Electronic Textiles and Ambient Belonging

Richard Lee Davis, Stanford University, rldavis@stanford.edu
Paulo Blikstein, Columbia University, paulob@tc.columbia.edu

Abstract: There is a growing body of evidence showing that electronic textiles provide a promising way of closing gender gaps in computing and electrical engineering. The prevailing explanation for this is framed in terms of attractive forces—women are drawn to e-textiles because of their alignment with "historically feminine practices" (Buchholz et al., 2014). However, these gender differences may also be due to repulsive forces. Traditional tools and materials may broadcast ambient identity cues that indicate women do not belong. This hypothesis leads to two predictions: (1) Women and girls are less likely to be interested in workshops that involve tools like wires and soldering irons because they associate those tools with feelings of exclusion and alienation, and (2) e-textiles may be more appealing to women and girls because these tools do not broadcast messages of exclusion. We tested these predictions in an online study with 42 university students (22 male, 20 female). We found that "standard" items like soldering irons and wires broadcast ambient identity cues that lowered women's sense of belonging while having no effect on men. Additionally, we found that e-textiles did not have a similar discriminatory effect. Thus, "standard" items are not neutral, but charged with meaning, and these items broadcast messages to women that they do not belong.

Introduction

In 2007, Leah Buechley and Mike Eisenberg released the first commercially available, novice-friendly construction kit for e-textiles called the LilyPad. Buechley and Eisenberg predicted that the kit would make computational design attractive to people that might otherwise be uninterested (L. Buechley & Eisenberg, 2008, p. 15). Buechley found evidence for this hypothesis in subsequent research: early workshops with the LilyPad were attended by overwhelming majorities of girls and women (L. Buechley & Eisenberg, 2008; Leah Buechley et al., 2008), and women were far more likely to purchase the LilyPad than they were to purchase other Arduino boards (Buechley & Hill, 2010).

These findings have been positioned within the context of the gender gap in computing and electrical engineering. Buechley has argued that current efforts to increase gender diversity are failing (Buechley et al., 2008), and that instead of asking "how can we get girls and women to participate in traditional computer science and support them once they are there?" the question should be "how can we integrate computer science with activities and communities that girls and women are already engaged in?" (p. 431, Buechley et al., 2008). The essence of this hypothesis is that the gender gap in computing is largely due to women and girls' lack of interest in typical computing activities. Women's drastically higher rates of participation in e-textiles and higher purchasing percentages of the LilyPad are presented as evidence for this hypothesis. By bringing computing into alignment with "communities that girls and women are already engaged in", the LilyPad provides an attractive and accessible entry-point into computing for women and girls.

While much of the literature on e-textiles builds on this hypothesis (e.g., Buchholz, Shively, Peppler, & Wohlwend, 2014), we believe that this hypothesis may be incomplete, in that it overlooks potential discriminatory and repulsive forces that may push women and girls away from computing and engineering. In the next section, we introduce the hypothesis that gender differences in e-textiles may be partially driven by sense of belonging (and lack thereof).

Ambient belonging and forces that repel women and girls from computing

Ambient belonging is built on the idea that the objects in an environment act as ambient identity cues that send messages about who does and who does not belong in that environment (Cheryan, Plaut, Davies, & Steele, 2009). The original studies on ambient belonging found that women had lower interest in taking a computer science course than men after being exposed to classrooms containing stereotypical objects, and higher interest than men after being exposed to nonstereotypical classrooms (Cheryan et al., 2009). The same effect has been found in virtual classrooms (Cheryan, Meltzoff, & Kim, 2011) and when viewing photographs and reading descriptions of classrooms (Master, Cheryan, & Meltzoff, 2016).

Here we extend the work on ambient belonging to the research on e-textiles in education. Our hypothesis is that wires, breadboards, and soldering irons are charged with meaning, broadcasting ambient identity cues about who belongs and who does not. Likewise for the tools and materials used in e-textiles kits: conductive thread, fabric, and needles. If our hypothesis is correct, this means that the prevailing hypothesis that the gender gap in

computing is largely due to women and girls' lack of interest in typical computing is incomplete.

Methods

Participants

We recruited N=42 current university students to take part in the study on the online platform Prolific.ac (Palan & Schitter, 2018). 22 of the participants were male (M_{age} = 22.7 years old, SD = 4.9) and 20 were female (M_{age} = 22.7 years old, SD = 4.6). All spoke English as their first language.

