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**THINKING BEYOND THE DEFAULT USER: THE IMPACT OF GENDER AND STEREOTYPES
ON DESIGNERS' INTERPRETATION OF USERS AND THEIR NEEDS**

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ABSTRACT

Throughout the mechanical design process, designers, the majority of whom are men, often fail to consider the needs of women, resulting in consequences ranging from inconvenience to increase risk of death or serious injury. Although these biases are well-studied in other fields of research, the mechanical design field lacks formal investigation into this phenomenon. In this study, undergraduate engineering students ($n = 151$) took a survey in which they read a Persona describing a student makerspace employee and a Walkthrough describing their interaction with the makerspace while completing a project. During the Walkthrough, the user encountered various obstacles, or Pain Points. Participants were asked to recall and evaluate the Pain Points that the user encountered, then evaluated their perceptions of the makerspace and user. Six different experimental conditions were used to investigate the impact of gender-stereotyped tasks and the gender of a user on designers' interpretation of them and their needs. In addition to finding that the gender of a user impacted the way a task environment was perceived, results confirmed the presence of androcentrism, or "default man" assumptions, in the way designers view end users of unknown gender. Future work will explore methodologies of overcoming this bias so that designers are able to consider the diverse needs of a range of users.

Keywords: problem definition, user needs, stereotypes, gender bias

1. INTRODUCTION

Gender bias is defined in previous research as an "unintended but systematic neglect of either men or women" [1]. Implicit gender bias impacts the products and services available in the world today through its transfer from designer to product

throughout the design process. Because under 20% of engineers currently employed in the US are women [2], products created by engineers often fail to serve women as effectively as men. Design requires intentional consideration of peoples' behavior and needs, so a bias that leads designers to fail to consider a group of people can have a potentially disastrous impact on the excluded group. Women are more likely to be injured in a car crash [3] and less likely to receive and survive CPR [4] – both of these consequences stemming from the lack of testing and training on female-bodied dummies. Although there are well-documented and studied instances of the mechanisms and outcomes of gender bias outside the field of mechanical design [1], [5], [6], there is currently a gap in understanding when and how gender bias manifests in the mechanical design process. This work will explore the impact of gendered stereotypes and assumptions at early stages of the design process, specifically the problem definition phase.

2. RELATED WORK

2.1 User-Centered Design

Before a design can be developed into a tangible product for usage and testing, conceptual and embodiment, certain design phases must first take place [7]. The conceptual design phase begins with problem definition and customer need identification so that designers understand who their end users are and what unmet needs they have [8]. Customer needs are often explored through interviews, focus groups, complaints, and surveys [9].

Cook stoves make an excellent case study for failure to consider the end user in early stages of the design process. In South Asia, 75% of families use biomass fuels for energy [10]. When used indoors, biomass stoves create toxic fumes that are

responsible for 2.9 million deaths annually worldwide [11]. However, efforts to develop and implement improved cookstoves have low adoption rates because they lack basic design attributes that would meet the needs of users [12], causing an increase in cooking time and active attendance to the stove [3]. In this scenario, the problem was that stove designers, men located in the U.S., did not consult the Bangladeshi women who would be using the stove, instead prioritizing technical parameters in their design process. As a result, 98% of the population of rural Bangladesh continues to use traditional biofuel-burning stoves, despite hundreds of attempts to introduce cleaner stoves since the 1980s [3], [10].

As a counterexample, the Embrace baby incubator is an award-winning incubator designed for low-birth-weight babies in countries with less industrialized economies [13]. While designing this product, the design team traveled to rural Nepal to conduct their customer needfinding, where they found that an incubator would be useless to the users who needed it most if it was to run on electricity and be kept in a hospital. As a result, the Embrace incubator was developed to keep babies warm using a packet of phase-change material inside a type of sleeping bag that was designed for easy integration into local culture [14]. In this case, effective customer need identification promoted understanding between the designer and end user, resulting in a successful product. Nevertheless, incorporating the ‘voice of the consumer’ early in the design process remains rarely or poorly conducted [15], although experts engage more with this phase of the design process than novices do [16].

Designers must have empathy for users in order to be able to consider their diverse perspectives. In the design field, designers empathize more easily with others who are similar to them [17], [18], which presents a problem when engineers, who are over 80% men [2], create designs to be used by the general population, which is 50.5% women [19]. Although many customer needfinding methods double as empathy-building tools, such as user observations and interviews [20], designers’ inherent cognitive biases can inhibit the development of equitable designs, although this phenomenon is not well-studied in the field of mechanical design.

When an individual’s gender is not specified, people often default to an assumption of the individual as a man [3]. People generally associate generic labels such as *person* with men, while women are described by their gender-specific label [21]. This phenomenon of androcentrism may have come about as a result of men’s higher visibility throughout history, or the higher value placed on masculinity [22]. In the examples of poor design previously discussed, the “default man” becomes the “default user” when considering users’ needs, resulting in products that are not designed with equal considerations for women. Attempts to retarget the users as women, such as Bic’s ill-fated “Bic for Her” campaign [23], have come across as pandering, reducing customers to their gender and invoking categorization threat [24].

