ASME Journal of Mechanical Design
Online journal at:
https://asmedigitalcollection.asme.org/mechanicaldesign

Gender Identity and Sustainable Product Perception in Engineering Design

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This study investigates how gender identity interacts with ecodesign cues to shape consumer purchase preferences, focusing on the social perception of sustainability as a gendered behavior. Prior work identifies a "green-feminine stereotype" that associates environmentally friendly products with femininity and may discourage some men from engaging with sustainable offerings. This research examines whether integrating universal design principles that emphasize inclusivity and accessibility with ecodesign principles influences gendered perceptions of sustainability. Using smartwatches as a relatively gender-neutral case, the study employed behavioral priming and conjoint analysis with 197 participants. Participants were randomly assigned to conditions in which their gender identity was affirmed or threatened before evaluating smartwatch concepts that varied by design type, lifestyle framing, option variant, and gendered styling. The concepts were developed as controlled experimental stimuli to isolate design cues rather than represent fully optimized sustainable products. Results show that men experiencing gender identity threat expressed lower preference for designs incorporating ecodesign cues, particularly those combining universal design and ecodesign principles, while women's preferences remained stable. Across conditions, ecodesign-focused designs received the highest average ratings, while combined universal and ecodesign designs were evaluated positively primarily in control groups. These findings demonstrate that gender identity processes influence how ecodesign-related cues are socially interpreted in stated preference evaluations.
[DOI: 10.1115/1.4071312]

Keywords: sustainable design, universal design, gender identity, consumer preference, green-feminine stereotype, product perception, human-centered design, conjoint analysis, design theory, product design

1 Introduction

As environmental challenges intensify, ecodesign has become a central concern in engineering and consumer research. While much current work emphasizes reducing material and lifecycle impacts, an emerging body of research highlights the role of socio-cultural factors in shaping sustainable product perception and adoption. Among these, gender identity has been shown to influence how individuals perceive and engage with environmentally responsible products [1,2].

The "green-feminine stereotype" refers to the cognitive association between environmentally friendly behavior and femininity [1]. This stereotype frames sustainability not only as an environmental or ethical issue but also as a gendered one. Masculine norms emphasizing independence, risk-taking, and rejection of femininity can discourage some men from adopting sustainable behaviors or purchasing environmentally oriented products [3,4]. In contrast, women's stated sustainable preferences tend to remain comparatively stable across contexts, reflecting a broader flexibility in gender roles [2,5]. These patterns have implications for product adoption and how sustainability is communicated through design attributes.

In parallel, ecodesign and universal design have emerged as influential frameworks in engineering. Ecodesign aims to reduce environmental impact across a product's lifecycle [6,7], while universal design seeks to enhance accessibility and usability for users with diverse abilities and backgrounds [8,9]. Although both frameworks promote long-term value and inclusion, they have rarely been studied together. Integrating universal design principles with ecodesign cues may influence how sustainability-oriented features are socially interpreted, potentially shifting perceptions away from gendered associations.

The objective of this research is to examine how combining universal and ecodesign principles influences stated purchase preferences under varying gender identity conditions. A smartwatch was selected as the case study because it represents a widely adopted, relatively gender-neutral consumer product [10]. Behavioral priming was used to induce either gender identity affirmation or threat, and conjoint analysis was applied to quantify preferences across multiple design attributes.

This work contributes to design cognition research by linking social identity theory with engineering design methodology. It provides empirical evidence that gender identity moderates

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Contributed by the Design Theory and Methodology Committee of ASME for publication in the Journal of Mechanical Design. Manuscript received October 29, 2025; final manuscript received February 27, 2026; published online April 3, 2026. Assoc. Editor: Astrid Layton.

preferences for sustainable product forms and examines how universal design integration may influence product perception. The findings advance understanding of how designers can intentionally shape product perception to shape socially situated evaluations of sustainability.