Materials

The materials in this study consisted of descriptions of two variations of a course in physical computing, one with electronic textiles (the Flora course) and one with standard electronics (the Metro course). The students were told that there were two variants of the course being offered. One course variant was the Metro course, which contained eight photographs of the tools used in the course — the Metro Arduino, sensors, actuators, breadboards, wires, solder, and soldering irons — and three photographs of projects that had been made using these tools and materials (Figure 1). The other course variant was the Flora course, which contained nine photographs of the tools and materials used in the course — the Flora Arduino, conductive thread, conductive fabric, sensors, LEDs, needles, and a sewing machine — along with three photographs of projects made with these tools and materials (Figure 2). The content of each of the photographs was also described in text. The only differences between the two course descriptions were the names of the objects and activities. For example, the words "Metro" and "Flora" were used in their respective course descriptions, as were the words "soldering" and "sewing".

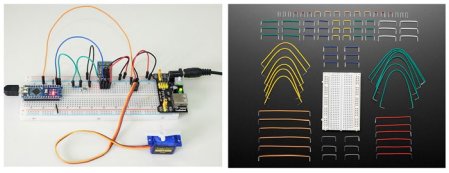


Figure 1. Example image from the Metro course.

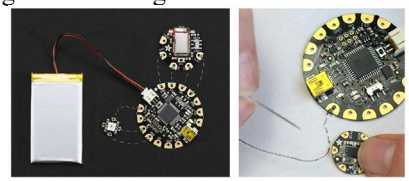


Figure 2. Example image from the Flora course.

Procedure

After reading about each course, the students were asked to choose which course they'd prefer to take, and then answered a series of questions about their interest in each course, their feelings of belonging in each course, and their fit with stereotypes related to each course (see items below).

Measures

Attention check

We included five multiple-choice attention checks. If a participant failed any of these attention checks none of their data was used in the analysis.

Choice

The students were asked to choose the course they would prefer to take: either the Flora or the Metro course variant.

Enrollment interest

The students were asked two questions about their interest in enrolling in the Flora course, and two questions about their interest in enrolling in the Metro course. All questions were scored from 1 (Not at all) to 5 (Extremely).

Fit with stereotypes

We asked students two questions about their fit with stereotypes associated with electrical engineering and computer science (EECS) and sewing. All questions were scored from 1 (Not at all) to 5 (Extremely).

Belonging

Four questions were asked about the students' sense of belonging in each course based on previously validated measures (Cheryan et al., 2009). Each set of four questions was averaged to create a single measure for sense of belonging in the Flora course and sense of belonging in the Metro course. All questions were rated from 1 (Not at all) to 5 (Extremely).

Results

Choice

There was a significant difference in classroom choice between genders, $\chi^2(1, N = 42) = 4.59, p = 0.03$. 65% of women chose the Flora classroom, while 73% of men chose the Metro classroom (Figure 3).

Enrollment interest

A two-way ANOVA examining the relationships between gender and course variant (Flora or Metro) on enrollment interest revealed a significant interaction between gender and course variant $F(1,80) = 14.13, p < 0.001$. Neither of the main effects were significant: Neither gender showed a significantly higher level of interest on average ($p < 0.54$), nor was either course rated significantly more interesting than the other ($p < 0.78$). Post-hoc analyses corrected for multiple comparisons using Tukey's HSD indicated that men were significantly more interested in the Metro course than women ($p < 0.02$), and that men were significantly more interested in the Metro course than the Flora course ($p < 0.04$). While women were not significantly more interested in the Flora course than men ($p < 0.13$), they were marginally significantly more interested in the Flora course than the Metro course ($p < 0.07$) (Figure 4).

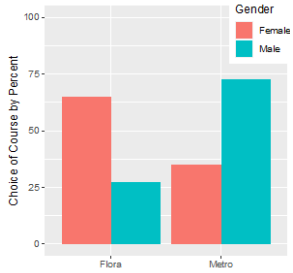


Figure 3. Course preferences.

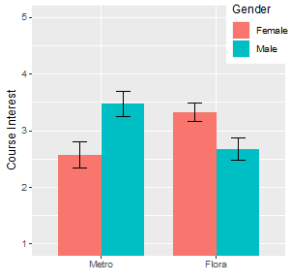


Figure 3. Course interest.

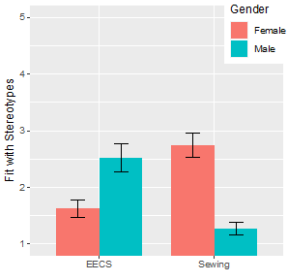


Figure 4. Fit with stereotypes.

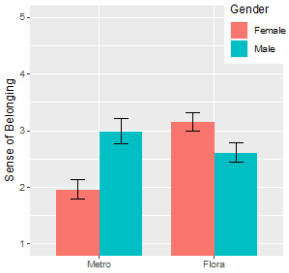


Figure 5. Sense of belonging.

