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Thinking Beyond the Default User: The Impact of Gender, Stereotypes, and Modality on Interpretation of User Needs

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 increased risk of serious injury or death. Although these biases are well studied in other fields of research, the mechanical design field lacks formal investigation into this phenomenon. In this study, engineering students ($n = 301$) took a survey in which they read a Persona describing a student makerspace user and a Walkthrough describing the user's 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 and then evaluated their perceptions of the makerspace and user. The independent variables under investigation were the gender of the user Persona (woman, gender-neutral, or man), the Walkthrough room case (crafting or woodworking makerspace), and the modality of the Persona and Walkthrough (text- or audio-based). Results showed that participants from the Text-based modality were better able to recall Pain Points compared to participants from the Audio-based modality. Pain Points were assessed as more severe when they impacted women users, potentially stemming from protective paternalism. 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. Promisingly, providing user Persona information in an audio modality significantly reduced this bias compared to text-based modalities, indicating that providing richer detail in user personas has the capability to reduce gender bias in designers. [DOI: 10.1115/1.4064263]

Keywords: cognitive-based design, conceptual design, design process, design theory and methodology, user-centered design

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 United States 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. Compared to men, women are more likely to be injured in a car crash [3] and less likely to receive and survive cardiopulmonary resuscitation (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

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understanding when and how gender bias manifests in the mechanical design process. Academic makerspaces, a common setting in which engineering design work is performed, have been previously identified as disadvantaging some users, particularly women, through their physical design features [7]. This work will explore the impact of gendered stereotypes and assumptions at the early stages of the design process in an academic makerspace task environment.

2 Related Work

2.1 Empathy in 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 [8]. 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 [9]. Customer needs are often explored through interviews, focus groups, complaints, and surveys [10].

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 [11,12], 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 [13]. Empathy can be built between the designer and user by establishing direct contact—designers may consider observing users performing tasks, interviewing users directly, or immersing themselves in the user's environment [14]. Another opportunity for empathic design arises when communicating the problem to the design team. Narrative techniques, such as storytelling, have been found to motivate engagement and originality in student designers [15]. Personas, or fictional representations of users, can be used to depict the perspective of the user and allow the designer to place themselves in users' shoes [16,17] and better consider their emotions while designing [18]. Visser and Stappers [19] found that personas with more visual detail stimulate more empathy and a deeper view of users' needs; however, the field lacks formal comparisons of the effectiveness of different persona modalities. Outside of personas, audio passages have been found to more effectively stimulate feelings of empathy compared to textual narratives [20]. Additionally, the length and complexity of text have been found to impact the effectiveness of information delivery [21]. Spoken words may promote better memory for shorter texts [22,23], but written text modality has been shown to benefit the recall of more complex information [24,25]. Comprehension of audio passages can also be impacted by perceived speaker gender; people find it easier to process gender-stereotype-adhering voices [26], as well as being more likely to trust a stereotypically male voice [27].

Although empathy tools may be integrated into customer need-finding methods, such as the aforementioned user observations and interviews [14], 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 labels [28]. This association is reinforced by the usage of "false universal" terms, such as *mankind* and *fireman*, in the English language [29]. This phenomenon of androcentrism, or the centering of society around men, may have come about as a result of men's higher visibility throughout history, or the higher value placed on masculinity [30]. As a result, both men and women assign a masculine association to words commonly used in the design field, such as *user*, *participant*, *person*, *designer*, and *researcher* [31]. This view of a "default user" as a "default man" when considering users' needs can result in products that are not designed with equal consideration for women. Attempts to retarget the users as women, such as Bic's ill-fated "Bic for Her" campaign [32], where "sleek" pens in pastel colors were marketed toward women, have come across as pandering, reducing customers to their gender and invoking categorization threat [33].

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 [34], often utilizing tools such as 3D printers, laser cutters, and hand tools. These tools are associated with a masculine stereotype [35], as confirmed by machine log data [36] and ethnographic studies [7]. Conversely, tools that are less traditionally found in makerspaces, such as sewing machines, electronic textiles, and craft supplies, are associated with feminine stereotypes [35]. 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 [37].

