotype threat may be particularly useful to examine.

Implicit Associations Implicit associations happen at the unconscious level due to stereotypes present in our culture; they occur automatically and may be unwanted (Nosek et al. 2009). For example, many people implicitly associate math and science with men. A large cross-national study using the implicit association test (IAT) found that approximately 70% of people implicitly associate science with men (Nosek et al. 2009). On a similar IAT task, participants were significantly more likely to associate math with men than with women (Nosek and Smyth 2011). People may also implicitly associate (or disassociate) themselves with math or science (known as self-science or self-math associations). Research regarding self-science or math associations is more limited. Two studies found that boys were more likely to associate themselves with math or science when compared to girls (Cvencek et al. 2015; Cvencek et al. 2011). Additionally, implicitly associating math with men was positively associated with boys' math-self associations, but negatively associated with girls' math-self associations (Cvencek et al. 2015). In other words, the more girls associated math with men (compared to women), the less they associated themselves with math.

Implicit associations between gender and science or math are related to science, technology, engineering, and math (STEM) performance and motivation. In a cross-national study, the likelihood of implicit gender-science stereotypes were significantly related to average gender differences in eighth grade math and science achievement within a country (Nosek et al. 2009). Additionally, gender-science implicit associations have been negatively linked to STEM identity and in turn STEM expectancy and value beliefs (Starr 2018) and STEM career motivation (Cundiff et al. 2013). Although less explored, implicitly associating (or not associating) pSTEM with one's self may also be related to pSTEM motivation among women. In a Singaporean sample of elementary school children, implicit self-math associations were positively related to standardized math performance (Cvencek et al. 2015). In light of these findings, increasing implicit associations between women and pSTEM and self and pSTEM is an important step to increasing women's pSTEM motivation.

Stereotype Threat Stereotype threat posits that when individuals feel threatened at a task due to stereotypes about their group membership, they perform worse on that task (Steele 2010). Because there are negative stereotypes about women's performance in math (and other pSTEM fields), women in high-stake settings that involve mathematical ability may experience anxiety about performing poorly due to their gender (Steele and Ambady 2006). Experimental studies using the stereotype threat framework typically find that when gender identity is primed or made salient, women's math performance is lower (for a meta-analysis, see Doyle and Voyer 2016). Correlational studies have additionally investigated self-reported or anticipated stereotype threat in academic settings, finding that women experience stereotype threat significantly more often than men in everyday life (e.g., Cromley et al. 2013). Based on these findings, it is important to explore ways to reduce math and pSTEM-related stereotype threat among women.

Identification as a Moderator

The goal of our study was to change the variables discussed above via a possible self-virtual reality simulation. However, media interventions may not affect everyone in the same way. According to social cognitive theory, people model behaviors based not only on behaviors they see externally but also on internal factors, such as identification (Bandura 2001; Bussey and Bandura 1999). Identification may be based on an individual's self-concepts or identity. Prior studies have found that other kinds of media (such as TV and movies) affect individuals differently depending on moderating factors such as self-concepts (Valkenburg and Peter 2013). Thus, two people viewing the same behaviors may react in very different ways (Bandura 2001; Bussey and Bandura 1999; Valkenburg and Peter 2013), and people may react to a possible self-intervention in different ways depending on their identity (Oyserman et al. 2006). For example, someone who already has positive associations between themselves and pSTEM may welcome a scenario that links themselves with pSTEM, and thus associate themselves even more strongly with pSTEM. However, someone who does not associate themselves with pSTEM may experience reactance and reject the same scenario. Among women who experience reactance, the scenario might not affect them or even reduce their association with and motivation in pSTEM, resulting in the opposite effect as what was intended. Thus, identification may be a potential moderator for the virtual reality intervention, leading the effect to happen for some people but not others.

Current Study

The current study investigated the impact of a short virtual reality simulation on undergraduate women's math, physical science, engineering, and computer science (pSTEM) motivation and related constructs (see Fig. 1 for a hypothesized model). Participants explored a virtual office with their name on several objects in the room that reflected competence and success in a domain and were told that they were exploring their office in the future. We compared a pSTEM-related VR office (experimental condition) to a humanities-related VR office (comparison condition).

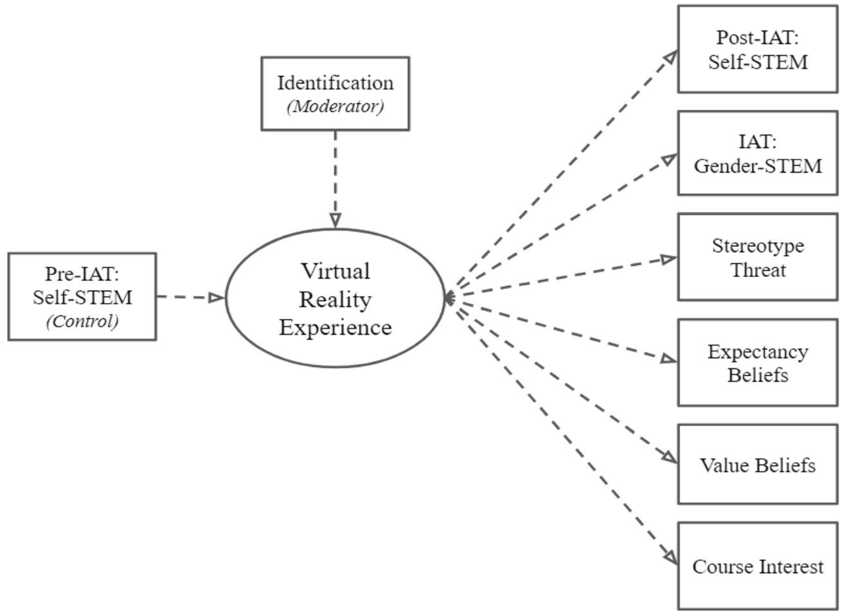
> **Hypothesis 1.** Prior implicit associations between self and pSTEM will be positively related to identification in the pSTEM condition, while prior implicit associations between self and pSTEM will be negatively associated with identification in the humanities condition.
>
> **Hypothesis 2a–e.** Controlling for prior self and pSTEM implicit associations, women in the pSTEM condition will have significantly (a) higher self-pSTEM implicit associations, (b) higher woman-pSTEM implicit associations, (c) lower stereotype threat, (d) higher expectancy and value beliefs, and (e) higher pSTEM course motivation, than women in the humanities condition. However, this will only occur among women who identify with the experience. The motivation of women who do not identify may change in the opposite direction as expected (reactance).