2.2 Bias in Makerspaces

Makerspaces provide an excellent case study for androcentrism in modern-designed spaces. Makerspaces are educational places where people gather to build knowledge and projects [25], often utilizing tools such as 3D printers, laser cutters, and hand tools. These tools are associated with a masculine stereotype [26], as confirmed by machine log data [27] and ethnographic studies [28]. Conversely, tools that are less-traditionally found in makerspaces, such as sewing machines, electronic textiles, and craft supplies are associated with feminine stereotypes [26]. The stereotyping of physical objects in makerspaces is important because physical cues, such as classroom decorations that carry a masculine stereotype, have been found to decrease women’s sense of belonging in an environment, causing them to be less interested in joining and more likely to leave a space [29].

Women’s sense of belonging in a space is also impacted by the other people in the space; they are less likely to want to participate in engineering conferences with unbalanced gender ratios [30]. Cues such as the gender-stereotyping of physical objects or the gender breakdown of an environment can trigger stereotype threat for women. Stereotype threat results from a fear of judgement based on negative stereotypes [31], and has previously been proven to cause women’s actual performance on STEM-related tests to suffer as they worry about fulfilling stereotypes about women in STEM [32]. Given the prevalence of both masculine-stereotyped equipment and an uneven gender balance in makerspaces, stereotype threat may impact the experience and performance of women in makerspaces. These perceptions may contribute to the difference in identity between men and women makers: while men are more likely to identify as “builders” or “engineers,” women are more likely to identify with less technical terms such as “crafters” or “artists” [33].

In addition to struggles resulting from stereotype threat, women in makerspaces may face additional physical barriers compared to men who use the space. Schauer et al. [28] found that problems in makerspaces can be more likely to disadvantage people of certain genders over others. Moreover, these issues tend to impact users who are breaking gender stereotypes in the space. For example, women using power tools for woodworking experience discomfort and put their safety at risk when using tools that are too large or heavy for them to easily maneuver, or when trying to use equipment that is too high off the ground. Conversely, men using sewing machines are often uncomfortable using machines on tables meant for someone smaller and shorter than themselves. These issues arise as a result of a lack of consideration between the designers of the space and the users. In this case, the designers of the woodworking area of the makerspace were men who failed to consider the unique needs of women users of the space, and the inverse trend was identified in the crafting area of the makerspace. These findings indicate that makerspaces may be a promising site to study biased and inequitable design practices.

2.3 Hypotheses

Based on existing literature, the field of mechanical design lacks investigation into how the gender-stereotyping of users, tasks, and spaces influence designers throughout the design process. This work will use makerspaces as a task domain to focus in on the customer need identification phase of the design process and answer the following research questions. Hypotheses have been formed by making connections to analogous literature from different fields.

RQ1: How do gender stereotypes and bias impact designers' recollection and interpretation of user needs?

In the medical field, gender bias has been identified in patient-clinician interactions, which may reflect the dynamic between users and designers. When assessing the pain of a patient, clinicians assess women's pain as lower than men's, and are more likely to attribute women's pain to psychological rather than medical problems [34]. Additionally, doctors who are aware of the gender of their patient are less able to recognize behavior or symptoms that are not stereotypically associated with that gender [35]. If these trends hold true in the field of mechanical design, it is hypothesized that designers will perceive men's customer needs as more urgent than women's, and will be more likely to attribute their problems to physical design issues rather than a lack of skill. We also predict that designers will recall fewer customer needs from users whose gender contradicts the stereotyping of the task they are performing or issues they are encountering.

RQ2: How do gender stereotypes and bias impact designers' interpretation of a task environment?

Because stereotype threat results in increased anxiety for users of a space [31], it is expected that conflict between the gender of a user and the gender-stereotyping of the environment may result in less favorable views of the space, just as women are less likely to want to be involved in a space with masculine-stereotyped indicators [29], [30]. Additionally, it is expected that previously-established differences in the way people view masculine- and feminine-stereotyped making activities [28] will result in perceptions of a crafting environment as more casual and fun than a woodworking environment.

RQ3: How do gender stereotypes and bias impact designers' perception of users?

Research into hiring practices indicates that gender bias exists in perceptions of job candidates. Multiple studies investigated gender bias in the hiring process for academic STEM positions and found that STEM faculty evaluated men as more competent than women candidates, even when candidate profiles were identical except for the gender [36], [37]. Similarly, men principal investigators (PIs) were more likely than women to have their proposal to use the Hubble Space Telescope accepted [38], although women's success rate increased when proposals were anonymized [39]. It is hypothesized that parallel trends will be observed in designers' evaluation of users, with men being viewed as performing tasks more competently than women. Additionally, because both men and women face social backlash when violating gender stereotypes [40], [41], it is expected that users who are performing stereotype-conforming

tasks will be viewed more favorably than those violating stereotypes.

