Welcome to the Course: Early Social Cues Influence Women's Persistence in Computer Science

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ABSTRACT
First impressions influence subsequent behavior, especially when deciding how much effort to invest in an activity such as taking an online course. In computer programming courses, a context where social group stereotypes are salient, social cues early in the course can be used strategically to affirm members of historically underrepresented groups in their sense of belonging. We tested this idea in two randomized field experiments (N=53,922) by varying the social identity and status of the presenter of a welcome video and assessing online learners' persistence and achievement. Counter to our hypotheses, we found lower persistence among women in certain age groups if the welcome video was presented by a female instructor or by lower-status peers. Men remained unaffected. The results suggest that women are more responsive to social cues in online STEM courses, an environment where their social identity has been negatively stereotyped. Presenting a male and female instructor together was an effective strategy for retaining women in the course.

Author Keywords
Education, Computer Science, Inclusion, Gender, Psychology

CCS Concepts
•**Human-centered computing** → *Empirical studies in HCI;*
•**Applied computing** → *Education;*

INTRODUCTION
The state of diversity in computer and mathematics occupations in the US is alarming. Women's participation has declined by almost 10% in the past three decades, and women now comprise just over a quarter of this workforce [72]. Historically underrepresented groups such as Blacks and Hispanics also constitute less than 10% of this workforce [70]. The representation of women and ethno-racial minorities is even lower in post-secondary computer science education [71]. Online learning—and massive open online courses (MOOCs) in particular—has been cited as a promising strategy to increase access for traditionally marginalized students, especially in science, technology, engineering, and mathematics (STEM) disciplines [74, 24]. However, there is growing evidence to suggest that these enrollment and participation gaps in STEM courses also exist in online learning environments [59, 33, 43, 40, 7, 35]. Recent studies have identified a potential cause of these gaps: visual cues in online learning environments that activate psychological biases and make certain groups of learners (e.g., women and minorities in computer science courses) feel unwelcome [42, 52, 8]. The distinct lack of female and minority role models in many computer science courses may contribute to an unwelcoming learning environment and activate psychological bias for certain groups of learners [30, 29]. There is a pressing need to understand how the social identity of instructors and peer role models affect the participation and success of women and minorities in online computer science courses.

Social content that appears at the very beginning of the course, such as a welcome video or collaborative activity, are commonplace in online courses and cited as important design elements that can improve social presence, the feeling of being "there" with others [56, 31]. These course elements can contain cues that influence students' perceptions of the social environment and, in turn, play an important role in determining subsequent engagement and achievement [60, 27, 61, 38]. In particular, they provide learners with initial information regarding the gender, race, ethnicity, and age of the instructor(s) and other participants in the course. These social cues can affect groups of learners differentially based on their own social identity; gender, ethnicity, and age of learners have all been shown to influence how they perceive social cues in the online environment [36, 45]. For instance, prior research demonstrates that social cues presented before enrollment can be threatening to women in online STEM courses, while men are largely unaffected [42, 52]. Thus, social cues may be used strategically

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to affirm members of historically underrepresented groups in their sense of belonging. Yet how social cues at the start of a course impact learner engagement and achievement warrants further research to advance psychological theory and inform instructional design practice.

This research contributes causal evidence to our understanding of how social cues early in a course impact the engagement and achievement of learners over time. Building on numerous lab studies showing that a female role model can aid women in a male-dominated environment, we conducted a realistic test of this idea to collect real-world evidence that can inform decision-making for instructors and instructional designers. In two large-scale randomized field experiments, we investigated how the social identity of the presenter of a welcome video influences learner persistence and grades in online courses on computer programming. In one study, we manipulate the gender of the instructor (male, female, or both); in a second study, we manipulate the social status of the presenter (instructors versus peers). The two studies ran in parallel because the courses in which they were implemented launched simultaneously as part of a new certificate program. Both manipulations yield significant effects on persistence and partly on grades, but not in the hypothesized direction. Exploratory analyses reveal gender-age intersectionality as an important moderator of the effects of socio-demographic cues in online learning [18]. The implications of this study's findings and directions for future research are discussed.

RELATED WORK

Understanding the experience of people interacting with technology and influencing their experiences by adjusting the digital environment lies at the core of people-centered design. How a person experiences an environment is subjective because of the processes by which they perceive and interpret information. A student's first impression, which is influenced by verbal and non-verbal social cues, is known to be a strong predictor of their subsequent evaluations of an academic environment [1, 10]. It is therefore critical to understand the impact of and strategically use social cues early in the learning experience. Prior work has studied the effect of showing the instructor in lecture videos and found that it made them overall more engaging [32, 41, 38], but there is no systematic investigation of the impact of social cues on groups of people in the literature. In this section, we review relevant psychological theories on social identity and belonging with respect to academic achievement in in-person and online environments.