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 [38]. Cues such as the gender-stereotyping of physical objects or the gender breakdown of an environment can trigger stereotype threats for women. Stereotype threat results from a fear of judgment based on negative stereotypes [39] 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 [40]. 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" [41].

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. [7] 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 [7]. 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.

3 Analogous Findings From Other Fields

Although there has been little experimental work conducted on gender bias in engineering design, case studies from other fields may serve as analogies for hypothesis formation. In the medical field, gender bias has been identified and investigated 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 [42]. Additionally, doctors who are aware of the gender of their patients are less able to recognize behavior or symptoms that are not stereotypically associated with that gender [1].

Table 1 List of Pain Points included in each Walkthrough

Pain point	Wood walkthrough	Craft walkthrough	Gendered
1	Lathe chuck overtightened	Needle screw overtightened	Yes (strength)
2	18 V 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	Had to wait for epoxy to cure	Scissors are dull	No

Research into hiring practices indicates that gender bias exists in perceptions of job candidates. Multiple studies have 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 gender [43,44]. Similarly, men principal investigators (PIs) were more likely than women to have their proposal to use the Hubble Space Station Telescope accepted [45], although women's success rate increased when proposals were anonymized [46].

4 Research Questions and 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 on the customer need identification phase of the design process and investigate the following research questions. In order to expand the body of work on user personas, this work also utilizes text- and audio-based modalities to compare their impact on the dependent variables. Hypotheses have been formed by making connections to analogous literature from various fields.

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

If trends from the medical field 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 (H1A). We also anticipate 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 (H1B). Based on literature comparing recall ability for information presented in text and audio formats [24,25], it is hypothesized that participants will recall a higher number of customer needs when information is presented in a written text modality compared to an audio modality (H1C).

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

Because stereotype threat results in increased anxiety for users of a space [39], 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 (H2A), just as women are less likely to want to be involved in a space with masculine-stereotyped indicators [37,38]. Additionally, it is expected that previously established differences in the way people view masculine- and feminine-stereotyped-making activities [7] will result in perceptions of a crafting environment as more casual and fun than a woodworking environment (H2B). Finally, it is hypothesized based on narrative persuasion research [20] that participants will display a more favorable view of the makerspace environment when information is presented in the audio modality (H2C).

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

It is hypothesized that trends observed in designers' evaluation of users will parallel those documented in STEM hiring practices, with men being viewed as performing tasks more competently than women (H3A). Additionally, because both men and women face social backlash when violating gender stereotypes [47,48], it is expected that users who are performing stereotype-conforming tasks will be viewed more favorably than those violating stereotypes (H3B). Similarly to H2C, it is hypothesized that participants will display more empathy and a more favorable view of users when information is presented in the audio modality (H3C).

5 Materials and Methods

In order to answer the research questions, data were collected using a Qualtrics survey, the full version of which is available from the corresponding author upon request. 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 or listen to a profile of a fictional makerspace user (referred to as the Persona) and picture the user in their head as they read or listened. 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 or listen to 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 11 obstacles along the way, summarized in Table 1. 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 are further discussed in the "Study Material Development" section of this paper.

After the Persona and Walkthrough, 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 [49] and 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