Method

Participants

A power analysis indicated that 80 participants (40 per group) were needed to achieve 80% power to detect a moderate-sized correlation with a 0.05 alpha. To account for missing data, five additional participants were recruited. Participants were 85 undergraduate women recruited from introductory psychology courses at a large public university in Northern California. Data from six participants in the humanities condition were dropped due to missing self-pSTEM IAT data ($n = 3$), because the VR tracking system stopped working ($n = 1$) or because the server containing the online survey crashed ($n = 2$). One person did not complete the women-pSTEM IAT but were kept with the sample given they had completed all other scales

Figure 1 Hypothesized model



and IATs. Of the remaining 79 participants, 43 were in the pSTEM office condition and 36 in the humanities condition. All participants received course credit in exchange for their participation. Participants on average were 20.32 years old ($SD = 1.70$, range 18–28). Nearly half of students identified as Asian ($n = 36$, 45.6%), and roughly one third identified as Latina ($n = 25$, 31.6%). The remaining participants identified as white ($n = 11$, 13.9%), multiethnic ($n = 4$), and black, Middle Eastern, and other ($n = 1$ for each). A little over a third of participants were the first in their family to attend college ($n = 27$, 34.2%). Participants reported that they had completed on average 5.1 college courses in math, physical sciences, engineering, or computer science. Finally, participants were asked to write in their declared or intended major. Most participants reported psychology or another non-pSTEM major (92.4%), while three people reported a pSTEM major (e.g., engineering) and three people reported planning to major in a pSTEM domain.

Increasing Identification

To increase women's identification with the VR space, our study placed the participant's name in several places in the office (e.g., on the desk name plate). Names may be one viable mechanism to increase a person's identification with their presented future self, because people attach special meaning to their own names and they are strongly linked to a person's identity (Jagieła and Gębuś 2015). Studies find that personal names are emotionally salient (Wang et al. 2015) and can be used to motivate people (Haney 2002). As a result, a participant's name coupled with environmental cues of success in a domain may be enough to instigate identification and influence a participant's self-concept.

Virtual Reality Environment

The virtual reality environment was developed by the researchers in Unity 5.6.1 (Unity Technologies 2017). Participants entered the virtual space using the HTC Vive headset (HTC Corporation 2017). The HTC Vive is a PC-based virtual reality system with that uses motion tracking to allow the user to move freely within a room-scale (approximately 12″ × 12″ maximum) virtual environment. Compared to phone-based VR systems such as Google Cardboard, the HTC Vive has position and orientation tracking for head movement (6 degrees of freedom), a higher resolution screen (2160 × 1200), a higher image refresh rate (90 Hz), and is less likely to induce nausea in its users (Singla et al. 2017). The HTC Vive system includes the headset, two wall-mounted base-stations that enable motion tracking, and two handheld motion-tracked controllers that were not used in this study. Participants were randomly assigned to experience a virtual office that reflected the participant's successful career either as a computer engineer and programmer (pSTEM condition), or as a writer and editor (humanities condition). Both versions of the virtual office contained a desk, computer, several posters, a bookshelf, printer, and other appropriate miscellaneous office supplies. To increase identification in both conditions, the participant's name was listed on several places in the virtual office (on a master's degree, desk nameplate, and award plaque) (see Fig. 2).

The two offices contained different objects which were intended to influence specific outcomes. To increase self-pSTEM implicit associations, encourage expectancy beliefs, and increase motivation to take future courses in pSTEM, the participants name was listed on a "computer science" master's degree ("literature" for the humanities condition) and "most

Figure 2 Office environment for the pSTEM condition

improved programmer" award ("editor" in the humanities condition). To encourage pSTEM or humanities value beliefs, there were thank you cards from school children on the wall and drafts of articles about environmental issues placed around the room. To reduce gender-based stereotype threat and increase implicit associations between women and pSTEM, posters in the pSTEM office included prominent women in the field such as Grace Hopper (Margret Attwood in the humanities condition).

Procedure

The study took place on campus in a quiet room designed for psychology studies. After providing informed consent, participants completed an initial IAT (self-pSTEM). Next, they proceeded through a self-paced VR orientation in an empty environment. When participants indicated that they were comfortable and ready, participants entered their randomly assigned virtual environment (pSTEM or humanities). Participants in both conditions were told "Now, you'll be experiencing a randomized room in VR. The room is your office, 15 years in the future. Your job is to go into the office and discover who you are." They were then encouraged to look for evidence of their future accomplishments and were told they would be answering questions about their future self afterward. Time in the virtual environment was self-paced to a maximum of 5 min.

Immediately after exiting VR, participants filled out a questionnaire about who they were and what they saw in the virtual environment. Four questions, such as "What kind of work do I do?," "What kind of advanced degree do I have?," and "What are some of my major accomplishments?" were asked. This was used as a manipulation check to determine whether participants related the experience to either pSTEM or humanities; participants were considered to have passed the manipulation check if they mentioned something pSTEM related (e.g., computer science or engineering) for the pSTEM environment and something humanities related (e.g., literature or editing) for the humanities environment. All included participants passed this manipulation check. This short manipulation check was followed by the second self-pSTEM IAT. Next, participants completed a series of questionnaires related to the VR experience as well as attitudes and beliefs about pSTEM and the humanities. In the online survey, the word STEM was used rather than pSTEM. This was done to avoid acronym-related confusion given that the STEM acronym is more familiar to college students than pSTEM. However, so that the definition of STEM fell in line with pSTEM, STEM was defined on each page as "math, physical sciences, engineering, and computer science." The survey additionally acknowledged that "while the social sciences (e.g., psychology) and life sciences (e.g., biology) are often included within science, this particular study does not include them within STEM." Finally, participants took the women-pSTEM IAT. On average, participation in the study took 50 min. At the end of the study, participants were encouraged to ask questions and thanked for their time.