Social Identity and Psychological Cues

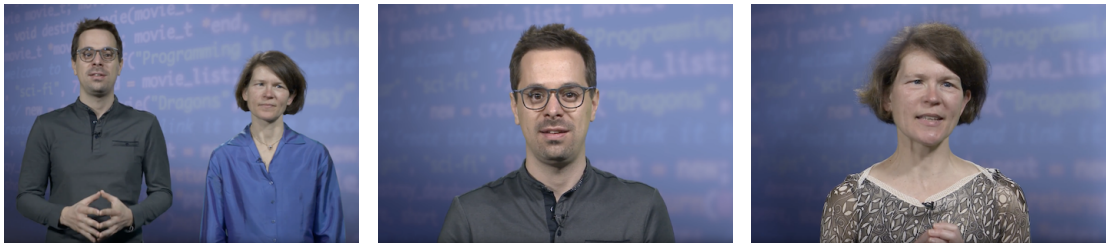
Membership in social groups is an essential part of people's identities [6] and people strive to maintain a positive perception of the various social groups with which they identify (e.g., gender, race, ethnicity, nationality) [68]. The concern that one is seen as less competent or treated unfairly because of a particular social identity one holds is a phenomenon known as social identity threat [66, 47]. It can impair cognitive and social processes including student learning [69], working memory [62], and self-regulation [5]. Negative group stereotypes are a key source of fears of social exclusion and the prospect of confirming these stereotypes is psychologically threatening. Stereotype threat has been linked to major academic achievement gaps in the United States, including the underperformance of women in historically male-dominated STEM programs [65, 54, 77].

Questions of social belonging are closely related to concerns about one's social identity in an environment. When entering a new environment, people tend to ask themselves a simple yet consequential question about the perceived fit between the self and a context: "Do I belong here?" A sense of belonging is a critical antecedent to motivation and success in academic environments [75, 57]. Feeling that one does not fit in or feeling uncertain about one's fit can cause disengagement and underperformance [76]. Interventions aimed at improving learners' sense of belonging target cues in the environment and how people make sense of the cues (or themselves) to help them develop a resilient sense of belonging [78]. By virtue of the recursiveness of these psychological processes, a change in how learners perceive themselves and their context can have a sustained impact [16].

Psychological processes of belonging and social identity threat matter not only in face-to-face but also computer-mediated environments. The cues present in digital environments can differentially influence the perceptions for people who identify with different social groups. Psychologically Inclusive Design [37, 42] is an approach to creating digital environments that afford equal opportunities to diverse learners by strategically manipulating content and design cues that influence how learners perceive the environment and how they fit into it. Accumulating evidence shows that stereotypical cues in digital environments can shape perceptions about the diversity climate and reduce anticipated belonging, while psychologically inclusive cues can be added strategically to affirm members of underrepresented or negatively stereotyped groups. Multimedia cues have been shown to raise identity-based concerns and influence anticipated belonging in various settings, including gender-stereotypic TV commercials [19, 20], online social advertising [42], promotional videos for STEM events [55], lecture videos [8], virtual-reality classrooms [13, 50], and course websites [52, 42, 44].

Social Cues of Gender and Status

Matching the social identity of students and teachers has been found to benefit students. From the teacher's perspective, they hold more positive expectations of students with similar race, ethnicity, and gender [22]. From the student's perspective, at least in the case of gender matching, they tend to see the teacher as a role model rather than expecting favorable treatment on the basis of gender [58]. In particular, female role models are known to psychologically support women in STEM environments by protecting them from some of the consequences of negative gender stereotypes [48, 67]. We therefore hypothesize that an in-group gender cue at the start of an online course will improve female learners' persistence and achievement:



(a) Both Instructors (b) Male Instructor (c) Female Instructor

Figure 1. Presenter gender manipulation in the welcome video. The welcome video was recorded three times with the same text and visuals but showing either both instructors (male and female), only the male instructor, or only the female instructor.

H1 Featuring a female (compared to a male) instructor in the course welcome video will raise the persistence and achievement of female learners.

The community of inquiry framework emphasizes the importance of instructors and students establishing social, cognitive, and teaching presence in online learning [26]. Yet instructors and peers differ in social status due to their position of power and credibility—their perceived expertise and trustworthiness [28]. Social status is defined by the amount of respect, influence, and prominence people enjoy in the eyes of others [2]. Although instructors hold higher social status, peers can be more relatable to other learners and therefore more persuasive [15]. Interventions to increase perceptions of social belonging, for example, frequently use peer testimonials to assuage concerns [76, 77, 75]. In fact, prior work found that the same message about the value of a course delivered by a peer is more effective in raising course achievement than delivered by the instructor [64]. Accordingly, we hypothesize that younger learners will benefit from early exposure to lower-status peer role models:

H2 Featuring peers (compared to instructors) in the course welcome video will raise the persistence and achievement of younger learners.

GENDER CUE EXPERIMENT

This study investigates the effect of gender cues on the persistence and achievement of learners enrolled in a free online CS course. It is the first in a seven-course series to earn a professional certificate in C programming. The content comprises interactive coding videos, regular lecture videos, and a large number of automatically graded programming assignments and quizzes. The course has one male and one female instructor. We manipulated a salient gender cue at the start of the course: who presents the course welcome video, that is, the first video lecture in the course. Learners were randomized at the time of enrollment to receive either the default video with both instructors (control), a version with only the male instructor, or a version with only the female instructor. The gender cue was clearly communicated via visual (see Figure 1) and auditory (a notable difference in pitch) channels, notwithstanding other observable differences between instructors such as their age: the female instructor was 48 while the male instructor was 34. Everything else was held constant including the spoken text and non-social visual cues in the first video and all other course materials.

The manipulation is not subtle but it is focused on just one video at the start of the course. This study design choice is guided by logistical and empirical observations. First, the recording of professional lecture videos bears a high financial cost (studio time, videographer, sound technician, etc.) and it is time consuming as several takes are required for each video. Second, as the course is officially offered by both instructors, omitting one instructor from lectures entirely was not an option. Third, early cues are more influential than later cues based on research about first impressions [1, 10] and as most dropout occurs at the beginning of the course [21]. Fourth, given that prior work has found large effects due to small changes in MOOCs [39, 43], we were cautious not to implement a strong manipulation that might cause substantial dropout.