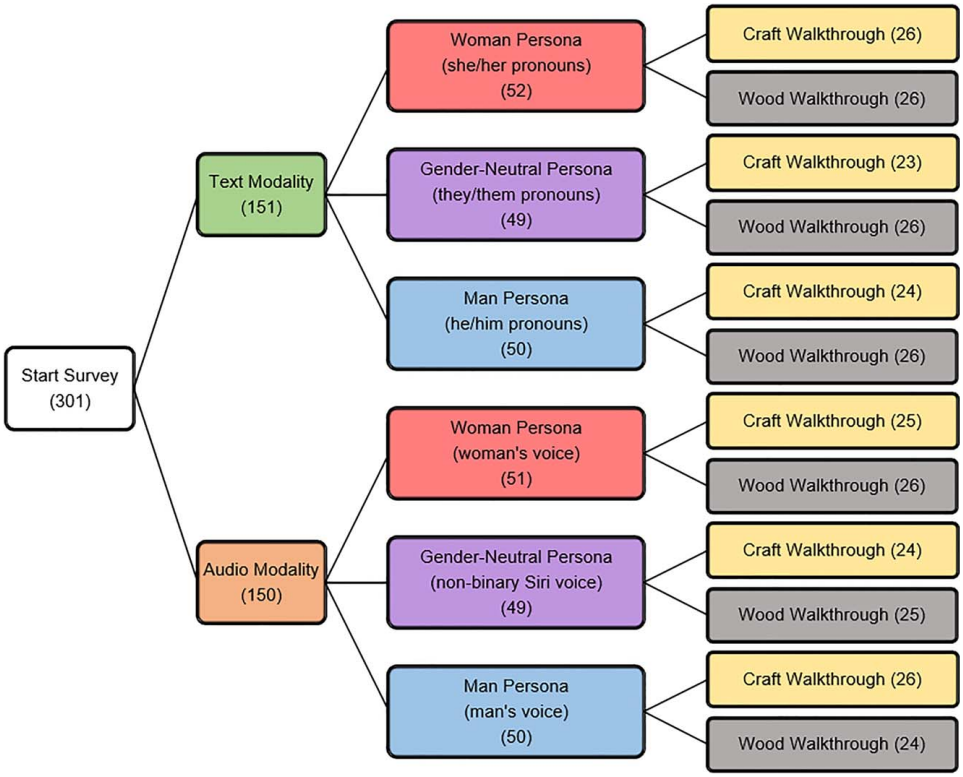

Fig. 1 Division of participants into experimental conditions based on Modality, Persona gender, and Walkthrough room case. Numbers in parentheses indicate the number of participants in each condition.

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 toward 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).

6 Study Material Development

In order to address the research questions, the gender of the Persona and the activity performed in the Walkthrough were treated as independent variables. In the Text modality, the Persona was written in the third-person perspective, using either feminine (she/her), masculine (he/him), or gender-neutral (they/them) pronouns to refer to the user. In the Audio modality, the Persona was written in first-person perceptive and was recorded using one of three voices: a cisgender woman (author Schauer), cisgender man (author Kohls), and Apple's gender-neutral "Quinn" Siri voice. In the Audio modality, the Persona used the following script:

I am a 22-year-old fourth-year undergraduate student. I am a student Teaching Assistant (TA) for a hands-on "making" course in my university's makerspace. My favorite part of the TA job is helping people who are new to the space make projects and discover their capability for making. Between classes, I sometimes use the makerspace in my free time to work on personal projects.

The Walkthrough text was identical for both modalities and was written in first-person perspective. 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. A visualization of the experimental conditions can be viewed in Fig. 1.

The Pain Points included in the Walkthroughs were adapted from the list of common makerspace problems developed by Schauer et al. [7]. The procedures in the Walkthroughs were developed based on a 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. [7] 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 for the Text modality varied drastically during piloting, participants' time to read the Persona and Walkthrough passages and respond to the questions was not limited. In the Audio modality, participants were unable to proceed to the

next page until the duration of the audio recording had elapsed. Throughout the entire survey, participants were not able to access the Personas or Walkthroughs or return to previous questions once they had progressed to the next in order to accurately gauge participants' assumptions and unbiased first impressions.

To describe their perceptions of the makerspace, 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 randomized. The adjectives in this section were inspired by student makerspace employees' descriptions of an academic makerspace in the interviews conducted by Schauer et al. [7] Likert scale questions used to assess the participants' perceptions of the user were developed based on prior work used to assess self-efficacy [44,50] and perceptions of STEM participants [51].

7 Data Analysis

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. Three additional responses were eliminated because participants had accidentally progressed through the survey without reading the Persona and Walkthrough passages, leaving 301 responses for analysis, which were divided nearly evenly into the experimental conditions, as indicated by the numbers in parentheses in Fig. 1.