Measures

Demographic Variables Students were asked to report their gender, ethnic and racial background, first-generation status, age, number of years in college, number of pSTEM courses they had taken, and major or planned major. Additionally, participants reported whether they had prior experience with VR.

Self-pSTEM Implicit Association Test Implicit associations between self and pSTEM were measured using an adapted version of the self-other IAT (Greenwald et al. 2003). In the task, participants were asked to quickly sort words on a computer using the "e" and "i" keyboard keys into categories presented at the top left and right corners of the screen. The words were presented at random and fell into the categories of self or other and pSTEM or humanities. Self-oriented words included I, me, and my; other-oriented words included they, them, and their. Although some versions of the self-other IAT also contain he and her, we excluded these to keep the measure gender neutral. pSTEM-oriented words included math, computer science, and physics; humanities-oriented words included literature, art, and English. Each word was presented one at a time, and participants were instructed to quickly sort each word into the correct corner. In the self-pSTEM condition, participants were asked to sort words from the categories self and pSTEM into one corner, and other and humanities words into the adjacent corner. In the other-pSTEM condition, participants were asked to sort words from self and humanities into one corner, and other and pSTEM into the adjacent corner. Participants who more readily associate pSTEM with self and humanities with other should be faster at sorting words in the pSTEM-self condition when compared to the pSTEM-other condition. IAT scores were calculated using a newer scoring procedure described in Greenwald et al. (2003). Larger discrepancies (indicated by higher IAT scores) between the two conditions indicate a higher implicit association between pSTEM and self, when compared to pSTEM and other.

Women-pSTEM Implicit Association Test An adapted version of the Gender-Science IAT was used to measure implicit associations about women and men with pSTEM and humanities. In this version, non-pSTEM science words (e.g., biology, chemistry) were replaced with pSTEM words (e.g., computer science, computer engineering). pSTEM and humanities words used were identical to those used in the self-pSTEM IAT test. The task was like the self-pSTEM IAT described above, except that instead of self and other words, the task used woman-oriented words (e.g., she, woman) and man-oriented words (e.g., he, man).

Stereotype Threat A modified scale was used to measure anticipated stereotype threat in pSTEM-related tasks and humanities-related tasks (Cromley et al. 2013). Participants were asked two questions about whether they would worry their performance was due to their gender ("If I don't do well on a math, physical science, engineering, or computer science task, I would worry it might be because of my gender" and "Sometimes I worry that I won't do well in math, physics, engineering, or computer science because of my gender"). Participants reported their answers on a 6-point scale going from 1 (strongly disagree) to 6 (strongly agree) ($\alpha = 0.85$).

Expectancy-Value Beliefs Thirteen items adapted from Eccles' expectancy-value motivation model (Eccles and Wigfield 1995) were used to measure participants' expectancy and value beliefs in pSTEM. All items were rated on a 5-point scale. The expectancy beliefs scale included seven questions ($\alpha =$ 87). Sample items include "How good are you at learning something new in STEM?," answered on a scale of 1 (not at all good) to 5 (extremely good), and "In general, how difficult are STEM courses for you?", which was answered from 1 (very difficult) to 5 (very easy). The value beliefs scale included six items ($\alpha = 90$). Sample questions include "How much do you like doing STEM related tasks or assignments?," answered on a scale of 1 (dislike very much) to 5 (like very much) and "How important is it to you to get good grades in STEM courses?," where responses ranged from 1 (not at all important) to 5 (most important).

pSTEM Course Interest To measure future course interest in pSTEM, participants were asked "How interested would you be in taking advanced courses in the following subjects in college?" They were then asked to rate their interest in taking four pSTEM courses (mathematics, physics, engineering, and computer sciences) on a scale of 1 (not interested) to 5 (most interested). Participant answers were averaged to create a scale ($\alpha = 0.76$).

Identification A 9-item scale ($\alpha = 0.90$) was created for this study to measure self-reported identification with the presented future self. The questions asking participants to indicate the degree to which they identified with the future self they were embodying. Examples include "I identified with the 'future me' presented in the office," "The 'future me' in the office felt like it could be me," and "Seeing the office made me wonder what my life would be like if I pursued that future." Participants answered on a scale of 1 (strongly disagree) to 7 (strongly agree).

Results

Preliminary Analyses

Independent sample t tests were used to examine potential differences between participants in the two VR office conditions. As expected, there were no significant main effects between those who had experienced the pSTEM VR office compared to the humanities VR office (see Table 1 for means, standard deviations, and t tests; see Table 2 for correlations between main variables). Specifically, we

Table 1 Descriptive statistics and comparisons by VR office condition

Measure	Scale alpha	Scale range	All ($n = 79$), M (SD)	pSTEM office ($n = 43$), M (SD)	Humanities office ($n = 36$), M (SD)	$t(77)$
Number of pSTEM courses	n/a	0–20	5.14 (4.16)	5.16 (4.50)	5.11 (3.76)	− 0.06
Pre-VR self-pSTEM IAT	n/a	n/a	− 0.126 (0.460)	− 0.126 (0.460)	− 0.115 (0.471)	0.11
Identification	0.89	1–7	4.15 (1.20)	3.97 (1.10)	4.36 (1.29)	1.47
Post-VR self-pSTEM IAT	n/a	n/a	− 0.088 (0.461)	− 0.111 (0.418)	− 0.060 (0.513)	0.49
Women-pSTEM IAT	n/a	n/a	− 0.315 (0.442)	− 0.382 (0.413)	− 0.238 (0.467)	1.45
Stereotype threat	0.82	1–6	2.36 (1.40)	2.27 (1.43)	2.47 (1.37)	0.65
pSTEM expectancy beliefs	0.88	1–5	2.12 (0.64)	2.09 (0.59)	2.16 (0.70)	0.53
pSTEM value beliefs	0.80	1–5	3.29 (0.98)	3.31 (1.11)	3.26 (0.80)	− 0.23
pSTEM course interest	0.90	1–5	2.15 (0.93)	2.16 (0.98)	2.13 (0.88)	− 0.12