The study design allows us to test hypothesis H1 that a female role model increases persistence and achievement among female learners. Instructor(s) introduced themselves as professors in the video to clearly convey their status in the course. Given that the manipulation occurs at the start of the course, we expect to observe a proximate effect following the welcome video. We first conduct a confirmatory analysis to test H1 and then explore the study outcomes for further trends.

Method

Participants and Context

The study occurred in an introductory computer programming course offered by a US university in collaboration with a French University on the EdX platform, one of the largest providers of massive open online courses. The course is free and open for anyone to enroll and complete at their own pace. Optionally, a verified course certificate is available for $49 USD. The study includes 39,796 learners who enrolled and accessed the course materials. Five-hundred and six learners (1.27%) paid for the option to earn a verified course certificate and 316 of them (62.5%) were awarded one. Self-reported demographic information collected independently by the platform was available for half of the learners, a typical response rate for MOOC platform self-report data. As all our planned analyses estimate demographic subgroup effects, we study learners with available demographic information (n=20,180 with gender information; n=20,416 with age information; n=18,681 with both), which focuses the analysis on learners who tend to be more motivated to complete the course [25]. The average age of learners is 27 years (SD=10.0), 18.9% are

female, and the highest level of education achieved was a Masters'/Doctorate degree for 16.2%, a Bachelors'/Associates' degree for 37.7%, and a (Junior) High School diploma for 40.9%.

Procedure and Materials

Learners were divided into three experimental conditions by simple random assignment with equal probability: 13,157 in the Female Instructor condition, 13,196 in the Male Instructor condition, and 13,443 in the Both Instructors condition. The first lecture video in the course was manipulated according to the assigned condition. Figure 1 shows a screenshot of the same moment in the three versions of the video. All other course materials were exactly the same across conditions. In particular, the next two videos after the welcome video are on how to use the tools in this course and find special characters on the keyboard, presented by the female instructor; followed by a video on the history of C by both instructors. All of the core teaching content uses a voice-over recording without video and instructors alternate in providing them.

Measures

Persistence and achievement are common measures of success in learning environments. In self-paced MOOCs, where learners can progress at their own pace, persistence is commonly defined in terms of interactions with course content such as lectures or assessments [21]. Our primary outcome of persistence is measured in terms of attempting the 26 graded assignments that are spread out in the course. In particular, the first graded assignment follows shortly after the video manipulation and therefore provides an immediate indicator of persistence (initial persistence). Our secondary outcome of achievement is measured by the overall grade a learner achieves in the course. This final grade is partly determined by the grades received on the 26 assignments and whether the assignments were attempted at all. The grade therefore provides a global measure of academic achievement in the course. To define learner subgroups in the analysis, we use demographic information collected by the online course platform at the time of enrollment: learners report their age, sex, and highest level of education completed (descriptive statistics and response rates provided above).

Analytic Approach

We use linear regression models (ordinary least squares) with robust standard errors to estimate the immediate effect on persistence (i.e. whether a learner attempted the first graded activity) and the overall grade (a percentage). For the binary persistence variable this is equivalent to a linear probability model (LPM), commonly used in economics and political science, as well as in prior work with randomized experiments in MOOCs (e.g. [43]). A notable advantage of LPMs is the interpretability of their output: coefficients denote differences in proportion instead of log odds ratios in logistic regression [3]. We checked that findings were qualitatively equivalent when using logistic regression. To estimate the longitudinal effect on persistence in terms of attempting each graded assignment we use a random-intercept logistic mixed-effects model fitted with *lme4* in *R* [4].

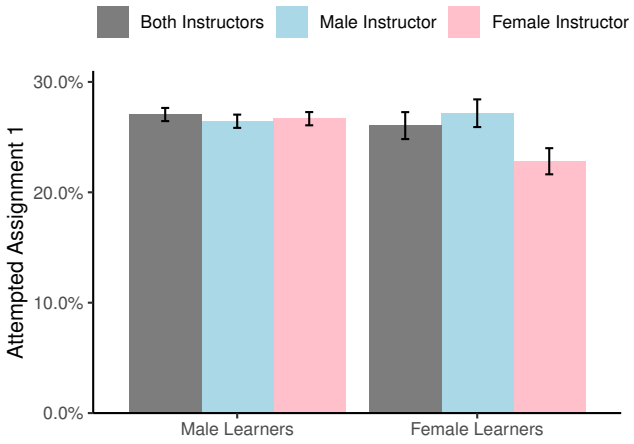


Figure 2. Effect of gender cue on initial persistence: Proportion of male learners (left) and female learners (right) attempting the first graded assignment by experimental condition (color). Persistence among female learners dropped in the Female Instructor condition, while male learners were unaffected. Error bars show 1 SEM.

Results

Before testing the predicted subgroup effect, we first check if the intervention had an overall effect on persistence or achievement. There was no significant evidence that it changed average initial persistence (i.e. attempting the first assignment; $F_{2,39793} = 1.11, p = 0.33$) or the average course grade ($F_{2,39793} = 0.34, p = 0.71$).