Because Pain Points were reported by participants as free responses, coding was conducted to standardize responses. Coding for the Text and Audio modality data was conducted separately, at the time that each of the two datasets were collected. For the data collected in the Text modality, two independent judges (authors Schauer and Schaufel) 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 a single judge (Schaufel). For the data collected in the Audio modality, authors Schauer and Kohls achieved a sufficient Cohen's Kappa of 0.902 on 25% of the data, allowing Schauer to code the remainder of the data.

In accordance with the research questions, the independent variables studied during data analysis were the Persona gender, Walkthrough room case, and the study modality. 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. When statistically significant trends were identified by ANOVA, Dunn's test was used to perform multiple pairwise comparisons [52].

8 Participants

The online subject recruitment site Prolific [53] and undergraduate student email lists at a large, public, Midwestern United States university were used to distribute the survey to 301 undergraduate- and graduate-level engineering students. Participants were paid $15 for completing the survey, which took an average of 13 min to complete. Efforts were made to recruit a balanced ratio of men and women for the experiment by focusing recruitment on biomedical engineering, a major with near-gender-parity at the university, in addition to other engineering majors. As a result, 137 participants identified as women, 156 as men, and 7 as non-binary. The average participant was 23 years old (±7.5 SD) and had completed two years of their undergraduate engineering education. Of participants who reported their race, 181 were White, 55 were Asian, Native Hawaiian, or Other Pacific Islander, 15 were Hispanic or Latino, 14 were Black or African-American, 1 was Native American, and 29 identified as more than one race. When asked

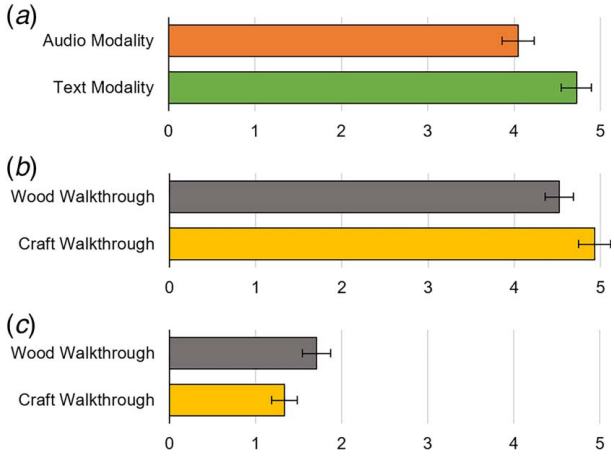

Fig. 2 Number of Pain Points recalled based on (*a*) Persona and Walkthrough, (*b*) Walkthrough activity (Text modality only), and (*c*) Walkthrough activity (gendered Pain Points 1–4 only); error bars indicate ±1 SE

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 2.22 (±1.03 SD) working in makerspaces, 1.95 (±0.97 SD) in woodworking, and 2.59 (±1.06 SD) in crafting.

9 Results and Discussion

9.1 Pain Points (RQ1). First, ANOVA was used with the number of recalled Pain Points as the dependent variable. Results in Fig. 2(*a*) showed that the study modality had a significant impact on the number of Pain Points recalled, as participants who read the Text-based Persona and Walkthrough recalled more Pain Points (mean = 4.722) than participants who received the same information in the Audio modality (mean = 4.047, $p = 0.011$), aligning with H1C. This result is supported by Clinton-Lisell's finding that self-paced reading provides benefits to comprehension over listening [54]. When focusing only on the Text modality, participants who read the Neutral Persona recalled more Pain Points from the Craft Walkthrough (mean = 5.478) compared to the Wood Walkthrough (mean = 4.269, $p = 0.038$), as shown in Fig. 2(*b*).

When isolating Pain Points with a gendered impact (Pain Points 1–4), it was found that participants who read the Wood Walkthrough alongside the Woman Persona recalled more Pain Points (mean = 1.706) than participants who read the Craft Walkthrough alongside the Woman Persona (mean = 1.137, $p = 0.011$), as shown in Fig. 2(*c*). At first glance, this result may seem to contradict hypothesis H1B based on Hamberg's findings that doctors struggle to recognize gender-stereotype non-conforming symptoms [1], as the task environment of the Wood Walkthrough is stereotyped as masculine. 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. Therefore, Pain Points encountered in the Wood Walkthrough were more likely to be associated with a feminine stereotype, resulting in closer stereotype adherence for the Woman Persona in the Wood Walkthrough compared to the Craft Walkthrough, which may have contributed to participants' ability to recall more Pain Points for the Woman Persona in the Wood Walkthrough. As a result, this finding can be interpreted as supporting Hypothesis H1B.