Note. For the self-pSTEM IAT, higher score = higher self-pSTEM associations, lower score = higher self-humanities associations. For the women-pSTEM IAT, higher score = higher women-pSTEM associations, lower score = higher women-humanities associations

found no significant difference in pre-VR self-pSTEM implicit associations between participants who were assigned to the pSTEM VR office and participants assigned to the humanities office. There was also no significant difference in prior pSTEM courses taken between VR pSTEM office compared to participants who were assigned to the humanities office. Additionally, there was no significant difference found in prior VR experience between those assigned to the pSTEM office (67.4% no prior VR experience) and the humanities VR office (66.7% no prior VR experience). Finally, we did not find a difference in self-reported identification for participants who went through the pSTEM office compared to those assigned to the humanities office.

Correlations and t tests were employed to examine potential differences in identification based on demographic variables. We found no significant difference in identification based on age, year in school, declaration of major, number of pSTEM courses taken, race/ethnicity, or first-generation status (all $p > 0.05$).

Hypothesis 1: Identification and Pre-VR Self-pSTEM Implicit Associations

Because media affects people differently depending on their self-concepts, we expected that prior implicit associations between self and pSTEM will be positively related to identification in the pSTEM condition, while prior implicit associations between self and pSTEM will be negatively associated with identification in the humanities condition. To test this, we examined the correlation between pre-VR implicit associations and the office condition by identification interaction. We found that the relationship between pre-VR implicit associations and office × identification was marginally significant, $r(79) = 0.22$, $p = 0.068$.

Hypothesis 2: Plan of Analysis

We hypothesized that there would be a significant interaction between room and identification for each of our dependent

Table 2 Bivariate correlations between major variables

Measure	1	2	3	4	5	6	7	8
1 Identification	.	.	.	.	.	.	.	.
2 Identification × office	0.68***	.	.	.	.	.	.	.
3 Pre-VR self-pSTEM IAT	0.14	0.22^{+}	.	.	.	.	.	.
4 Post-VR self-pSTEM IAT	0.02	0.23	0.50***	.	.	.	.	.
5 Women-pSTEM IAT	− 0.04	0.18	0.43***	0.51***	.	.	.	.
6 Stereotype threat	0.10	− 0.14	− 0.05	− 0.19^{+}	− 0.05	.	.	.
7 pSTEM expectancy beliefs	− 0.01	0.16	0.12	0.18	0.15	− 0.06	.	.
8 pSTEM value beliefs	0.20	0.40***	0.44***	0.35**	0.41***	− 0.11	0.67***	.
9 pSTEM course interest	0.18	0.42***	0.28*	0.37**	0.32**	− 0.10	0.58***	0.71***

Note. $^{+}p < 0.10$, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$

variables: the post-VR self-pSTEM IAT, the women-pSTEM IAT, stereotype threat, expectancy and value beliefs, and course interest. Before creating the interaction term of office condition × identification, we first centered identification. Then for each dependent variable, a three-step hierarchical regression was employed to test this hypothesis. To control for participants' preexisting associations between themselves and pSTEM, we entered participants' self-pSTEM IAT from prior to the VR experience in the first step. In the second step, we entered the VR office condition (pSTEM or humanities) and identification. In the third step, we tested the interaction term (VR office × identification).

Next, for regressions with significant interactions we probed the interaction by calculating the simple slope for each dependent variable at high identification (+ 1 SD), moderate identification (at the mean), and low identification (− 1 SD), while still controlling for pre-VR self-pSTEM implicit associations. The results of the eight hierarchical regressions and simple slopes are summarized below.

Hypothesis 2: Findings

Hyphothesis 2a: Self-pSTEM Implicit Association Test Identification was examined as a moderator of the relationship between the post-VR self-pSTEM IAT and VR office condition. As a control, pre-VR self-pSTEM IAT score was added as the first variable. Identification and VR office condition were entered in the second step of the regression analysis. In the third step of the regression analysis, the interaction term between VR office and identification was entered. It explained a significant increase in variance in self-pSTEM implicit associations, $\Delta R^2 = 0.04$, $F_{\text{change}}(1, 74) = 4.01$, $p = 0.049$. Probing the interaction revealed that our hypothesis was only partially correct; after controlling for pre-VR self-pSTEM implicit associations, the simple slope between office environment and post-VR self-pSTEM implicit associations was marginally significant only for women who reported low identification ($b = -0.25$, $SE = 0.13$, $t(74) = -1.86$, $p = 0.067$). Women who reported high ($b = 0.12$, $SE = 0.13$) or moderate ($b = -0.06$, $SE = 0.09$) identification typically were not affected by the VR office in terms of implicit self-pSTEM associations. See Fig. 3 for a portrayal of this interaction.

Hypothesis 2b: Women-pSTEM Implicit Association Test Identification was examined as a moderator of the relationship between the post-VR self-pSTEM IAT and VR office condition. After the initial steps described in the analysis plan, the interaction term between VR office and identification was entered as the third step. The interaction between VR office and identification explained a significant increase in variance in women-pSTEM implicit associations, $\Delta R^2 = 0.05$, $F_{\text{change}}(1, 73) = 4.79$, $p = 0.032$. Unexpectedly, probing the interaction revealed that after controlling for pre-VR self-pSTEM implicit associations, the simple slope between office environment and post-VR self-pSTEM implicit associations was not significant for women who reported high identification ($b = 0.03$, $SE = 0.12$). However, the relationship was significant among women who reported low identification ($b = -0.36$, $SE = 0.13$, $t(73) = 3.99$, $p = 0.007$). Additionally, the relationship was marginally significant for women who reported moderate identification ($b = -0.16$, $SE = 0.09$, $t(73) = -0.16$, $p = 0.077$) (see Fig. 4).