2 Background

2.1 Maintaining Gender Identity. Gender identity influences how individuals process information about themselves and others [1]. On a binary scale, it reflects the extent to which a person identifies as feminine or masculine [11]. Possessions and behaviors can serve as expressions of identity [12], so purchasing decisions often reinforce gender identity.

The green-feminine stereotype links environmentally friendly behavior with femininity [1]. Stereotypical feminine traits, such as caring and nurturing, are associated with environmentalism and conservationism [13], while stereotypical masculine traits emphasize aggression, risk-taking, and avoidance of femininity [3]. As a result, some men may resist sustainable products because they conflict with masculine self-concepts. Dominant masculinity norms place masculine traits above feminine ones in social value [2,14]. Women are often encouraged to express both sets of traits, while men are pressured to display only masculinity [2,15]. To preserve social status, men tend to pursue stereotypical masculine-typed behaviors and avoid stereotypical feminine ones [16]. When boys engage in nonconforming play, they are penalized more harshly than girls [17], reinforcing men's vigilance in maintaining gender identity [1].

Visual and sensory cues also convey gender. Color, shape, and form language can signal masculinity or femininity [18]. Squares, sharp edges, and straight lines are perceived as masculine, while circles and curves appear feminine [19]. When masculinity is threatened, men often avoid products with feminine associations, a reaction known as masculine overcompensation [4]. Women, whose gender roles are broader, exhibit less change under identity threat [2,5].

Behavioral priming enables the study of these effects. Priming, well established in psychology and increasingly used in design cognition research, activates cognitive frames through specific stimuli [20]. Nakagawa and Hart developed a validated priming task to manipulate gender identity affirmation and threat: recalling *two* versus *eight* instances of feeling masculine or feminine [2]. The easier two-instance task affirms identity, while the difficult eight-instance task induces uncertainty and threat. The present research uses this approach to investigate how gender identity affects preferences for sustainable design.

2.2 Sustainable Consumption and Gender Identity. Gender identity also shapes sustainable product evaluation and adoption. Men often avoid products perceived as feminine, such as those marketed as eco-friendly [21], whereas women display more stable sustainable behaviors [22]. Because masculine traits are socially privileged and sustainability is cognitively linked to femininity [1], adopting eco-friendly consumption may reduce perceived status for men.

Sustainable consumption is often culturally framed as "having and doing less," which can conflict with status-oriented masculine norms [23]. Both men and women who behave sustainably are often categorized as feminine [24]. Some men, therefore, avoid sustainable products to maintain masculine identity, while women experience less tension between gender and sustainability due to greater behavioral flexibility [25].

2.3 Ecodesign. Ecodesign principles aim to meet consumer needs while reducing environmental impacts throughout a product's life cycle [7,26,27]. Strategies include minimizing material use, selecting low-impact or recycled materials, and designing for reuse and recycling [6]. For products such as smartwatches, rapid technological turnover and component obsolescence create waste that ecodesign seeks to reduce [28].

Contemporary ecodesign research increasingly intersects with lifecycle systems thinking and circular economy frameworks, which emphasize resource recirculation, extended product lifespans, and value retention across use phases [29,30]. These perspectives expand traditional impact reduction approaches by considering product systems, business models, and user engagement. Within this broader context, perceptual factors and sustainability communication play a critical role in whether environmentally oriented design strategies translate into adoption.

However, the link between ecodesign implementation and market success is complex. Certain strategies, such as product-service systems and intensified product use, improve market outcomes, whereas packaging reduction or austere esthetics may limit appeal [31,32]. Ferrero noted that repositories connecting product functions and environmental impacts help guide eco-labeling, but variability in production and disposal introduces uncertainty [33].

Recent research has emphasized that sustainability communication influences perceived value as strongly as objective performance. Studies have shown that visible design cues can enhance perceived creativity and eco-value even without functional differences [31,32,34,35]. Reviews by Marcon et al. found that consumers are most responsive to sustainability features in the use and end-of-life phases, while upstream production changes often go unnoticed [36]. Therefore, effective ecodesign involves both technical impact reduction and perceptual strategies that make environmental value legible to consumers [37,38].