Next, ANOVA was used to analyze participants' perceptions of the severity of the Pain Points. An aggregate Pain Point severity score was developed by calculating the average of every severity

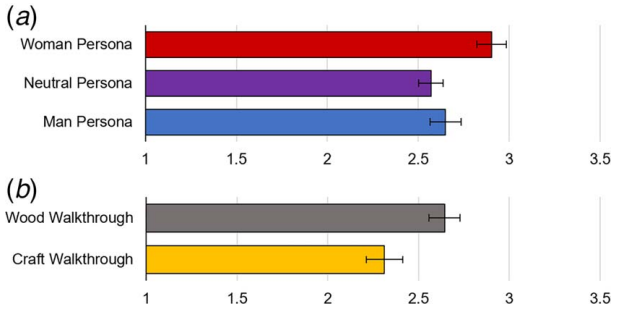

Fig. 3 Assessed Pain Point severity by participants from Text modality based on (*a*) Persona gender (all Pain Points) and (*b*) Walkthrough activity (gendered Pain Points 1–4 only); error bars indicate ±1 SE

rating assigned by each participant. In the Text modality, problems encountered by women were assessed as more severe (mean = 2.904) than problems encountered by the Man Persona (mean = 2.650, $p = 0.035$) or the Neutral Persona (mean = 2.570, $p = 0.018$), as shown in Fig. 3(*a*). This contradicts hypothesis H1A that men's problems would be taken more seriously than women's and may result from "protective paternalism" treatment toward women in STEM fields [55]. Similarly, in the Text modality, the gendered Pain Points were assessed as more severe when they occurred in the Wood Walkthrough (mean = 2.653), when they were more likely to impact women, compared to the Craft Walkthrough (mean = 2.307, $p = 0.005$), as shown in Fig. 3(*b*). This finding additionally aligned with trends identified by Schauer et al. [7] of woodworking-focused makerspaces generally being viewed as more serious and dangerous spaces than crafting-focused makerspaces.

9.2 Makerspace Perceptions (RQ2). As hypothesized, the makerspace was viewed differently depending on the Walkthrough room, as summarized in Fig. 4. Compared to the Wood Walkthrough room, the Craft Walkthrough room was viewed as significantly more simple on a scale from Elaborate-Simple ($p < 0.001$), more casual on a scale from Formal-Casual ($p = 0.028$), and more safe on a scale from Dangerous-Safe ($p < 0.001$). The Wood Walkthrough room was viewed as significantly more difficult on a scale of Easy-Difficult ($p = 0.031$) and more serious on a scale of Lighthearted-Serious ($p < 0.001$). These findings aligned with H2B and previous literature [7] that found woodworking-focused makerspaces to be viewed as more serious and dangerous spaces than crafting-focused makerspaces.

Additionally, the modality in which the Persona and Walkthrough were presented impacted how participants viewed the makerspace, as shown in Fig. 5. When presented in the Audio modality, the space was viewed as significantly more simple on a scale from Elaborate-Simple ($p = 0.030$), warmer on a scale of Warm-Cold ($p = 0.015$), more creative on a scale of Creative-Unoriginal ($p = 0.010$), and more welcoming on a scale from Welcoming-Intimidating ($p = 0.010$). As predicted in hypothesis

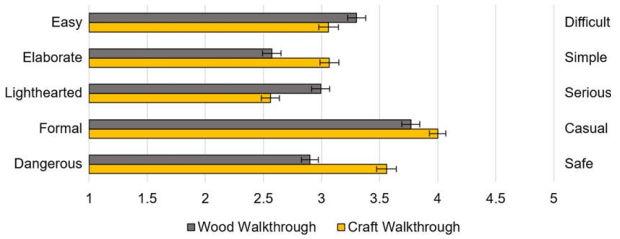

Fig. 4 Statistically significant ($p < 0.05$) differences in makerspace perceptions based on Walkthrough activity; error bars indicate ±1 SE