Hypothesis 2c: Stereotype Threat Identification was examined as a moderator of the relation between stereotype threat and VR office condition. After initial regression steps, the interaction term between VR office and identification was entered, and it explained a significant increase in variance in stereotype threat, $\Delta R^2 = 0.08$, $F_{\text{change}}(1, 74) = 6.15$, $p = 0.015$. Thus, identification was a significant moderator of the relationship between stereotype threat and VR office condition. As expected, probing the interaction revealed that the simple slope between office environment and anticipated stereotype threat in pSTEM tasks was significant for women who reported high identification ($b = -0.91$, $SE = 0.43$, $t(74) = -2.09$, $p = 0.040$). Unexpectedly, women who reported low ($b = 0.65$, $SE = 0.45$) identification were not typically affected by the VR office when it came to stereotype threat; i.e., there was not significant reactance. Additionally, there was no effect for women who reported only moderate identification ($b = -0.13$, $SE = 0.31$) (see Fig. 5).

Hypothesis 2d: Expectancy-Value Beliefs In the last step of the regression analysis, the interaction term between VR office and identification was entered, and it explained only a marginally significant increase in variance in expectancy beliefs, $\Delta R^2 = 0.04$, $F_{\text{change}}(1, 74) = 2.92$, $p = 0.092$. Thus, identification was only a marginally significant moderator of the relationship between expectancy beliefs and VR office condition.

However, the interaction between VR office and identification did explain a significant increase in variance in value beliefs, $\Delta R^2 = 0.09$, $F_{\text{change}}(1, 74) = 8.93$, $p = 0.004$. Thus, the identification was a significant moderator of the relationship between stereotype threat and VR office condition. As expected, probing the interaction revealed that the association between office environment and pSTEM value was significant for women who reported high identification ($b = 0.66$, $SE = 0.27$, $t(74) = 2.47$, $p = 0.016$). Additionally, as expected we found evidence of reactance; women who reported low identification also reported marginally significantly higher pSTEM value in the

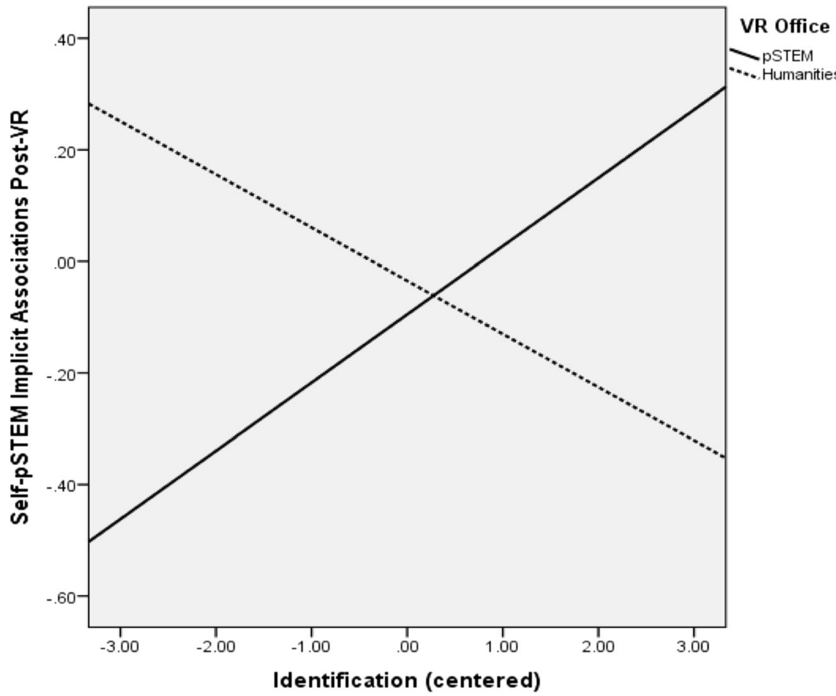


Fig. 3 Interaction: self-pSTEM implicit associations by VR office and identification. Controls for pre-VR self-pSTEM implicit associations. Higher score = higher self-pSTEM associations, lower score = higher self-humanities associations

humanities condition ($b = -0.49$, $SE = 0.28$, $t(74) = -1.77$, $p = 0.081$). Regarding pSTEM value, women who reported moderate ($b = 0.08$, $SE = 0.19$) identification typically were not affected by the VR office (see Fig. 6).

Hypothesis 2e: pSTEM Course Interest In the final step of the regression analysis, the interaction term between VR office and identification was entered, and it explained a significant increase in variance in pSTEM course interest, $\Delta R^2 = 0.14$, $F_{\text{change}}(1,\ 74) = 13.14$, $p = 0.001$. Thus, identification was a significant moderator of the relationship between future course interest and VR office condition. As expected, probing the interaction revealed that the association between office environment and pSTEM course interest was significant for