2.4 Value Perception of Green Products. A persistent challenge in sustainable product design is the attitude-behavior gap, where consumers express pro-environmental intentions yet choose conventional alternatives. Maccioni et al. combined self-reports and biometric data to demonstrate that green products evoke impressions of creativity and innovation but require greater cognitive effort to evaluate [31,32]. These effects are strongest among consumers already engaged with sustainability topics.

Eco-labels and simplified sustainability scores can partially close this gap. Pereira showed that A–E grading systems increased responsible purchases but did not consistently raise willingness to pay [39]. Similar findings in studies on eco-feedback interfaces indicate that explicit sustainability communication may raise awareness but not always lead to behavior change [38,40]. Consequently, visible product attributes, emotional engagement, and form cues often play a more decisive role than textual sustainability information in shaping preferences [37].

2.5 Universal Design Principles. Universal design aims to make products and environments usable by the widest range of people, regardless of age, ability, or experience [8,9]. The seven principles of universal design are equitable use, flexibility in use, simple and intuitive operation, perceptible information, tolerance for error, low physical effort, and appropriate size and space [41]. Originally developed in architecture, universal design now extends to product and interaction design as a framework for social inclusion and long-term usability [9,42]. Because it promotes durability, adaptability, and broader access, universal design has conceptual overlap with sustainability goals [43].

While early formulations of universal design focused on usability across ability ranges [41,44], more recent work emphasizes inclusive engineering approaches that integrate human diversity throughout system development processes [45]. This evolution reflects a shift toward framing accessibility as a core design value rather than a specialized accommodation.

Within engineering design, universal design principles have been applied to assistive technologies, ergonomic tools, and adaptive manufacturing interfaces [46,47]. Recent research highlights

inclusive human–machine interaction and human-centered engineering methods as approaches that increase accessibility and equity in design [28,48]. However, universal design has rarely been studied as a perceptual or cognitive factor that influences user response. Integrating universal design with ecodesign cues may influence how sustainability-oriented features are socially interpreted, potentially shifting associations away from gendered framing.

2.6 Intersections of Universal Design and Ecodesign. Although universal design and ecodesign pursue different objectives, both aim to enhance usability, efficiency, and long-term value. Ecodesign emphasizes environmental performance, while universal design focuses on human diversity and accessibility. Their combination can reinforce sustainability through increased product lifespan and reduced exclusion [43,49]. Inclusive usability also supports repairability and continued engagement, extending service life and reducing environmental burden [9,42].

Empirical work on integrated universal design–ecodesign approaches remains limited. Frameworks such as "design for all" and "design for sustainability" show conceptual overlap but lack consistent implementation guidance. Studies on sustainable design cognition suggest that merging user-centered and ecological considerations improves the adoption of sustainable solutions [28,35,50]. The present study builds on these insights by testing whether visible universal design cues can offset gender bias in sustainable product perception.

2.7 Product Semantics and Perception in Design. Product semantics link tangible design attributes with perceived meaning [51]. Designers intentionally employ form, color, texture, and material to communicate values, such as durability, sophistication, or environmental responsibility [45]. Research in design cognition shows that users often infer product qualities from visual cues more readily than from technical data [52,53].

Recent contributions demonstrate that visual communication can significantly influence perceived sustainability. She and MacDonald showed that prompting designers to emphasize sustainable features changes user interpretation [35], while El Dehaibi et al. validated visual indicators that successfully convey environmental value [34]. These findings imply that esthetic and semantic choices interact with cognitive framing to shape preference for sustainable products.

2.8 Design Cognition and Sustainable Decision Making. Design cognition research examines how people perceive, interpret, and evaluate design information [54]. In sustainability contexts, cognitive framing and affective response strongly influence user preference. Prior studies indicate that emotional attachment and pride in eco-friendly behavior enhance product adoption [37,38]. She and MacDonald found that sustainability triggers embedded in product form can evoke pro-environmental choices [40].