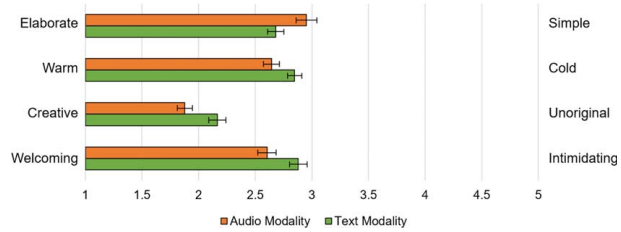

Fig. 5 Statistically significant ($p < 0.05$) differences in makerspace perceptions based on Persona and Walkthrough modality; error bars indicate ±1 SE

H2C, these perceptions of the makerspace were generally more favorable in the Audio modality, showing that the audio recording may have served to "humanize" the space, as Alexander and Nygaard [56] have found that listeners draw conclusions about a speaker's identity and emotional state from audio recordings.

Finally, 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 Persona was a woman (mean = 4.010), rather than gender-neutral (mean = 3.673, $p = 0.021$). Interestingly, this trend was not impacted by the gender-stereotyping of the task being performed in the makerspace, which does not support hypothesis H2A.

9.3 User Perceptions (RQ3). 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." Participants from the Text Modality case exhibited androcentrism in their view of users, viewing both the male (mean = 3.480, $p < 0.001$) and the gender-neutral (mean = 3.306, $p < 0.001$) Persona as significantly more masculine than the woman Persona (mean = 2.442), as shown in Fig. 6. There was no significant difference in the perceived masculinity of the man and neutral Persona cases ($p = 0.407$). These results were unaffected by the Walkthrough room case. 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. However, participants from the Audio Modality case did not exhibit a similar bias, as they viewed the gender of the woman (mean = 1.627), neutral (mean = 2.694), and man (mean = 4.060) Personas statistically significantly different from each other (all $p < 0.001$). Additionally, the Walkthrough room case impacted the way participants from the audio modality interpreted the gender of the neutral Persona, as they viewed the neutral Persona as more masculine when it was associated with the Wood Walkthrough (mean = 3.120) compared to the Craft Walkthrough (mean = 2.250, $p = 0.008$).

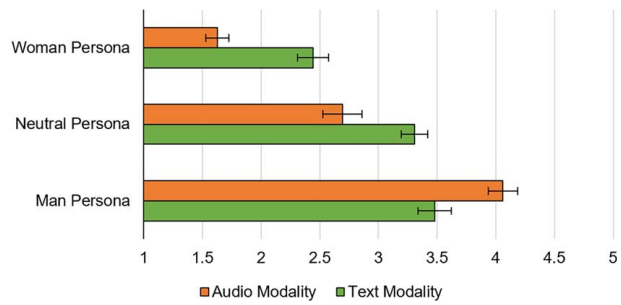

Fig. 6 Differences in the perception of makerspace user gender (1 = feminine, 5 = masculine) based on the Persona gender and Persona and Walkthrough modality; error bars indicate ±1 SE

Directly comparing the perceptions of participants based on Modality showed that participants who listened to the Audio Modality viewed the woman (mean = 1.627) and neutral (mean = 2.694) Personas as more feminine, and the man Persona (mean = 4.060) as more masculine, compared to participants who read the Text Modality (means = 2.442, 3.306, 3.480, $p < 0.001$, $p = 0.003$, $p = 0.003$, respectively). This tendency to draw stronger conclusions about speaker gender is summarized in Fig. 6 and supported by findings that listeners identify and retain speaker gender from audio recordings, which can influence the perceptual processing of speech [56,57].