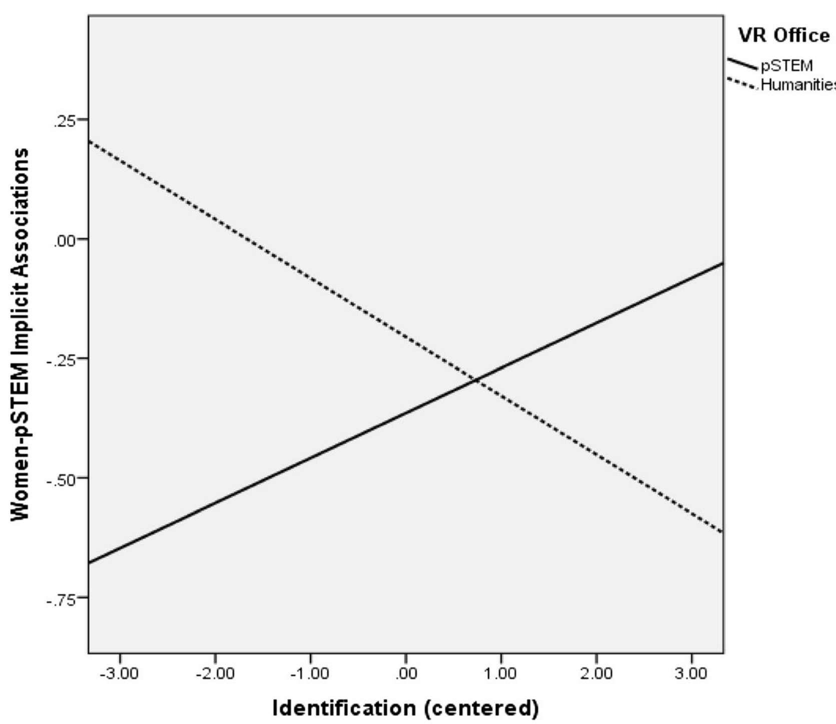


Fig. 4 Interaction: women-pSTEM implicit associations by VR office and identification. Significant for women with low identification. Controls for pre-VR self-pSTEM implicit associations. Higher score = higher women-pSTEM associations, lower score = higher men-pSTEM associations

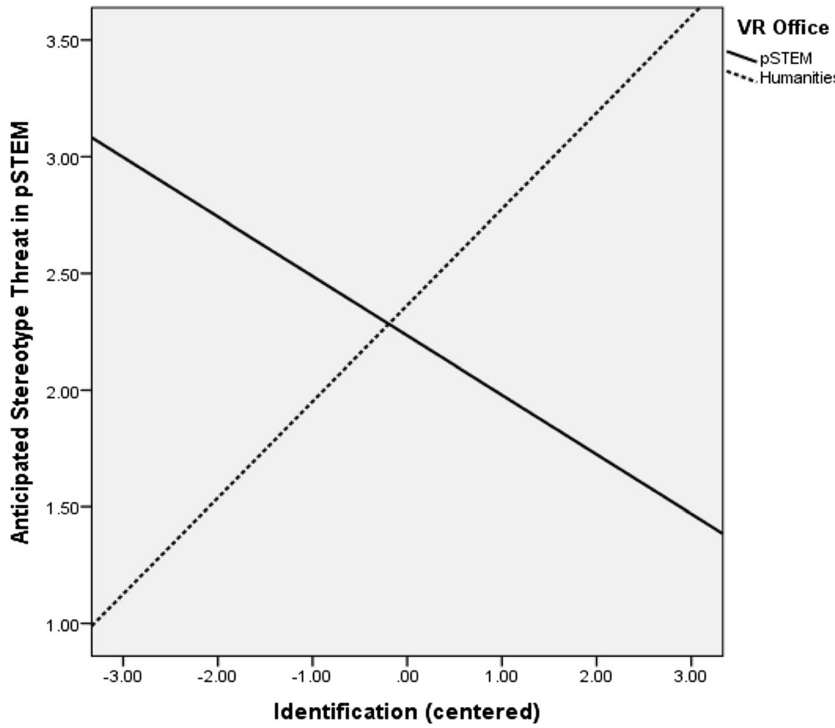


Fig. 5 Interaction: anticipated stereotype threat in pSTEM by VR office and identification. Significant for women with high identification. Controls for pre-VR self-pSTEM implicit associations. Higher score = higher anticipated stereotype threat in pSTEM situations

women who reported high identification ($b = 0.74$, $SE = 0.26$, $t(74) = 2.80$, $p = 0.007$). Additionally as expected, women who reported low identification also reported significantly higher pSTEM course interest in the humanities condition ($b = -0.64$, $SE = 0.28$, $t(74) = -2.34$, $p = 0.022$). Regarding pSTEM course interest, women who reported moderate ($b = 0.05$, $SE = 0.19$) identification typically were not affected by the VR office (see Fig. 7).

Discussion

Our study explored the effects of a virtual reality scenario aimed at inspiring pSTEM motivation among emerging adult women. After controlling for participant's prior implicit associations with pSTEM, we found that women in the pSTEM VR condition had significantly lower anticipated stereotype threat in pSTEM situations, higher pSTEM value, and higher pSTEM course interest when compared to women in the humanities condition. However, this was only true for the women who identified with the future self they embodied in the virtual environment. Additionally, we found that in some cases there was reactance to the VR room, where women who reported low identification in the pSTEM VR condition had significantly lower implicit associations between women and pSTEM and had lower course interest in pSTEM when compared to those in the humanities condition.

Our study is among the first to investigate whether virtual reality can increase academic motivation and academic self-concepts. VR may be a useful tool to reduce stereotype threat and increase pSTEM value and course motivation among women; however, this may only occur when identification is high. This builds on prior possible self-research which has found that imagining a successful future for yourself can lead to increased optimism about meeting your goals (Meevissen et al. 2011). Finally, this research complements other studies that have found identification to be an important moderator for interventions and media (e.g., Valkenburg and Peter 2013).

Implicit Associations and Stereotype Threat

Prior research has found that implicit associations between gender and science is related to other measures, such as expectancy and value beliefs (Starr 2018) and career motivation (Cundiff et al. 2013). Additionally, gender-based stereotype threat is linked to worse performance on math tests for women (Doyle and Voyer 2016). Thus, to increase expectancy and value beliefs in pSTEM, it is important to decrease implicit bias and stereotype threat.