We test for subgroup effects starting with the hypothesized effect on female learners. Figure 2 shows how the video intervention affected initial persistence among male and female learners separately. We hypothesized the female gender cue to have a positive effect on female learners, but it backfired instead. Female learners were 19% less likely to attempt the first assignment in the Female Instructor condition than in the Male Instructor condition, a drop from 27.2% to 22.9% ($t_{3808} = -2.52, p = 0.0117$). Surprisingly, female learners were 4.3% more likely to attempt the first assignment in the Male Instructor than Both Instructors condition, though this difference was not significant ($t_{3808} = 0.641, p = 0.522$). As shown in Figure 2, the intervention did not impact initial persistence for male learners ($F_{2,16366} = 0.264, p = 0.768$). In terms of learner achievement, the grade pattern mirrored the gender-based pattern for persistence, as evidenced by the linear model predicting grades with a condition-gender interaction ($F_{5,20174} = 2.93, p = 0.012$). However, the reduction in the average grade among female learners from 12.6% to 11.0% was not statistically significant ($t_{3808} = -1.51, p = 0.132$).

Longitudinal Analysis

The longitudinal trend in persistence over all graded assignments is illustrated in Figure 3. For female learners (top panel), the initial effect of the female cue carries forward through most of the course. This suggests that the video caused a portion of female learners to disengage right at the beginning. In fact, conditional on completing the first graded assignment, female learners across conditions had a similar likelihood of

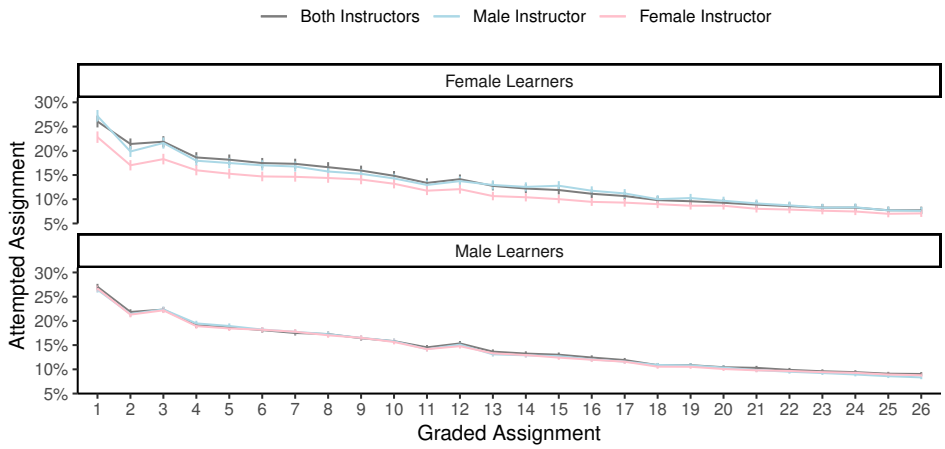


Figure 3. Longitudinal effect of gender cues on persistence: Proportion of male learners (top) and female learners (bottom) attempting each graded assignment by experimental condition (color). Female learners saw a sustained drop in persistence immediately following the female instructor cue. Error bars show 1 SEM.

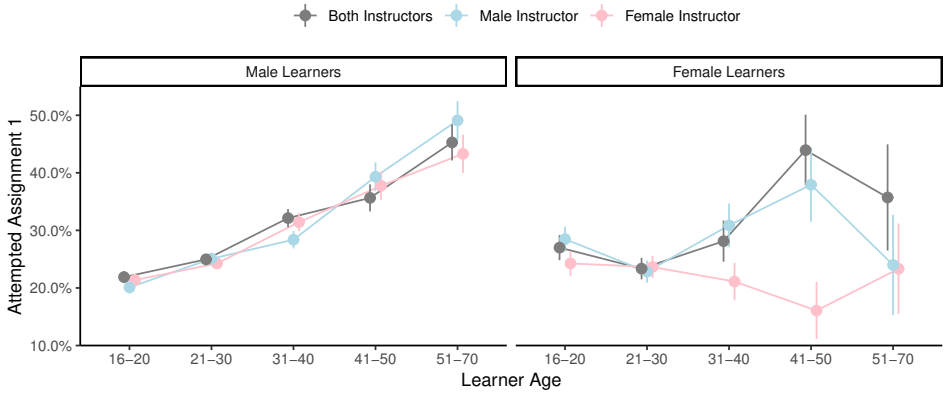


Figure 4. Age-based heterogeneity in the effect of gender cues on persistence: Proportion of male learners (left) and female learners (right) attempting the first graded assignment by age group (x-axis) and experimental condition (color). Persistence among female learners over 30 dropped in the Female Instructor condition. Error bars show 1 SEM.

completing the second ($F_{2,963} = 2.39, p = 0.092$) and third assignment ($F_{2,963} = 0.144, p = 0.866$). For male learners, in contrast, there was neither an initial nor longitudinal effect on persistence as seen in Figure 3. Results of a random-intercept mixed-effects logistic model confirm that female learners start off with a significantly lower likelihood of attempting in the Female Instructor condition ($b = -0.757, z = -2.01, p = 0.044$) but the slope is less negative ($b = 0.048, z = 3.68, p = 0.0002$). Comparing the same model fitted for male learners with and without the treatment indicators confirms that the gender cue did not affect them on average ($\chi^2_4 = 2.165, p = 0.705$).

Gender-Age Subgroup Analysis

As an exploratory analysis, we examine how observed treatment effects vary by age given that course participants span a wide range of age groups. Figure 4 shows that the negative effect of the female cue on females is concentrated among older learners. Female learners over 30 were 78% less likely to attempt the first assignment in the Female Instructor condition than in in the default Both Instructor condition, a drop from 18% to 10% ($t_{730} = -2.90, p = 0.0038$); younger female learners' persistence was notably unaffected by the intervention ($F_{2,2737} = 0.14, p = 0.87$).