These studies suggest that sustainable product evaluation depends on more than technical performance. Emotional engagement and social meaning are central components of design perception. Integrating cognition-based frameworks with gender identity theory can reveal how self-concept interacts with design cues, a relationship not yet explored empirically within engineering design research.

2.9 Modeling User Preferences in Design. Quantifying user preference connects perceptual factors with engineering variables. Conjoint analysis offers a structured way to estimate the relative importance of design attributes and their interactions [55]. In design research, conjoint methods have been used to study trade-offs among esthetic, functional, and environmental features [53,56]. Prior work has advanced conjoint analysis through visualization, virtual prototypes, and hybrid models that integrate cognitive and affective dimensions [50,57,58].

Behavioral priming complements conjoint analysis by experimentally manipulating psychological states, such as gender identity affirmation or threat [2,20]. The combination of these methods enables analysis of how social identity influences preference in measurable ways. The present study uses this combined approach to evaluate how gender identity affects preference for sustainable design attributes.

2.10 Research Gap. Existing literature highlights several areas where further investigation is needed. Sustainable products are frequently perceived as feminine, which can discourage engagement among some men. Universal design principles may reduce exclusion but have not been studied as a mechanism for mitigating gendered perceptions of sustainability. Few engineering design studies integrate behavioral identity manipulation with quantitative preference modeling. This research addresses these gaps by examining how the integration of universal design and ecodesign principles affects stated purchase preference under different gender identity conditions. Through a controlled experiment that combines behavioral priming and conjoint analysis, the study contributes new evidence linking social identity, cognition, and sustainable engineering design.

2.11 Research Questions and Hypotheses. The background literature above establishes that social identity processes influence consumer engagement with sustainable products and that integrating universal design and ecodesign principles may provide a pathway toward more inclusive design perception. Prior research has shown that sustainability is often socially constructed as feminine [1] and that this association discourages sustainable behavior among some men who may perceive it as incongruent with masculine norms [3,4]. Within engineering design, studies on design cognition and product semantics demonstrate that visible cues and cognitive framing affect perceived sustainability more strongly than objective environmental performance [34,35]. Building on these findings, this study examines how gender identity, design framing, and perceptual cues interact to shape preference for sustainable products. The following research questions are the basis of this work:

> RQ1: How does combining universal design and ecodesign principles compares to using basic design or solely ecodesign principles in terms of impacting stated purchase preference for sustainability-oriented products?

> RQ2: How does priming individuals to consider their gender identity in a threatening or affirming manner impact their sustainable purchasing preferences?

Based on prior work showing that some men tend to reject any associations with femininity [16], this research study combines ecodesign principles with universal design principles in an attempt to create a product that is more "gender neutral." The green-feminine stereotype links ecodesign as more "feminine" than "masculine," and universal design is intended to be inclusive to people from all backgrounds. By incorporating universal design principles with ecodesign (Uni-Eco design), the green-feminine stereotype linked with ecodesign may disappear. With this goal in mind, the following hypotheses aim to predict the answers to the research questions in this research:

> H1: Men who are primed to have their gender identity affirmed will have a higher preference for smartwatches designed using a combined universal and ecodesign principle approach than men who are primed to have their gender identity threatened.

Prior research has found that some men are less likely to engage in "feminine" behavior when their gender identity is threatened [1]. Therefore, the masculine threat group is expected to have a lower

preference for smartwatches with Uni-Eco design principles than the masculine control group. This is because the green-feminine stereotype links "greenness" or "Eco" with "feminine" behavior, which may be avoided by men whose gender identity is threatened.

> H2: Women who are primed to have their gender identity threatened will have a similar preference for smartwatches designed using a combined universal and ecodesign principle approach as women who are primed to have their gender identity affirmed.