Unexpectedly, our study did not find a significant difference in implicit associations among women who reported high identification in either group. Instead, we found evidence of reactance—women who experienced our pSTEM virtual reality environment and reported low identification had marginally significant lower implicit associations between themselves and pSTEM when compared to the humanities comparison condition, even after controlling for prior implicit associations between themselves and pSTEM. Similarly, women who experienced the pSTEM VR environment and reported low identification had significantly lower associations between women and pSTEM (versus men and pSTEM) when compared to the humanities condition.

As expected, women who experienced the pSTEM VR office and identified with the future self they embodied reported that they would feel significantly less stereotype threat while performing pSTEM tasks when compared to women in the humanities condition, even after controlling for prior self-pSTEM associations. In this case, we did not find any evidence of reactance among women who did not identify with the presented future self.

PSTEM Expectancy-Value Beliefs and Course Interest

Prior studies have found that both expectancy and value beliefs in a domain are positively related to pursuing and persisting in that domain (Guo et al. 2015). Thus, to increase motivation to pursue pSTEM, it is important to increase expectancy and value beliefs, as well as course interest. Our study found that after controlling for prior self-pSTEM associations, women in the pSTEM condition who identified with scenario reported significantly higher value beliefs and course interest than women in the humanities condition. We only found marginally significant support for an increase in expectancy beliefs, indicating that the VR simulation might have been more effective at increasing value beliefs compared to expectancy beliefs. Alternatively, expectancy beliefs might be slower to change. Finally, we found evidence of reactance among women who did not identify with their presented future self. After controlling for prior associations, women with low identification in the pSTEM condition reported lower pSTEM value and future course interest than women in the humanities condition.

Identification as a Moderator of Possible Self-Interventions

It is important to remember that the effects we discuss in this paper were only true when identification with the future self that participants embodied was added as a moderator. In the case of several outcomes, participants who did not identify with the future self presented displayed reactance, or outcomes in the direction opposite of what was intended, despite having experienced the pSTEM office condition. This brings home the point that many media researchers make—media, including virtual reality, affects individuals differently (Valkenburg and Peter 2013). Those who identified with the future self they embodied may have felt inspired by the scenario, and thus reported less anticipated stereotype threat and higher value beliefs and course interest in pSTEM. However, this was in some cases the opposite for those who had low identification. Although the relationship between prior self-pSTEM associations and identification was only marginally significant, it is possible that those who came in with higher self-pSTEM associations were more likely to identify with the VR situation and thus incorporate it into their self-perception and self-concepts, while those with lower self-pSTEM associations were more likely to reject it. Other potential reasons for lower identification are elements of the office environment itself, such as its environmental focus that may not have appealed to everyone. It is notable that identification did not significantly differ based on age, year in school, declaration of

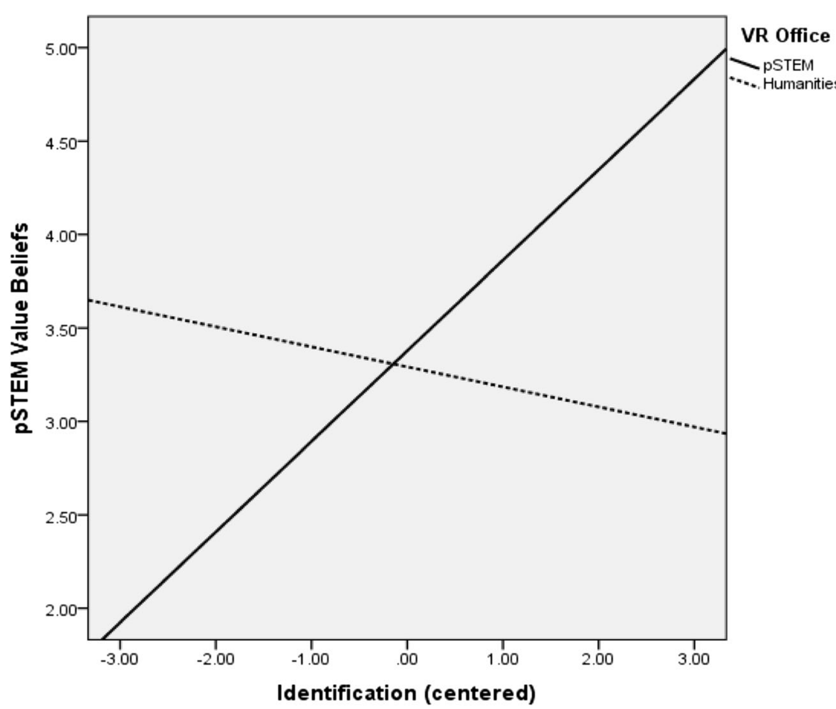


Fig. 6 Interaction: pSTEM value beliefs by VR office and identification. Significant for women with high and low identification. Controls for pre-VR self-pSTEM implicit associations. Higher score = higher pSTEM value beliefs

major, number of pSTEM courses taken, race/ethnicity, or first-generation status.

VR: a Tool for Possible Self-Interventions?