Next, participants evaluated the skill level of the user. Regardless of Persona gender, participants from the Text Modality viewed the user from the Craft Walkthrough as more skilled (mean = 3.795) than the user from the Wood Walkthrough (mean = 3.564, $p = 0.048$). This trend was not statistically significant for participants from the Audio Modality ($p = 0.529$). Interestingly, when asked to predict the user's undergraduate major, there was a statistically significant difference ($p = 0.001$) in the percentage of participants who predicted that the Wood Walkthrough user (90%) was a STEM major compared to the Craft Walkthrough user (74%). In the Audio modality only, 93% of participants predicted that the man Persona was a STEM major, compared to 70% for the neutral Persona ($p = 0.019$) and 78% for the woman Persona ($p = 0.089$). Given the link between STEM subjects and masculinity [58], the stronger interpretation of the user's gender in the Audio modality may have caused this trend to be present in the Audio modality but not in the Text modality.

Finally, participants used 1–5 Likert scales to indicate their level of agreement with various statements about the user in the Persona. The gender of the Persona, the Walkthrough room case, as well as the presentation modality impacted the way the participants viewed the user. Despite the previously discussed perception of Craft room users as more skilled than the Wood room users in the Text modality, this did not impact how participants viewed the user's level of struggle ($p = 0.538$), while participants from the Audio modality viewed the Craft room user as struggling more (mean = 2.933) than the Wood room user (mean = 2.467, $p = 0.018$). Similarly, participants viewed the Craft room user as complaining more (mean = 2.858) than the Wood room user (mean = 2.464, $p = 0.009$).

Participants who read the Craft Walkthrough viewed the user as physically larger (mean = 2.851) compared to perceptions of the user from the Wood Walkthrough (mean = 2.484, $p < 0.001$), although there was no significant difference in the perceived physical strength of the users ($p = 0.857$). 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.

Perceptions of the user also varied based on their gender in the Persona. In line with stereotyping of women as more casual, creative makers than men [7,59], women users were viewed as having more fun (mean = 3.680) than the man (mean = 3.340, $p = 0.021$) and as being more approachable (mean = 3.990) than the man (mean = 3.640, $p = 0.013$). In the Text modality only, women users (mean = 4.269) were viewed as more creative than men (mean = 3.900, $p = 0.036$). While protective paternalism was proposed earlier as a potential cause for the difference in assessed Pain Point severity, conflicting trends were observed in this section of the survey, as participants viewed the man Persona as needing more help (mean = 2.590) than the woman (mean = 2.155, $p = 0.021$). The gender of the user in the Persona did not impact how competent participants perceived them to be, contradicting hypothesis H3A. Additionally, none of the statistically significant findings discussed earlier were impacted by the gender-stereotyping of the task performed in the Walkthrough, contradicting hypothesis H3B.

Finally, the presentation modality impacted the way participants viewed users. Participants from the Audio modality viewed the user as more approachable (mean = 3.993) than participants from the Text modality (mean = 3.629, $p < 0.001$), which aligns with hypothesis H3C. Riggs and Knobloch-Westerwick [20] found that participants exhibited higher empathy for narratives presented in audio modalities compared to textual modalities, which may explain this more favorable view of the makerspace user in the Audio modality. Additionally, the Woman Persona was viewed as physically larger in the Text modality (mean = 2.558) compared to the Audio modality (mean = 2.196, $p = 0.022$), aligning with the previously discussed view of the Audio-based Woman Persona as more feminine than the Text-based Woman Persona.

10 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 in the Text-based modality, 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 [60]. Although the Audio modality reduced the androcentric bias exhibited by participants in the Text modality, future work is needed to explore additional 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 discussed previously, the gender-stereotyping of the task and environment for the Walkthroughs contrasted the gender-stereotyping of the gendered Pain Points associated with each Walkthrough. Although the scenarios were 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. Variations in the way participants interpreted adjectives throughout the section of the survey on makerspace perceptions, given a lack of definition or context, may have also led to confusion among participants.