Fit with stereotypes

A 2 × 2 ANOVA (gender × activity [sewing, EECS]) examining the relationships between gender and fit with stereotypes for sewing and EECS revealed a significant interaction between gender and activity, $F(1,80) = 37.95, p < 0.001$. Neither main effect was significant. A simple effects post-hoc analyses conducted using Tukey's HSD test found that men reported a higher fit with EECS stereotypes than women ($p < 0.01$), women reported a higher fit with sewing stereotypes than men ($p < 0.001$), men reported a higher fit with EECS stereotypes than with sewing stereotypes ($p < 0.001$), and that women reported a higher fit with sewing stereotypes than with EECS stereotypes ($p < 0.001$) (Figure 5).

Belonging

A two-way ANOVA examining the relationships between gender and sense of belonging for each course variant (Flora or Metro) revealed a significant interaction between gender and belonging, $F(1,80) = 17.93, p < 0.001$. The main effect for course variant was also significant, $F(1,1) = 4.08, p < 0.05$, indicating that participants felt a higher sense of belonging in the Flora course regardless of gender. The main effect for gender was not significant ($p = 0.20$). Post-hoc analyses corrected for multiple comparisons using Tukey's HSD indicated that women felt a significantly lower sense of belonging in the Metro course than men ($p < 0.01$), and that women felt a significantly higher sense of belonging in the Flora course than the Metro course ($p < 0.001$) (Figure 6).

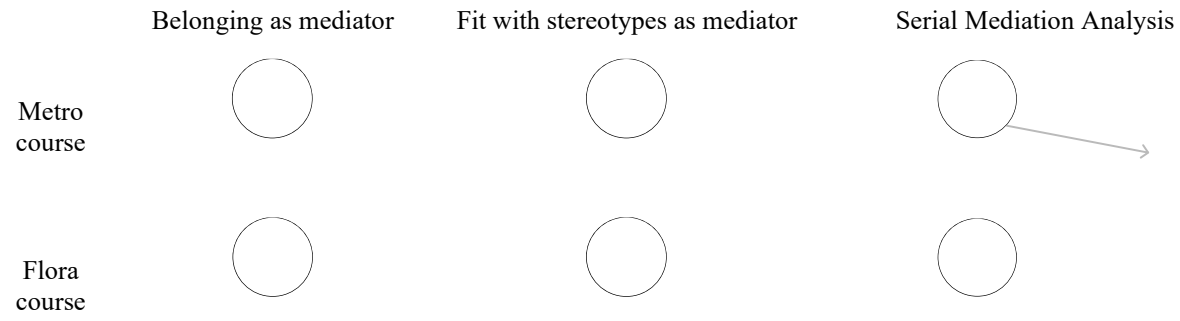
Simple and serial mediation analyses

Earlier we found that men were more interested in taking the Metro course and women were more interested in taking the Flora course. We conducted two simple mediation analyses to explore reasons for these differences. The mediators tested were sense of belonging and fit with stereotypes. In each course variant, both were found to fully mediate the relationship between gender and interest (see the first two columns of Table 1 for full details).

Because the simple mediation analysis uncovered two significant mediators between gender and course interest, the next step was to bring both mediators together in a serial mediation analysis to test if one factor was driving the other. The path of interest in both of these models was the indirect path through sense of belonging. If that path were to remain significant, it could be interpreted as indicating that one's sense of belonging is directly related to their gender. In the Flora course, this path was not significant. This meant that women and men who felt a similar fit with sewing stereotypes also felt the same sense of belonging. Thus, in the Flora course one's

gender did not directly affect their sense of belonging. However, in the Metro course this path remained significant. This meant that even when women felt the same fit with EECS stereotypes as men, they still felt a significantly lower sense of belonging (see the third column of Table 1 for full details).

Table 1: Black arrows indicate paths significant at $\alpha \leq 0.05$



Conclusion

In the Metro course, we found that women's lower interest was primarily due to a lower sense of belonging, and that even when women felt the same fit with EECS stereotypes as men, they still reported a lower sense of belonging than men. This was not the case in the Flora course. Men who felt the same fit with sewing stereotypes as women reported feeling a similar sense of belonging as women. In other words, women felt unwelcome in the Metro course simply because of their gender, but men did not feel unwelcome in the Flora course simply because of their gender.

Recall that the only differences between these two course descriptions were the names and images of the objects. This implies that the objects themselves were the source of the gender differences we observed. The prevailing explanation frames these gender differences in terms of attractive forces—generally, women are uninterested in working with traditional tools and materials; however, they are attracted to e-textiles because e-textiles are aligned with "historically feminine practices" (Buchholz et al., 2014). However, this hypothesis fails to fully explain our results, which provide evidence that gender differences are also driven by discriminatory, repulsive forces that primarily affect women. In other words, "standard" items are not neutral, but charged with meaning, and these items broadcast messages to women that they do not belong.

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