3. MATERIALS AND METHODS

In order to answer the research questions, data was collected using a Qualtrics survey. First, participants read and agreed to a consent document. The study, including the consent procedure, was conducted under the guidance of the Institutional Review Board at the University of Wisconsin-Madison. After agreeing to participate in the study, participants proceeded to a page where they were instructed to read a profile of a fictional makerspace user (referred to as the Persona) and picture the user in their head as they read. Participants were then asked to imagine that the makerspace user was telling them about a project that they recently completed in the makerspace, and to read a three-paragraph passage (referred to as the Walkthrough) carefully. In the passage, the fictional user walked the reader through the process of completing a project, encountering either 10 or 11 obstacles, summarized in Table 1 along the way. The Walkthrough simulated information that a designer would receive while conducting user observations or interviews during the customer needfinding phase of the design process. The Walkthroughs and their development will be further discussed in the "Study Material Development" section of this paper.

After completing the readings, participants proceeded to the first of two main sections of the survey. In the first section, participants recalled and evaluated obstacles, or Pain Points that the user encountered in the Walkthrough. They were provided with text entry boxes and asked to list as many as they could recall. Then, the survey software presented each recalled Pain Point individually. For each obstacle listed, participants then evaluated its severity on a 1-5 Likert scale adapted from risk assessment practices [42], then assessed whether or not the problem should be addressed by selecting "yes" or "no." Participants who selected "yes" were also given the option to provide ideas for solutions. This process was repeated for every obstacle that the participant was able to recall.

In the second section of the survey, participants provided information about their perceptions of the fictional user and makerspace. First, they used a 1-5 scale to evaluate their perception of the makerspace in relation to 10 different adjective pairs, such as formal-casual and dangerous-safe. Next, participants used Likert scales to evaluate their view of the user's gender and experience level in the makerspace. They were then presented with a series of statements about the user and assessed their level of agreement with the statements on a 1-5 Likert scale. At the end of this section, participants were also asked whether they had been told the user's major or gender, and then asked to report what each was (or to guess if they weren't sure). Finally, participants filled out demographic information, including their age, gender identity, race/ethnicity, major, and progress towards their degree. They also evaluated their level of experience with working in makerspaces, woodworking, and crafting on a scale from 1 (novice) to 5 (expert).

TABLE 1: LIST OF PAIN POINTS INCLUDED IN EACH WALKTHROUGH

Pain Point	Wood Makerspace	Craft Makerspace	Gendered
1	Lathe chuck overtightened	Needle screw overtightened	Yes (strength)
2	18V drills too large to use with one hand	Needle hole small compared to hand (difficult to thread)	Yes (hand size)
3	Disposable gloves are a size large	Scissors are too small for fingers	Yes (hand size)
4	Miter saw is on tall table (awkward to use)	Sewing machine is on short table (tired, went home)	Yes (body size)
5	People forget to put away the clamps	People forget to put away the sharpie	No
6	Someone left sawdust and wood chips everywhere	Someone left threads everywhere	No
7	Someone squeezed through aisle and bumped user (bumped e-stop)	Someone squeezed through aisle and bumped user (crooked stitches)	No
8	Wood scraps too small to be useful	Vinyl scraps too small to be useful	No
9	Digging through the unlabeled cabinets looking for drill	Digging through the unlabeled cabinets looking for scissors	No
10	Trash bag is ripped	Sewing needle is broken	No
11	N/A	Scissors are dull	No

3.1 Study Material Development

In order to address the research questions, the gender of the Persona, as well as the activity performed in the Walkthrough, were treated as independent variables. The Persona was written in third-person perspective, using either feminine (she/her), masculine (he/him), or gender-neutral (they/them) pronouns to refer to the user. There were two versions of the Walkthrough: one in which the user was making a pen in a woodworking-focused area of the makerspace, and one in which the user was making a hat with an iron-on logo in a crafting-focused area of the makerspace. The full text of the Walkthroughs can be found in the Appendix. With three different Personas and two different Walkthroughs, participants were randomly assigned to one of the six unique experimental conditions upon beginning the survey. The Pain Points included in the Walkthroughs were adapted from the list of common makerspace problems developed by Schauer et al. [28]. The procedures in the Walkthroughs were developed based on discussion of commonly seen projects from the same series of ethnographic interviews. Efforts were made to keep the Pain Points as analogous to each other as possible, and to keep the number of Pain Points even. Schauer et al. [28] found that many problems encountered in makerspaces had a tendency to impact people of various genders differently. For example, while disposable gloves in the Wood Shop were often too large for women users, scissors in the Craft Area were too small for some men's larger fingers. Four Pain Points with potentially "gendered" effects were included in each Walkthrough, keeping the two conditions as similar to each other as possible while also accurately representing problems in actual makerspaces. Table 1 contains a description of the Pain Points from each Walkthrough, including their designation as potentially gendered or not.