Since women have not been shown to reject femininity when their gender identity is threatened [2,5], the Feminine Threat group is expected to have a similar preference for smartwatches designed with Uni-Eco design principles as the Feminine Control group.

> H3: Men who are primed to have their gender identity affirmed will have a similar preference for smartwatches designed using a combined universal and ecodesign principle approach as women who are primed to have their gender identity affirmed.

Men are more likely to engage in "feminine" behavior when their gender identity is affirmed [2]. Therefore, the Masculine Control group is expected to have a similar preference for smartwatches designed with Uni-Eco design principles as the Feminine Control group, because their gender identity is affirmed.

> H4: Men who are primed to have their gender identity threatened will have a lower preference for smartwatches designed using a combined universal and ecodesign principle approach than women who are primed to have their gender identity threatened.

As stated previously, women do not have the same rejection of "feminine" behavior when their gender identity is threatened, as some men do [2,5]. Therefore, the Masculine Threat group is expected to have a lower preference for smartwatches with Uni-Eco design principles than the Feminine Threat group.

3 Methodology

3.1 Participants. A total of 197 participants (101 male, 92 female, 4 nonbinary or undisclosed) were recruited through Prolific. Participants ranged in age from 18 to 60 years ($M = 32.6$, $SD = 9.8$) and represented diverse occupational and educational backgrounds. All participants resided in the United States and provided informed consent under institutional review board approval. Participants received monetary compensation.

3.2 Procedure. Participants completed the study online using Qualtrics. After consent and demographic questions, they completed the priming task. They were then presented with a series of smartwatch choice sets generated for conjoint analysis. Each profile included a rendered image and a brief description corresponding to assigned attribute levels. Within each choice set, participants selected the option they preferred. Response time and order were recorded automatically. Periodically, participants answered attention-check questions to ensure the quality of their responses.

The survey was created in Qualtrics and distributed using Prolific to collect preferences for the 24 smartwatch designs from 197 participants. The survey had four main sections—one for each factor. In each section, the levels of the corresponding factor were compared. To do so, each question in a particular section held the levels of the other factors constant across the two or three smartwatch choices. The number of choices depended on the number of levels of the factor corresponding to the section of questions. Each of the two or three choices had a different level of the section's factor. For example, in the design section, the design factor is being studied. Therefore, a question in this section would have three smartwatch choices, each with a different design principle approach: basic, Eco, or Uni-Eco. All levels of the other three factors were thus held constant.

All participants were shown the same questions regardless of the control or threat group they were randomly assigned to; however, the order of the four main sections was randomized. This helped address potential survey fatigue and ensure higher quality responses.

3.3 Study Design. The study investigated how gender identity and sustainable design principles interact to influence product preference. A mixed-design experiment combined behavioral priming with conjoint analysis to measure preference across product attributes and identity conditions. A smartwatch was selected because it is widely adopted and exhibits minimal gender skew in usage rates [10]. Four attributes with two or three levels each were selected based on prior literature on sustainable and inclusive design [1,34,35], as shown in Table 1.

The experiment followed a $2 \times 3 \times 2 \times 2$ mixed factorial design. The between-subjects factor was identity condition (affirmation or threat). Within-subjects factors included design type (basic, ecodesign, universal-ecodesign), lifestyle framing (leisure or luxury), gendered styling (masculine or feminine), and option variant (one or two).

Each participant rated a subset of randomized profiles generated through an orthogonal fractional factorial design to minimize attribute correlation. The study measured user preferences of designs generated with three different sets of design principles in mind for different participant groups. The design principle approaches used in the study were a basic design principle approach, an ecodesign principle approach, and a combined Universal-Eco (Uni-Eco) design principle approach, shown in Figs. 1–3, respectively. The basic designs were chosen as a familiar option for all participants and do not incorporate ecodesign or universal design principles. Ecodesign models incorporated materials and manufacturing strategies intended to reduce environmental impact. The combined Uni-Eco designs incorporated both ecodesign and universal design principles to examine whether adding inclusive features altered user preference.