The written and audio modalities for the Persona and Walkthrough were selected over more immersive setups, such as viewing a video recording or participating in a simulated scenario, in order to isolate the variables of interest and avoid influence from sources of bias such as the perceived race, attractiveness, or gender expression of the speaker. Although prior work [1] has validated the ability of written-format communication to produce gender bias, additional visual cues of the Persona or makerspace may have impacted participants' perception of stereotype threat in the scenario. Future work could examine the impact of images, videos, or even augmented/virtual reality (AR/VR) modalities. Due to the limitations of the selected modalities, Pain Points recalled by participants may have been impacted by variation in natural recall ability, as well as primacy or recency bias [61]. Although randomizing or varying the order in which Pain Points are presented in the Walkthrough may assist in mitigating this bias, the linear order in which the pen- and hat-making procedures must be done interferes with this potential solution.

Finally, the results of this survey may have been impacted by demographic limitations. Although seven 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 [62]. 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, only two participants, both of whom listened to the gender-neutral Audio recording from the Wood Walkthrough, indicated that they viewed the user as non-binary or gender-neutral. Even non-binary participants and participants who read the Persona that explicitly used they/them pronouns were susceptible to a gender binary interpretation. Inclusion of participant gender as an independent variable in the ANOVA testing throughout this paper did not yield any statistically significant trends. 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. Specifically targeting recruitment toward underrepresented groups may be necessary in order to draw conclusions based on diverse perspectives.

11 Conclusion

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

> *RQ1: How do gender stereotypes and presentation modality impact designers' recollection and interpretation of user needs?*

Hypothesis H1C was supported by the finding that more Pain Points were recalled by the Audio modality group compared to the Text modality group, aligning with prior findings on the benefits of self-paced reading over listening for comprehension [54]. There was little correlation between gender-stereotyping and the number of Pain Points recalled. However, compared to the Wood Walkthrough, fewer gendered 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 [1] and supporting hypothesis H1B. Additionally, the finding that women's problems were assessed as more severe than men's contradicted hypothesis H1A and may be attributable to protective paternalism [55].

> *RQ2: How do gender stereotypes and presentation modality impact designers' interpretation of a task environment?*

There was no relationship between participants' perception of the space and the alignment of the stereotyping of the Persona gender and Walkthrough room case, contradicting hypothesis H2A. Rather, existing stereotyping of makerspace areas, such as perceptions of crafting makerspaces as more casual, lighthearted areas [7], appeared to dominate the assumptions of users in this study, validating hypothesis H2B that the Craft space would be viewed as more casual and simple than the Wood space. H2C was validated by the finding that the makerspace was viewed more favorably in the Audio modality compared to the Text modality, regardless of the task being performed. 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 (as denoted by the woman Persona) were viewed as more fun, regardless of the task being performed.

> *RQ3: How do gender stereotypes and presentation modality 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, contradicting hypothesis H3A. However, perceptions of women users as more approachable and having more fun supported expected trends based on stereotypes, although hypothesis H3B was contradicted by the lack of interaction between the Persona gender and Walkthrough task. Similar to perceptions of the makerspace, perceptions of the user were more positive in the Audio modality compared to the Text modality, aligning with hypothesis H3C and validating the ability of audio-based design tools to elicit higher empathy. Notably, this study confirmed the strong presence of designers' androcentric assumptions about users in the mechanical design process when presented with a user Persona in a Text-based modality. Participants who read a Text-based 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. Most importantly, participants who listened to the Audio-based Persona and Walkthrough did not exhibit the same androcentric bias compared to participants who received the same information in a Text-based modality, showing that providing richer, personifying detail in user personas has the capability to reduce gender bias in designers.

By exploring the research questions discussed earlier, this paper has contributed to our understanding of gender bias in design, empathy between designers and users, and design persona modality. Gender bias influences not only perceptions of users but also perceptions of their problems and task environment, which can be harmful to designers' ability to empathize with users. Overall, the authors recommend that information about end users should be presented in a variety of modalities in order to promote recall of user needs while mitigating biased assumptions.

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Conflict of Interest

There are no conflicts of interest.

Data Availability Statement

The datasets generated and supporting the findings of this article are obtainable from the corresponding author upon reasonable request.

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 on 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 18 V drills, which are too big for me to use with one hand, so I dug through the unlabeled cabinets until I found the smaller 12 V 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 h 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 on 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 it into the machine. It took me a while to get the thread through the needle because the hole in the needle was 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, and 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.

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