Because reading times varied drastically during piloting, participants' time to read the Persona and Walkthrough passages

was not limited. Throughout the survey, participants were not able to go back to previous questions once they had progressed to the next in order to accurately gauge participants' assumptions and unbiased first impressions. Likert scale questions used to assess the participants' perceptions of the user were developed based on prior work used to assess self-efficacy [37], [43] and perceptions of STEM participants [44]. In the following Results & Discussion section of this paper, the "competency metric" developed by Moss-Racusin et al. [37] and adapted by Schauer et al. [44] was calculated for each participant by averaging together their perceptions of how "qualified" and "competent" the user was.

The survey utilized an attention check to ensure that responses were of high quality. After reading the passages, participants were asked to briefly describe the task that the user was trying to accomplish. If a participant did not provide the correct answer, their response was eliminated from the data set. Two participants' responses were removed for this reason. Two additional responses were eliminated because participants had accidentally progressed through the survey without reading the persona and walkthrough passages, leaving 151 responses for analysis, which were divided into the six experimental conditions as shown in Table 2.

TABLE 2: BREAKDOWN OF NUMBER OF PARTICIPANTS IN EACH EXPERIMENTAL CONDITION

	Feminine Persona	Neutral Persona	Masculine Persona
Wood Walkthrough	26	26	26
Craft Walkthrough	26	23	24

3.2 Participants

Undergraduate student email lists were used to distribute the survey to mechanical and biomedical engineering majors at a large, public, Midwestern university. These majors were selected for recruitment due to the higher likelihood of participants having some familiarity with the tools and processes discussed in the Walkthroughs. Participants were paid \$15 for completing the survey, which took an average of 13 minutes to complete. Efforts were made to recruit a balanced ratio of men and women for the experiment by recruiting from biomedical engineering, a major with near-gender-parity at the university, in addition to mechanical engineering. As a result, 64 participants identified as women, 83 as men, and 4 as non-binary. The median participant was 20 years old and had completed two years of their undergraduate engineering education. Of participants who reported their race, 108 were White, 23 were Asian, Native Hawaiian, or Other Pacific Islander, 4 were Hispanic or Latino, 1 was Native American, and 12 identified as more than one race. When asked to evaluate their level of experience as novice, beginner, proficient, advanced, or expert (corresponding to a scale from 1-5), participants reported average experience levels of 2.45 working in makerspaces, 2.14 in woodworking, and 2.67 in crafting.

4. RESULTS AND DISCUSSION

In accordance with the research questions, the independent variables studied during data analysis were the Persona gender, Walkthrough room case, and the gender of the participant. With the application of the Central Limit Theorem for sufficient sample sizes, ANOVA statistical testing was conducted in RStudio version 2021.09.2 to check for significance and interactions between these variables

4.1 Pain Points

Because Pain Points were reported by participants as free responses, coding was conducted to standardize responses. Two independent judges (authors Schauer and Schaufel of this paper) used the categorizations in Table 1 to code 25% of the participants' Pain Point responses. Because they achieved a sufficient Cohen's Kappa of 0.863, the remainder of the data was coded by Schaufel.

First, ANOVA was used with the number of recalled Pain Points as the dependent variable. Results showed that neither the Persona gender, Walkthrough room case, nor participant gender has a significant impact on the number of Pain Points recalled. When isolating Pain Points with a gendered impact, there was again no significant influence of Walkthrough room case or Persona/participant gender. However, isolating the analysis to general Pain Points (ones with no gendered impact), it was found that participants who read the feminine Persona case and Craft Walkthrough (mean = 0.412) recalled fewer Pain Points than those who read the neutral Persona case and Craft Walkthrough (mean = 0.565, $p = 0.043$).

Next, ANOVA was used to analyze participants' perceptions of the severity of each Pain Point. First, an aggregate Pain Point

severity score was developed by calculating the average of every severity rating assigned by each participant, and ANOVA revealed that the gender of the Persona impacted the perceived severity of the problems the user encountered. Problems encountered by women were assessed as more severe (mean = 2.887) than problems encountered by the man Persona (mean = 2.650, $p = 0.045$) or the gender-neutral Persona (mean = 2.564, $p = 0.024$). This contradicts the hypothesis that men's problems would be taken more seriously than women's, and may result from "protective paternalism" treatment towards women in STEM fields [45].