Three other factors were included alongside the design factor in the study, including lifestyle, option variant, and gender styling. Each of these factors has two levels. The two levels of the lifestyle factor are leisure and luxury, shown in Figs. 4 and 5, and were included to have the participant consider the cost of the smartwatch.

Table 1 Attribute levels and descriptions

Attribute	Levels	Description
Design principle approach	Basic, ecodesign, universal-ecodesign	Ecodesign models incorporated materials and manufacturing strategies minimizing environmental impact. Universal-ecodesign models added inclusive features such as simplified interfaces and adaptable straps.
Lifestyle framing	Leisure, luxury	Marketing descriptions emphasized everyday active use or premium esthetic appeal
Gendered styling	Masculine, feminine	Visual cues included color palettes, curvature, and material finishes informed by previous gender-coding research [19]
Option variant	One, two	Two separate smartwatch models to control for choice set effects

Fig. 1 Basic smartwatch example with a plastic wristband and a simple fastener

Fig. 2 Eco smartwatch example with a recycled plastic wristband and a complex fastener method

The two levels of the option variant factor are one and two, in Figs. 6 and 7, providing the participant a choice between two different smartwatches with the same design, lifestyle, and gender styling levels but different material choices or screen shapes.

The two levels of the gender styling factor are feminine and masculine, shown in Figs. 8 and 9, allowing participants to choose which they prefer the most.

All these additional factors and levels are used to better understand the preferences of the participants, specifically how they interact with the preferences for each of the three design levels: basic, Eco, and Uni-Eco. A total of 24 smartwatch designs with unique level combinations of the four factors were generated by a professional designer based on the above-mentioned principles.

3.4 Identity Manipulation. Building off Nakagawa and Hart, the survey had four different groups that participants were randomly assigned to depending on their gender identity [2]. The gender identity of a participant was collected using a slider scale-type question. The slider had a scale of 1–100, where 1 through 49 was feminine, 50 was both or neither, and 51 through 100 was masculine. Depending on how the participants answered, they were assigned to one of four groups: feminine control, feminine threat, masculine control, and masculine threat. Participants who answered between 1 and 49 were randomly assigned to feminine control or feminine threat. Participants who answered between 51 and 100 were randomly assigned to a masculine control or a masculine threat. Participants who answered 50 were randomly assigned to feminine control, feminine threat, masculine control, or masculine threat.

The use of the four groups was to examine the effect of one's self-perception of their gender identity on sustainable product preferences using different design principle approaches. The feminine and masculine control groups were created to help affirm one's gender identity to themselves [2], based on prior work. This was done by asking the participant to recall two times when they felt

Fig. 3 Uni-Eco smartwatch example with a recycled plastic wristband and a simple fastener method

Fig. 4 Leisure smartwatch example with a plastic wristband

feminine or masculine, depending on how they answered the gender identity question. These questions were taken from a previously validated article studying gender affirmation and threat [2]. The feminine and masculine threat groups were created to threaten one's perception of their gender identity [2]. To do so, participants in the feminine and masculine threat groups were asked to recall eight times when they felt feminine or masculine, respectively. Recalling eight different times one felt either feminine or masculine is more challenging than recalling two different times. The increased difficulty of the eight-instance recall task has been shown to induce identity threat. The study examined the effects of the feminine control and threat and masculine control and threat groups on design principle approach preference, lifestyle, gender styling, and option variant preference.