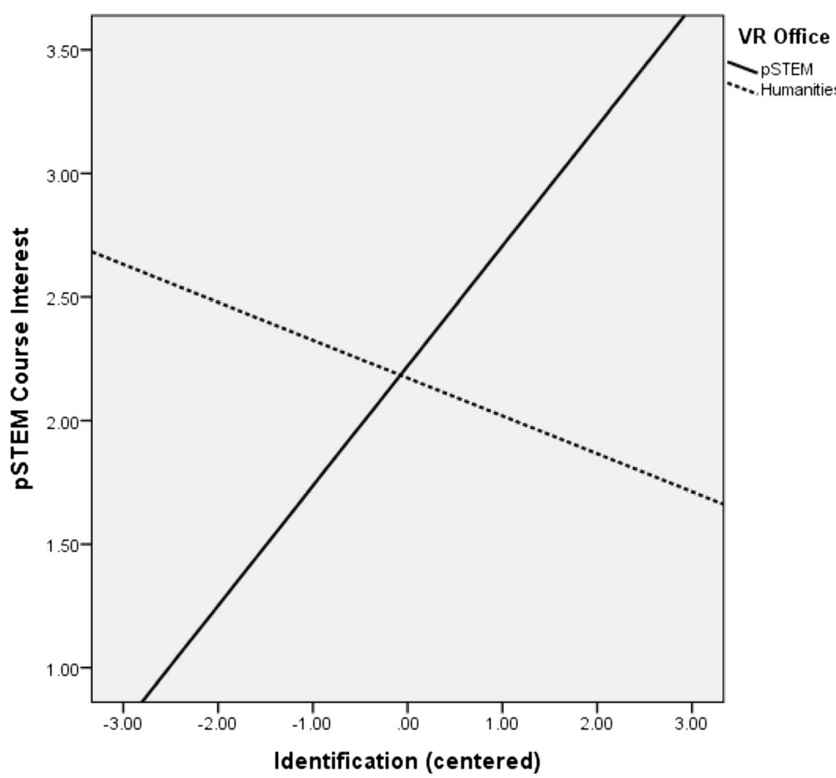
Overall, our results indicate that virtual reality scenarios might be a useful tool for possible self-interventions. Prior research in psychology has successfully used imagination and writing about a possible future self as interventions (e.g., Meevissen et al. 2011), and using virtual reality presents several added benefits. First, it allows the researchers more control over the possible self-environment to create a targeted and uniform intervention. Second, it may be more inspiring and motivating for people to be able to explore a possible future self in a realistic environment. During the current study, participants frequently commented on how realistic the environment was, avoided walking through objects in the virtual environment, and were excited to see their names presented in the office. Both points may be especially salient in research with children, who may not be as aware of potential careers and future possibilities (in which case, VR would especially help fuel their imagination) and who may be especially excited and inspired by a virtual environment. Additionally, children may have less developed self-concepts regarding careers, and thus be less prone to reactance. Because of this, using a VR possible self-intervention in STEM classrooms or elementary schools may be an interesting direction for future research. However, researchers should use caution when implementing similar interventions with children, given the potential for reactance that the present study found (discussed more below).

A reservation to using virtual reality environments such as this one to increase motivation is that at times women reacted in the opposite direction as intended when they did not identify with the future self they embodied. This may be in part due to prior self-concepts but given that the relation between prior self-pSTEM associations and identification was only marginally significant, this may not fully explain the reactance seen in some participants. Future studies should explore factors that are associated with high versus low identification in virtual reality environments. Understanding these factors could inform the development of environments that are adaptable to individual preferences or are more effective across a broader range of individuals.

Future Directions and Limitations

Despite promising results, this study had several limitations. First, we did not measure all variables prior to our experiment. This was chosen considering research that suggests that participant responses post-experiment are often biased if the participant answered the same questions prior to the experiment (known as practice effects; e.g., Green et al. 2014). Although this may still occur with implicit association tests, research suggest that it is less likely to happen because implicit association test have been found to be fairly resistant to practice effects and conscious attempts to achieve desired results

Fig. 7 Interaction: pSTEM course interest by VR office and identification. Significant for women with high and low identification. Controls for pre-VR self-pSTEM implicit associations. Higher score = higher pSTEM course interest



(Röhner et al. 2011). However, because we did not measure all the variables, we cannot control for the participants pre-VR assessment for all measures; instead, we used the self-pSTEM implicit associations score as a control. It is possible that this was not an adequate control for all variables. Future studies should account for this, perhaps by surveying participants 2 weeks before the intervention to measure all outcome variables while still avoiding practice effects. Additionally, we created our own identification scale. Although this gave the benefit of having scale questions specific to our VR scenario, the scale does not have pre-established validity or reliability.

Our sample size was relatively small, which may have contributed to marginally significant results. Conducting the study with a larger sample would allow more power to test for significance. Additionally, although our participants were diverse in terms of ethnic background and first-generation status, they were primarily undergraduates who were majoring in or planning to major in psychology. Future studies might explore similar research among emerging adults who are early in their college careers and have not yet declared a major. Additionally, future studies might explore virtual reality possible selves scenarios with children or adolescents, as their future plans and career interests are even less developed than emerging adults. It is possible that there would be higher identification and less reactance among children and adolescence due to more malleable self-concepts.

Finally, although this study had a humanities VR comparison condition, it did not include a non-virtual reality comparison condition. It would be interesting to explore a virtual reality future self-intervention in comparison to one where participants imagined themselves in a successful career in pSTEM, wrote about it, or perhaps read about a similar scenario to our virtual reality office on a sheet of paper. Exploring a VR simulation in comparison to a written one on paper would be especially interesting, as researchers could investigate whether identification is stronger when a participant experiences VR in comparison to reading about their success in pSTEM.

Future studies might additionally explore ways of increasing identification with the presented future self and space. For example, participants could fill out a survey about their hobbies prior to the experiment, which could then be included in the office space (e.g., a tennis racket). Having participants complete a pSTEM-related task in the space may also help increase identification and motivation. Additionally, emphasizing different aspects or affordances of the space might lead to increased identification. For example, prior studies have found that increasing communal aspects of STEM can increase women's interest (Diekman et al. 2010). Depicting pSTEM as communal or having participants interact or complete a task with a confederate in the virtual space might increase women's views that pSTEM is communal, and in turn increase motivation and identification.

Conclusion

Our study was among the first to explore whether a possible self-intervention supported by virtual reality, moderated by identification, could increase academic motivation. Using math, physical sciences, engineering, and computer science as our academic domain and emerging adult women as our participants, we found evidence that virtual reality can be used to increase motivation and decrease stereotype threat, when participants identify with the experience. This implies that virtual reality might be a useful tool for future self-interventions among students and speaks to the usefulness of identification as a moderator.

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Compliance with Ethical Standards

Conflict of Interest The authors declare that they have no conflict of interest.

Ethical Approval All procedures performed in studies involving human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki declaration and its later amendments or comparable ethical standards.

Informed Consent Informed consent was obtained from all individual participants included in the study.

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