Investigating each Pain Point individually, there was a significant impact of the Walkthrough room case on the perceived severity of Pain Points 2, 3, 7, and 10, which related to the size of the drill/needle hole, size of the gloves/scissors, being bumped by another person in the aisle, and the broken trash bag/sewing needle, respectively. For Pain Points 2, 3, and 7, participants rated the Pain Point from the Wood Walkthrough room case (mean = 2.667, mean = 2.700, mean = 3.520, respectively) as more severe than the Craft Walkthrough room case (mean = 1.632, $p = 0.001$; mean = 2.111, $p = 0.009$; mean = 2.932, $p = 0.013$; respectively). Conversely, participants rated Pain Point 10 from the Craft Walkthrough (mean = 3.103) as more severe than the Wood Walkthrough (mean = 2.044, $p < 0.001$). This aligns with trends identified by Schauer et al. [28] of woodworking-focused makerspaces generally being viewed as more serious and dangerous spaces than crafting-focused makerspaces.

4.2 Makerspace Perceptions

In the next part of the survey, participants used a 1-5 scale with antonymic adjectives on each side to evaluate various aspects of the makerspace in the Walkthrough. In order to reduce bias towards positively- or negatively-connotated words, the order in which adjectives on the scale were presented was varied. ANOVA testing was conducted using the scale ratings as the dependent variable, with the Persona gender, Walkthrough room case, and participant gender as the independent variables. On a spectrum from Dangerous to Safe, participants ranked the makerspace from the Craft Walkthrough (mean = 3.425) as safer than the makerspace from the Wood Walkthrough (mean = 2.872, $p = 0.001$). Similarly, they ranked the makerspace from the Wood Walkthrough (mean = 3.077) as more serious than the Craft Walkthrough (mean = 2.575) on a spectrum from Lighthearted to Serious ($p = 0.001$). The gender of the Persona also impacted the way participants viewed the makerspace itself. On a spectrum from Boring to Fun, participants considered the makerspace more fun when the user was a woman (mean = 3.962), rather than gender-neutral (mean = 3.510, $p = 0.045$). The remainder of the adjective-pair scale ratings were not significantly impacted by the independent variables, potentially due to differences in the way participants interpreted the adjectives given a lack of definition or context.