3.5 Conjoint Estimation. The method used to calculate the factor (design, lifestyle, option variant, and gender styling) and level (basic, Eco, Uni-Eco, leisure, luxury, leisure, option one, option two, feminine, and masculine) preferences was conjoint analysis. Conjoint analysis uses a regression model to find each level's coefficient, referred to as the level preference in this article. Discrete choice responses were modeled using logistic regression appropriate for binary selection data. Separate logistic regression models were estimated for each identity condition group. The assumptions for logistic regression are low multicollinearity and a large sample size. Multicollinearity is checked by finding the variance inflation factor (VIF), which quantifies how much the variance of a regression coefficient is inflated due to collinearity with other predictors. In this study, the predictors correspond to the factors. A VIF value less than five indicates low multicollinearity. All VIF values were around one, indicating low multicollinearity. Logistic regression generally requires 10–15 events per predictor variable. The number of observations per group exceeded recommended minimum thresholds for logistic regression estimation. Before running the logistic regression model, the collected data were processed and reformatted into the

Fig. 5 Luxury smartwatch example with a metal wristband

appropriate structure. The data were then separated based on participant group and R Studio was used to perform the logistic regression and find the factor and level preferences for each participant group. To do this, a baseline constraint was used, where levels "basic," "option one," "leisure," and "feminine" were all set equal to zero. This allowed the other levels to have a baseline to be compared against.

Once the level preferences were estimated, they were reset to facilitate interpretation. The reset preferences were calculated by determining the average preference of each level across all participants within a group and the average preference for each factor. The average level preference was then subtracted from the corresponding factor average. To compare level preferences across factors, the reset preference of each level was divided by the summation of the ranges of each factor. This transformation allows, for example, the level preference of "Eco" to be compared directly to the level preference of "luxury."

Factor preferences were calculated by dividing the range of each factor for a participant by the summation of the ranges of all factors for that participant. These participant-level factor preferences were then averaged to obtain group-level factor preferences. The standard error of each average factor preference was calculated as the standard deviation divided by the square root of the number of participants in that group.

3.6 Hypothesis Testing. After the preference for each factor and level was found, hypothesis testing was conducted to determine if the interaction between the factors and the levels was significant. If the interaction was found to be significant, the Tukey multiple comparison method was used to find which factor-level pairs were significant. Analysis of variance (ANOVA) hypothesis testing was performed on four main comparisons: feminine control versus feminine threat, masculine control versus masculine threat, feminine control versus masculine control, and feminine threat versus masculine threat. The null hypothesis was $\mu_0 = 0$, and the alternative hypothesis was $\mu_a \neq 0$.

Logistic regression models were used to obtain coefficients, and ANOVA functions in R Studio were applied to compute p-values.

Fig. 6 Option one smartwatch example with a circular screen and a recycled plastic

Fig. 7 Option two smartwatch example with an oval screen and a cork wristband

If the interaction's p-value was below 0.05, the Tukey multiple comparisons function was run to determine which factor-level pairs were significant.

4 Results

4.1 Factor Preference. Factor preferences represent the relative importance of each factor in participants' smartwatch choices. Figure 10 shows factor importance for the feminine control, feminine threat, masculine control, and masculine threat groups. Across all conditions, design and gender styling accounted for approximately 60% of total decision weight, whereas lifestyle and option variant accounted for less than 40% combined.

ANOVA results indicated significant differences in factor importance, $F(3, 188) = 23.9$, $p < 0.01$. Post hoc Tukey tests indicated that design and gender were significantly more important than lifestyle and option ($p < 0.01$). No significant interaction between lifestyle and option was observed.

4.1.1 Feminine Control. For the feminine control group, gender styling and design had importance values of $34.60\% \pm 0.28$ and $30.51\% \pm 0.22$, respectively. Lifestyle and option variant had importance values of $18.93\% \pm 0.24$ and $15.93\% \pm 0.24$, respectively. The ANOVA hypothesis testing results found that the factors are significantly different ($p < 0.01$). The F-statistic and degrees-of-freedom were 23.94 and 3, respectively. Tukey's multiple comparisons were performed to find which factor pairs were significant. The factor pairs gender styling-design and option variant-lifestyle were not significantly different.