STATUS CUE EXPERIMENT

This study investigates the effect of status cues on the persistence and achievement of learners enrolled in a free online CS course. The study occurred in the second introductory computer programming course offered in the same series of courses as the first study. The two studies ran in parallel because the series of courses was released all at once by the same two instructors. We manipulated a salient status cue at the start of the course in the course welcome video. Learners were randomized at the time of enrollment to receive either the default video with both instructors (high status) or a version with two ostensible peers (low status). Only the first video in the course was manipulated for the reasons laid out in the previous section.

The status cue was clearly communicated via visual, auditory, and verbal channels, while keeping constant the gender ratio, spoken text, and any non-social visual cues in the video,

as well as all other course elements. As shown in Figure 5, peers appeared younger and wore less formal clothes than instructors; they also sounded younger based on their tone of voice, and the video featured a horizontal text box at the start to identify the presenters as either “Professor" or “Student”. The male and female peers were a college junior and senior, while the male and female instructors were 34 and 48 years old, respectively. In addition, while both instructors are White, both peers are members of traditionally underrepresented ethno-racial groups in computer science. Together, the differences between the instructor and the peer welcome video constitute a strong manipulation of social status, presenting the course instructors as high-status figures of authority and the ostensible peers as low-status relatable role models.

The study design allows us to test hypothesis H2 that a peer role model increases persistence and achievement among younger learners. Again, we expect to observe a proximate effect on persistence following the welcome video. We first conduct a confirmatory analysis to test H2 and then explore the study outcomes for additional trends.

Method

Participants and Context

The study occurred in an introductory computer programming course offered by a US university in collaboration with a French University on the EdX platform. Course materials comprise interactive coding videos, regular lecture videos, a large number of automatically graded programming assignments and quizzes. As part of the same seven-course series to earn a professional certificate in C programming, this course is also free, open to anyone, and self-paced, with the option of a verified certificate for $49 USD. The study includes 14,126 learners who enrolled and accessed the course materials. Two-hundred and sixty-six learners (1.88%) paid for the option to earn a verified course certificate and 58 of them (78.2%) were awarded one. Self-reported demographic information was collected independently by the platform as explained above. We study learners with available demographic information (n=7,267 with gender information; n=7,541 with age information; n=6,790 with both). The average age of learners is 27 years (SD=9.8), 17.5% are female, and the highest level of education achieved was a Masters’/Doctorate degree for 16.8%, a Bachelors’/Associates’ degree for 37.5%, and a (Junior) High School diploma for 39.8%.

Procedure and Materials

Learners were divided into two experimental conditions by simple random assignment with equal probability: 7,016 in the Instructors condition, 7,110 in the Peers condition. Only the first lecture video in the course was manipulated depending on the assigned condition. Figure 5 shows a screenshot of the same moment in both versions. All other course materials were exactly the same across conditions.

Measures & Analytic Approach

We use the same outcome measures, covariates, and analytic approach as above. The course features 18 graded assignments used to assess persistence.

(a) Instructors (b) Peers

Figure 5. Presenter status manipulation in the welcome video. The welcome video was recorded twice with the same text and visuals but showing either two instructors (high status) or two ostensible peers (low status).

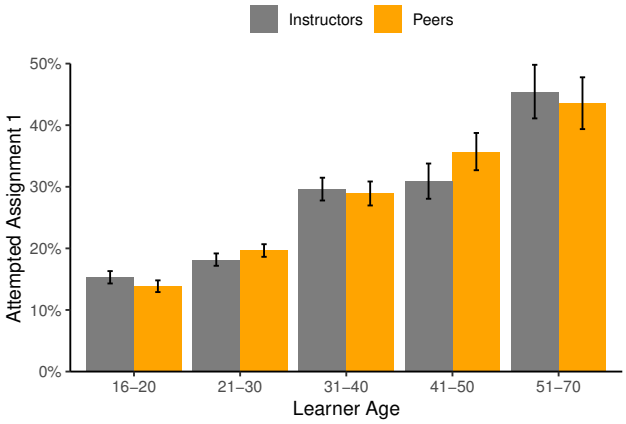


Figure 6. Effect of status cue on initial persistence by age: Proportion of learners attempting the first graded assignment by age group and experimental condition (color). Persistence did not change in the Peer condition for any age group. Error bars show 1 SEM.

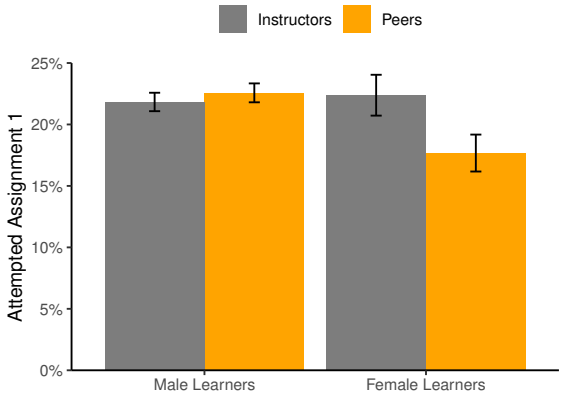


Figure 7. Effect of status cue on initial persistence by gender: Proportion of male learners (left) and female learners (right) attempting the first graded assignment by experimental condition (color). Persistence among female learners dropped in the Peer condition, while male learners were unaffected. Error bars show 1 SEM.