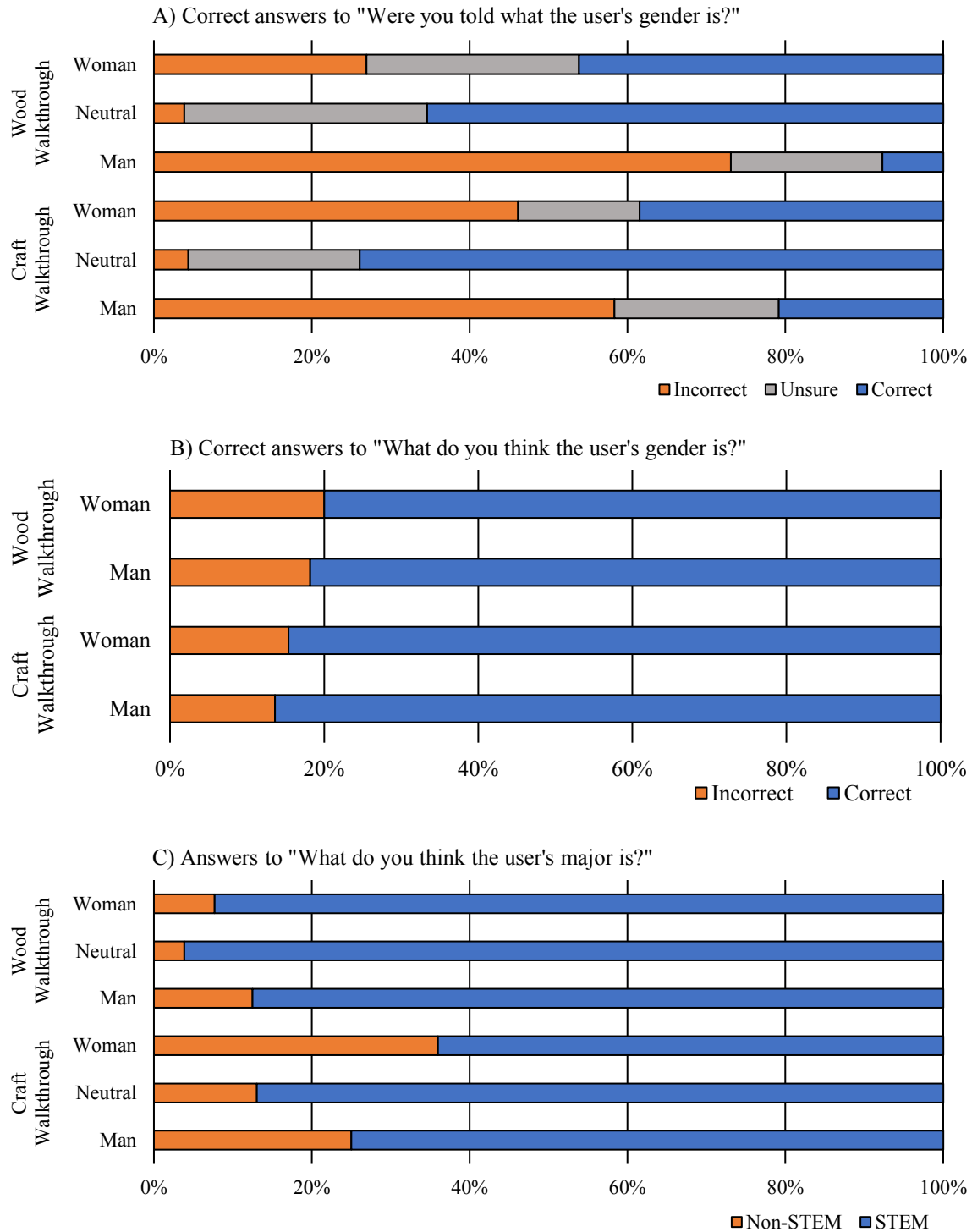


FIGURE 1: BREAKDOWN OF PARTICIPANT RESPONSES TO A) WHETHER THEY WERE TOLD THE GENDER OF THE USER, B) THEIR PERCEPTION OF THE USER'S GENDER, AND C) ASSUMPTION OF WHETHER USER IS A STEM OR NON-STEM MAJOR

4.3 User Perceptions

In the last part of the survey, participants provided information about the assumptions and perceptions they had of the user in the Persona. First, participants evaluated their interpretation of the user's gender expression using a Likert scale where 1 corresponded to "feminine" and 5 corresponded to "masculine." Both the man (mean = 3.480, $p < 0.001$) and the gender-neutral (mean = 3.306, $p < 0.001$) Personas were viewed as significantly more masculine than the woman Persona (mean = 2.442), as shown in Fig. 2. There was no significant difference in the perceived masculinity of the man and gender-neutral Persona cases ($p = 0.407$). These results were unaffected by the Walkthrough room case.



FIGURE 2: PERCEPTION OF THE GENDER OF MAN, NEUTRAL, OR WOMAN USER PERSONA COMPLETING A CRAFT OR WOOD MAKERSPACE WALKTHROUGH. HIGHER VALUES INDICATE MORE MASCULINE PERCEPTION; ERROR BARS INDICATE ± 1 SE.

In addition to showing that androcentrism is present in designers' views of users, this result most interestingly shows that this assumption is not impacted by the user performing a feminine-stereotyped task, such as using a sewing machine and crafting equipment. Participants were also asked to recall whether or not they were told the gender of the user from the Persona. As shown in Fig. 1a, participants who were given the gender-neutral Persona were generally able to correctly recall that they had not been told the gender of the user. However, participants who read the Persona with masculine or feminine pronouns were much more likely to incorrectly recall that they had not been told the gender of the user. In particular, over half of participants who read the man Persona did not believe that they had been told the gender of the user. However, as shown in Fig. 1b, when participants were asked to guess the gender of the user, over 80% of guesses were correct for each experimental case, showing that although participants did not consciously recall the user's gender, their assumptions, potentially based on unconscious recall, were correct.

Next, participants evaluated the skill level of the user. Regardless of Persona gender, participants viewed the user from the Craft Walkthrough (mean = 3.795) as more skilled than the user from the Wood Walkthrough (mean = 3.564, $p = 0.048$).

Interestingly, when asked to predict the user's undergraduate major, there was a statistically significant difference ($p = 0.007$) in the percentage of participants who predicted that the Wood Walkthrough user (92%) was a STEM major compared to the Craft Walkthrough user (75%), as shown broken down into all six experimental conditions in Fig. 1c.

Finally, participants used Likert scales to indicate their level of agreement with various statements about the user in the Persona. The gender of the participant and Persona, as well as the Walkthrough room case, impacted the way the participants viewed the user. Participants who read the Craft Walkthrough (mean = 2.877) viewed the user as physically larger compared to perceptions of the user from the Wood Walkthrough (mean = 2.500, $p = 0.008$), although there was no significant difference in the perceived physical strength of the users ($p = 0.225$). These perceptions aligned with information given by the Pain Points, rather than in the gender-stereotyping of the space. In the Craft Walkthrough, three of the gendered Pain Points occurred as a result of equipment being undersized for the user's hands and body, while three of the gendered Pain Points in the Wood Walkthrough resulted from oversized equipment. These differences appear to have resulted in the different perceptions of the user's physical size. The fourth gendered Pain Point was similar in both Walkthrough cases – a rotating element was overtightened, and the user did not have the physical strength to loosen it. This lack of physical strength was consistent across the Walkthroughs and corresponds to the lack of difference in perceived strength by participants. Additionally, the user from the Craft Walkthrough (mean = 4.458) was viewed as more confident compared to perceptions of the user from the Wood Walkthrough (mean = 3.962), but only when considering Walkthroughs accompanied by the man Persona ($p = 0.018$).

Perceptions of the user also varied based on their gender in the Persona. Women users (mean = 4.269) were viewed as more creative than men (mean = 3.900, $p = 0.036$) and as having more fun (mean = 3.635) than the gender-neutral Persona (mean = 3.163, $p = 0.038$). This aligns with stereotyping of women as more casual, creative makers than men [28], [46]. Finally, the gender of the participant impacted how they viewed the user. Men (mean = 2.458) viewed the user as more emotional than women did (mean = 1.984, $p = 0.026$), but were also more likely than women (mean = 4.000) to think that user's complaints were legitimate (mean = 4.373, $p = 0.040$). Focusing on women participants revealed that women viewed complaints from the user in the Wood Walkthrough (mean = 4.357) as more legitimate than complaints from the user in the Craft Walkthrough (mean = 3.722, $p = 0.008$).

5. LIMITATIONS AND FUTURE WORK

One of the main findings of this study was that participants utilized the androcentric "default man" assumption of the user's gender, even if the user was performing feminine-stereotyped tasks or encountering problems typically experienced by women. Research in other fields shows that feminine-stereotyped priming must be overt in order to overcome the "default man" assumption [47]. For the design field, future work is needed to

explore methodologies for helping designers overcome the “default man” assumption, and create designs with all users in mind. Each Walkthrough case of this study provided information that had the potential to prime the participants towards different assumptions. As indicated by previous literature [28], the task and environment from the Craft Walkthrough was associated with a feminine stereotype, while the Wood Walkthrough was associated with a masculine stereotype. However, three out of the four gendered Pain Points in each Walkthrough were primarily associated with the opposite gender; the Pain Points from the Wood Walkthrough were more likely to impact women due to their smaller average size, while the Pain Points from the Craft Walkthrough were more likely to impact men due to their larger average size. Although this scenario was set up to reflect real-world trends, the conflicting stereotypes in the Walkthroughs may have led to confusion and unexpected results related to participants’ perceptions and assumptions about the user in the Persona.

The written format for the Persona and Walkthrough was selected over more immersive setups, such as listening to an audio passage or listening to a script read by the researcher, in order to isolate the variables of interest and avoid influence from sources of bias such as the perceived race, attractiveness, accent, or gender expression of the speaker. Due to this format, Pain Points recalled by participants may have been impacted by variation in natural recall ability, as well as primacy or recency bias [48]. Although prior work [35] has validated the ability of communication performed solely in written form to produce gender bias, additional visual cues of the Persona or makerspace may have impacted participants’ perception of stereotype threat in the scenario. This study design is currently in the process of being repeated with an audio passage Persona and Walkthrough in order to study bias formation in differing modalities.

Finally, the results of this survey may have been impacted by demographic limitations. Although four participants who identified as non-binary were recruited, this sample size was insufficient to draw any statistically significant conclusions on. As a result, the analysis in this work was fairly limited to the gender binary, rather than the proper representation of gender as a spectrum [49]. In the future, efforts should be made, particularly in studies similar to this one, to target non-binary participants in recruitment so that they will be well-represented in data analysis. Interestingly, when guessing the gender of the user in the Persona at the end of the study, all participants who filled in a guess filled in either “man” or “woman” – even non-binary participants and participants who read the Persona that used they/them pronouns, showing that participants were also susceptible to the erroneous gender binary interpretation. Additionally, recruitment in this study suffered from a lack of racial diversity. Although demographics were generally reflective of the university at which the study was conducted, very few underrepresented minority groups were included in this study. Expanding recruitment to multiple institutions, to engineering graduate students, or to engineers who have completed their education may be necessary in order to draw conclusions based on diverse perspectives.

6. CONCLUSION

As a result of the analysis discussed above, this paper has answered the following research questions, filling established gaps in literature.

RQ1: How do gender stereotypes and bias impact designers’ recollection and interpretation of user needs?

The results of this study mostly contradicted the hypothesis related to this research question. There was little correlation between gender-stereotyping and the number of Pain Points recalled. However, fewer Pain Points from the craft Walkthrough were recalled when they were associated with a woman Persona. Because many of the Pain Points in the craft Walkthrough were associated with men’s typically larger body sizes, this mismatch in expectations may have caused Pain Point recall difficulty, reflecting clinicians’ struggle to recognize non-stereotype-conforming symptoms [35]. Additionally, the finding that women’s problems were assessed as more severe than men’s contradicted the hypothesis, and may be attributable to protective paternalism [45].

RQ2: How do gender stereotypes and bias impact designers’ interpretation of a task environment?

Contrary to the hypothesis, there was no relationship between participants’ perception of the space and the alignment of the stereotyping of the Persona gender and Walkthrough room case. It is possible that the user gender was communicated too subtly – by pronoun usage rather than explicitly – to have a significant interaction with existing stereotyping of the makerspace areas, which appeared to dominate the assumptions of users in this study. Notably, this study did find that the gender of a user completing a task impacted the way the task environment was perceived, as makerspaces being used by women were viewed as more fun, regardless of the task being performed.