Results

Before testing the predicted subgroup effect, we first check if the intervention had an overall effect on persistence or achievement. There was again no significant evidence for an overall effect on initial persistence ($t_{14124} = 0.93, p = 0.350$) or overall course grade ($t_{14124} = 1.32, p = 0.186$).

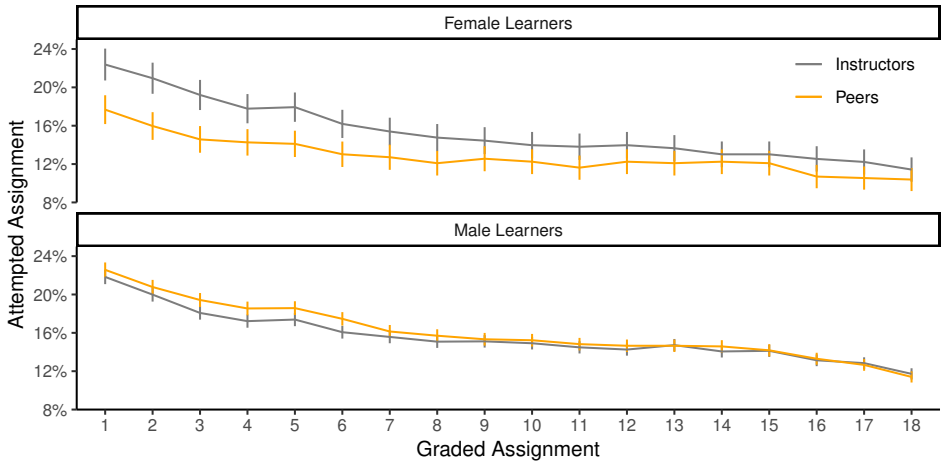


Figure 8. Longitudinal effect of status cues on persistence: Proportion of male learners (top) and female learners (bottom) attempting each graded assignment by experimental condition (color). Female learners saw a sustained drop in persistence immediately following the female instructor cue. Error bars show 1 SEM.

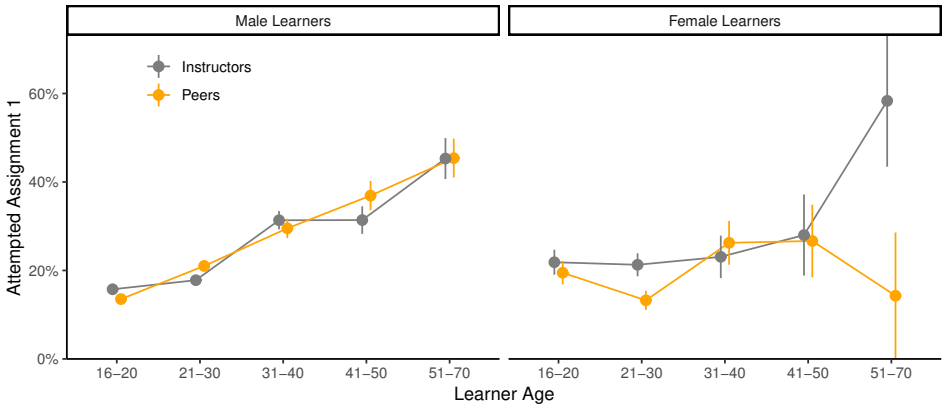


Figure 9. Age-based heterogeneity in the effect of status cues on persistence: Proportion of male learners (left) and female learners (right) attempting the first graded assignment by age group (x-axis) and experimental condition (color). Error bars show 1 SEM.

We tested for subgroup effects starting with the hypothesized effect on younger learners. Figure 6 shows how the video intervention affected initial persistence among learners in five age groups (the pattern of results is visually identical for course grades). A linear regression with a age-by-condition interaction confirms what the bar plot suggests: initial persistence increases with age ($t_{7537} = 10.5, p < 0.001$) but the intervention effect neither varies with age ($t_{7537} = 0.626, p = 0.531$) nor is it significant at the average age ($t_{7537} = 0.217, p = 0.829$). Results for learner achievement in terms of their overall grade are equivalent (age-condition interaction: $t_{7537} = 0.925, p = 0.355$).

Having found no evidence for the hypothesized age-based effect, we explored gender-based variability as in the other study. As shown in Figure 7, female learners' initial persistence was reduced by 26.6% in the Peer video condition, a drop from 22.3% to 17.7% ($t_{1273} = -2.10, p = 0.036$). Male learners, in contrast, remained unaffected by the video manipulation ($t_{5990} = 0.69, p = 0.490$). Female learners in the Peer video condition also earned 29% lower grades ($t_{1273} = -1.54, p = 0.123$) compared to the Instructor video condition, while male learners' grades were unaffected ($t_{5990} = -0.54, p = 0.591$).

Longitudinal Analysis

The longitudinal trend in persistence over all graded assignments is illustrated in Figure 8. For female learners (top panel), the initial effect of the low status cue carries forward through most of the course. This suggests that the Peer video caused some female learners to disengage right at the start. Results of the longitudinal mixed-effects model confirms that the pattern is statistically significant. Female learners started off less likely to attempt the first assignment in the Peers video condition (intercept: $b = -1.51, z = -2.08, p = 0.037$) but their drop-off in persistence was not as steep as in the Instructor video condition (interaction: $b = 0.170, z = 4.72, p < 0.001$). For male learners (bottom panel), the status cue did not significantly increase initial persistence ($b = 0.517, z = 1.62, p = 0.106$), but it made the slope in persistence (i.e. the rate of attrition) steeper (interaction: $b = -0.077, z = -4.91, p < 0.001$).

Gender-Age Subgroup Analysis

We investigate the unexpected effect on female learners further in light of our original hypothesis about age-based variation by estimating age-gender subgroup effects. Figure 9 shows that the observed gender effect on initial persistence varies with age. The negative effect of the low status cue on female

learners is concentrated among younger learners, especially those between 21 and 30 who were 61% less likely to attempt the first assignment in the Peer condition—a drop from 21% to 13% ($t_{496} = -2.38, p = 0.0018$). Although Figure 9 also shows a large effect for 51-70 year old female learners ($t_{17} = -2.14, p = 0.0475$), there are only 19 individuals in this subgroup. Male learners were notably unaffected by the intervention across all age groups ($F_{4,5604} = 1.70, p = 0.146$). The achievement results adhere to the same pattern as persistence but with marginal statistical significance (effect on females 21-30: 44% lower grades in the Peer condition, $t_{496} = -1.55, p = 0.123$).

DISCUSSION

The social cues at the beginning of a course can have substantial downstream effects on who persists and their academic achievement. This research examined how social cues embedded early in a course impact the persistence and achievement of learners based on their social identity. It builds on prior work on the influence of environmental cues on psychological barriers to women's participation in STEM education by demonstrating the behavioral consequences of gender and status cues in online environments. Across two large-scale field experiments, we also find evidence of significant heterogeneity in treatment effects. In computer programming courses, environments where women tend to be negatively stereotyped [49], we find that women are responsive to changes in both gender and social status cues in the course welcome video.

A gender effect in response to manipulating instructor gender was expected given prior work showing that women are perceived as role models, induce a sense of belonging, psychologically protect women against the consequences of gender stereotypes [22, 58, 48, 67]. However, we did not anticipate a drop in persistence among women after seeing the video featuring the female instructor. Likewise, we did not anticipate a drop in persistence among women after seeing the video featuring peers instead of instructors. In contrast, the persistence and achievement of men in the course remained unaffected by these manipulations of gender and social status cues, which is consistent with previous research measuring anticipated belonging and intentions among men in response to gender cues [50, 14, 13]. Consistent with models that differentiate how cues influence female recruitment into STEM from how they influence their retention [23], we found that presenting both the male and female instructor together was an effective strategy for retaining women in the course. Instructional designers should tread carefully with similar attempts to affirm underrepresented groups of learners given the danger of backfiring effects.

Taken together, the findings suggest that (1) women are alert and responsive to social cues in online computer science courses, an environment where their social identity has been negatively stereotyped, and (2) women are more likely to disengage if social cues violate perceived norms (e.g. that the programming course is taught by a male but not female instructor, that high-status instructors instead of peers should welcome new learners). Both implications are concordant with the integrated process model of stereotype threat effects proposed by Schmader and colleagues [63], who emphasize the role of vigilance for cues in the environment. A more exploratory result of this research is the role of age-gender intersectionality [18]. The negative effect of social cues on women were age-dependent, which could suggest generational differences in how gender cues are interpreted by women. Older generations may hold more traditional gender stereotypes about computer science and be more comfortable with younger peers welcoming them to a course on computer programming. This finding warrants further research to advance our generational understanding of computer science stereotypes and inform policies for targeting interventions.

On the Effects of Gender Cues

We hypothesized based on prior research that seeing a female role model at the start of the course should inspire and motivate female learners to persist in the course and perform highly. Instead, the opposite happened. This unexpected effect was however age dependent. While learners under 30 were not significantly affected by the video manipulation, female learners between the ages of 31–50 reacted negatively to the video of the female instructor. One interpretation of this age-based heterogeneity is that it reflects a generational difference and stereotypes of computer science may vary across generations. Generation Y ("Millennials") and Z were unaffected, while "Xennials" (late Millenials) and especially Generation X were strongly affected. Representation of the Baby Boomer generation (51-70) is limited and estimates have low precision. Previous research has shown distinct gender and generational differences in online behavior [34, 11]. For example, age- and gender-based market segmentation is nearly ubiquitous in online marketing practice and supported by a growing body of research [12]. This research has shown that the Generation X cohort is more responsive to cues congruent with expectations of the traditional retail buying experience—brand names, feature descriptions, and assurances (e.g., money-back guarantees)—and turned off by the slick, lifestyle-orientated campaigns that resonate more with Generation Y [46]. Additionally, related research suggests that women may be more reactive than men to gender-based marketing cues [53, 17], which corroborates social-psychological research that consistently finds women more attuned to social cues in online spaces. Our study is the first to our knowledge that has identified age-gender intersectionality and associated heterogeneous effects of gender cues in online learning behavior. Future research is needed to confirm whether gender-based stereotypes of computer science vary across generations, influence perceptions of gender cues, and affect persistence and achievement in online courses.

The finding that male learners remained unaffected by the manipulation is consistent with prior research showing that the majority group is less attuned to social and environmental cues related to their social identity [55, 14]. However, a prior study found that men became less likely to click on online advertising for a computer science course when it had verbal but not visual cues targeting women [42]. While the three versions of the welcome video contained the same spoken text, there were audible differences across speakers. One explanation for these contrasting results may be that differences in

verbal and audible cues in our study were relatively subtle. Men may tend to be more resilient to social cues targeting women, but are affected once cues pass a salience threshold. This may be particularly the case with verbal cues that leave less room for alternative interpretation, observing that men in both studies were unaffected by visual cues targeting women. Future research should explore whether this threshold effect exists for men by testing verbal cues of different strengths.