RQ3: How do gender stereotypes and bias impact designers’ perception of users?

The results of this study showed no significant difference in the assessed competence levels of makerspace users based on their gender. However, perceptions of women users as more creative and having more fun supported expected trends based on stereotypes. Finally, this study confirmed the strong presence of androcentric assumptions about users in the mechanical design process. Participants who read a gender-neutral Persona assessed the gender of the user in a similar way to assessments of a man Persona. Interestingly, this association was not impacted by the gender-stereotyping of the task that a user was performing, even when performing feminine-stereotyped tasks. This shows that significant priming or mental conditioning may be needed to urge designers to think of their end users in an equitable, gender-neutral way.

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APPENDIX

Wood Walkthrough

Recently, I made a pen in the campus makerspace. First, I bought a wooden blank rod at the store and found a cool design from the internet. Once I got to the makerspace, I started by using the miter saw to cut the blank into two pieces of wood to the length I needed. The miter saw is a bit uncomfortable to use since it's on such a tall table, but it was the best option. I grabbed the extra piece I'd cut from the blank and added it to the scrap bin for someone else to use since I didn't need the rest of it. While I was at the scrap bin, I saw that there were a bunch of wood scraps that were too small to be useful to anyone, so I moved them to the trash can. I noticed that the trash bag was ripped, so I took the trash outside to the dumpster and replaced the bag.

Now that I was back, I had the wood pieces cut to the right length, so I needed to drill a hole through each of the pieces of wood to put the pen tube and cartridge in. The only hand drills that were out on display were 18V drills, which are too big for me to use with one hand, so I dug through the unlabeled cabinets until I found the smaller 12V hand drill. Then, I had to hunt down a clamp, since people always forget to put them away. After clamping, measuring, and drilling the holes, I prepared the epoxy mixture. I fumbled with it a bit because the only disposable gloves in the wood shop were a size large, but I managed to get the pen hardware installed and epoxied. I had to wait 24 hours for the epoxy to cure, so I decided to clean up and head home for the day.

The next day, I went back into the makerspace to finish my project. I brought my supplies over to the lathe and as usual, someone had left it covered in sawdust and wood chips. I spent a few minutes cleaning up after them; then, I grabbed a pair of pliers to loosen the chuck on the lathe – whoever used it before me must have tightened it too much. Then, I was able to load my stock into the lathe and begin turning it. At one point, I had to restart the lathe because someone squeezed through the aisle behind me to use the belt sander, which made me bump the emergency stop button. Once I got started again, I was able to easily finish turning the pen. Now that I had it in the shape I wanted, I used some sandpaper to buff and polish it. I was able to easily restart the lathe, finish the buffing, and put the pen together.

Craft Walkthrough

Recently, I made a hat with a logo in the campus makerspace. First, I bought a yard of canvas at the store and found a cool pattern from the internet. Once I got to the makerspace, I started by tracing out my pattern with a sharpie and then cutting the canvas. I had to hunt down a sharpie, since people always forget to put them away. The first scissors I found were too small for my fingers, so I dug through the unlabeled cabinets until I found a larger pair. I think that the people before me were using the scissors on non-fabric materials again because they were very dull. After I was done cutting, I pinned everything together and dug through the thread cabinet until I found a white spool of thread. I sat down at the sewing machine and as usual, someone had left threads lying everywhere. I spent a few minutes cleaning up after them; then, I realized the sewing needle was broken, so I needed to change it out for a new one.

I started by loosening the screw that holds the needle in place. I had to use a pair of pliers because whoever used it before me must have tightened it too much. Then, I was able to load the new needle and thread into the machine. It took me a while to get the thread through the needle because the hole in the needle is so small compared to my hand. Once I had the bobbin threaded, I was able to start sewing. At one point, someone squeezed through the aisle behind me and bumped my chair, so I had to take out a few stitches that ended up crooked. Once I got started again, I was able to easily finish sewing up the hat. Next, I needed to make the iron-on sticker for the front of the hat, but I was tired from hunching over the low table that the sewing machine was on, so I decided to clean up and head home for the day.

The next day, I went back into the makerspace to finish my project. I brought my supplies over to the vinyl cutter and downloaded the logo design from the internet to the vinyl cutter computer. In the software program, I resized it and traced it to make individual shapes from the design. I loaded my heat transfer vinyl onto the mat, then when the cut was done, I used a weeding tool to peel away the scrap vinyl and added some of the bigger pieces to our vinyl scrap bin. While I was at the scrap bin, I saw that there were a bunch of vinyl scraps that were too small to be useful to anyone, so I moved them into the trash. I used transfer tape to pull the sticker off the backing and was able to finish my hat by ironing the sticker on the front.