On the Effects of Social Status Cues

We hypothesized based on prior research that exposure to younger role models who are closer in status and therefore more relatable to young learners should inspire and motivate young learners to persist in the course and perform well. However, we found no main effect for any age group; instead, we once again found an effect on female learners. Female learners were less persistent and earned lower grades if they saw the welcome video with peers rather than instructors. Yet this unexpected gender effect varied with age. While learners between 31-50 were not significantly affected by the video manipulation, younger female learners reacted negatively to the video featuring ostensible peers. Notably, the gender ratio was constant in both videos. One interpretation of the gender- and age-based heterogeneity is that (1) female learners are more attuned to social cues in an environment where their social identity is negatively stereotyped, and (2) while later generations view "young people" as knowledgeable and trustworthy on the topic of computer programming, learners of a similar age view them as equals with insufficient authority and experience to teach the topic.

Prior work on presenting students with rationales for taking a course by either the instructor or peers found that peer rationales are more beneficial for academic achievement in the long-run [64]. However, the substantive context in the present study is different in that peers are welcoming learners into the course (which instructors are expected to do) rather than providing a rationale for how the course is useful (which peers have credible and relatable opinions on). The discrepancy between the present findings and prior research may therefore be the result of an expectancy violation regarding the source of the welcome message [9]. Similarly, research on participation in online communities suggests that initial participation may be driven by expertise cues, while sustained interest is more tied to interaction with ostensible peers of similar status [73]. Future research should explore whether, and by what mechanism(s), the impact of status cues is mediated by expectations tied to the type and purpose of the message.

Limitations

We build on a large literature of lab experiments that have isolated specific factors to understand how they influence people's perceptions and intentions. Field experiments are inherently less controlled, but have the advantage of providing realistic and policy-relevant estimates of behavioral consequences. This requires a tradeoff. This research has high ecological validity because it was conducted in a field setting, and it allows for causal inference because it is a randomized experiment. However, there are also several limitations.

First, the manipulations are realistic but not entirely clean: we manipulate not only one social identity at a time because each instructor and peer has unique characteristics. For example, the instructors have different ages (34 and 48) and accents (French and German), and the peers have a darker skin tone than the instructors. Our experiments build on numerous lab studies showing that a female role model can aid women in a male-dominated environment, and we believe that this research serves as a realistic test of this idea in the field. It provides evidence that can inform decision-making for instructors and instructional designers who also cannot control everything. Nevertheless, we believe that our manipulations have high construct validity because instructor gender is clear based on appearance and vocal pitch in the video in Study 1, and status is clear based on the appearance and in-video introductions as "Professor" versus "Student" in Study 2. A pilot survey confirmed that video viewers notice the difference in instructor gender and perceive peers as lower status in the course. They also noticed the age difference between instructors, but the behavioral effect of age alone is not consistent across studies: in the first study, the older female instructor lowered female persistence, while in the second study, the younger peers reduced persistence. This suggests that the effect on women's persistence cannot be explained by variation in presenter age alone.

Second, while we observe important behavioral and achievement outcomes of learners, we do not assess psychological constructs like stereotype threat or social belonging in this study. Future work should combine both self-reported and behavioral outcomes to better understand the psychological processes underlying the behavioral effects. Third, the studies were conducted in the context of introductory computer programming courses. The findings are likely to extend to other computer science domains, but the generalizability to other STEM fields should be tested in future work.

Design Recommendations and Future Work

This research tests design recommendations grounded in numerous lab studies that have argued that a female role model can aid women in a male-dominated environment. In practice, there always are multi-dimensional and inter-temporal confounding factors when implementing a design intervention like this one. They go beyond our ability to study, and most instructor's ability to control. Because our findings do not align with our theory-based expectations, they raise additional questions. However, it is important to note that those expectations are primarily based on self-report measures and this is one of the first studies to understand behavioral effects. This study does not show that prior recommendations are wrong. Instead, it provides cautionary evidence that the behavioral effects of such interventions can be counter-intuitive. It implies that evidence from field studies, albeit not as controlled as a lab study, is important for our community. Based on the current evidence, we recommend having both a male and a female instructor welcome students to the course. Moreover, we recommend that instructors and instructional designers embrace the ability to run A/B tests in modern education platforms when considering implementing design recommendations, especially for early cues in the learning experience.

The findings raise a number of questions for future work. Why did women drop out after seeing the female instructor in the welcome video instead of being encouraged to stay in the course? How would persistence develop over time if the gender manipulation were sustained beyond the first video? And how could the welcome video be redesigned to incorporate social cues that increase (rather than decrease) the persistence of women in the course. Given the low rate of enrollment among women in the course, it may be necessary to place social cues earlier in the enrollment pipeline to encourage more women to participate in the course. Previous research has found that psychologically welcoming social cues placed on course enrollment pages and/or marketing collateral can increase female intentions to enroll [51] and actual enrollment in STEM courses [42]. It may be the case in our study that the course enrollment page—which had a notably "techy" design and reflected traditional computer science norms—filtered out women who felt unwelcome in such an environment and primed expectations of those who did enroll [23]. Thus, in addition to manipulating gender and status cues, future research should explore how timing (e.g., at enrollment versus within the course), type (i.e., visual, verbal, etc.), and dosage (e.g., one-off versus multiple over time) of social cues influence online course outcomes.

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