4.1.2 Feminine Threat. In the feminine threat group, the two most important factors were design and gender styling with

Fig. 8 Feminine smartwatch example with an oval screen

Fig. 9 Masculine smartwatch example with a rectangular screen

preferences of 33.35% ± 0.26 and 30.70% ± 0.32, respectively. Lifestyle and option variant were the two least important factors, with preferences of 23.73% ± 0.23 and 12.22% ± 0.24, respectively. The ANOVA hypothesis testing results found that the factors are significantly different ($p < 0.01$). The F-statistic and degrees-of-freedom were 23.06 and 3, respectively. Tukey's multiple comparisons were performed to find which factor pairs were significant. Only the factor pairs gender styling-design and lifestyle-gender styling were the only ones that were not significantly different.

4.1.3 Masculine Control. The most important factor for the masculine control group was design, with a preference of 33.37% ± 0.50. The other three factors, lifestyle, option variant, and gender styling, were within 5% of each other. Their preferences were 24.40% ± 0.34, 19.50% ± 0.36, and 22.72% ± 0.43, respectively. The ANOVA hypothesis testing results found that the factors are significantly different ($p < 0.01$). The F-statistic and degrees-of-freedom were 4.97 and 3, respectively. Tukey's multiple comparisons were performed to find which factor pairs were significant. The factor pairs gender styling-design and option variant-design were the only ones that were not significantly different.

4.1.4 Masculine Threat. In the masculine threat group, the most important factor was design with a preference of 36.93% ± 0.52. The second most important factor was gender styling with a preference of 26.88% ± 0.47. The two least important factors, lifestyle and option variant, had preferences of 20.95% ± 0.47 and 15.24% ± 0.37, respectively. The ANOVA hypothesis testing results found that the factors are significantly different (p-value < 0.01). The F-statistic and degrees-of-freedom were 13.28 and 3, respectively. Tukey's multiple comparisons were performed to find which factor pairs were significant. The factor pairs lifestyle-gender styling and option variant-lifestyle were the only ones that were not significantly different.

After determining which factors were significant in the four comparison groups, the level preferences for each factor were analyzed.

4.2 Level Preference. The level preferences of the four factors (design, lifestyle, option variant, and gender styling) were found for the feminine control and threat and masculine control and threat participant groups. Preferences were compared for feminine control versus feminine threat, masculine control versus masculine threat, feminine control versus masculine control, and feminine threat versus masculine threat. ANOVA hypothesis testing was conducted for each comparison to determine the significance of the factor-level interaction. The null hypothesis stated that group means were equal, and the alternative hypothesis stated that they were not equal. If the interaction p-value was less than 0.05, Tukey's multiple comparisons were performed to determine which factor-level pairs were significant. Tukey's multiple comparison results report adjusted p-values to account for multiple testing.

4.2.1 Feminine Control Versus Feminine Threat. The feminine control and feminine threat groups had significantly different preferences for most levels, with one exception being the "Uni-Eco" level preference. Within the gender styling factor, both groups preferred the "feminine" designs over the "masculine" designs—27% for the feminine threat group and 29% for the feminine control group. Within the design factor, both groups preferred the "basic" designs more than the "Eco" or "Uni-Eco" designs. The "Uni-Eco" design was least preferred by both groups.

The hypothesis testing results found all factor-level interactions of feminine control versus threat significant ($p < 0.05$). Therefore, Tukey's multiple comparisons were performed for design, lifestyle, option variant, and gender styling to determine which factor-level pairs were significantly different ($p < 0.05$). All factor-level pairs are significantly different except for the feminine threat and feminine control "Uni-Eco" pairing, whose adjusted p-value is 0.95, and the "feminine" and "masculine" pairings (p-value of 0.24).

4.2.2 Masculine Control Versus Masculine Threat. The masculine control and masculine threat groups had similar preferences for the lifestyle and option variant levels. Within the gender styling factor, both groups preferred the "feminine" designs over the "masculine" designs, with a preference of 20% for the masculine threat group and 29% for the masculine control group. Within the design factor, both groups preferred the "basic" designs more than the "Eco" or "Uni-Eco" designs. The "Uni-Eco" design was least preferred by both groups, but it was also preferred much less by the

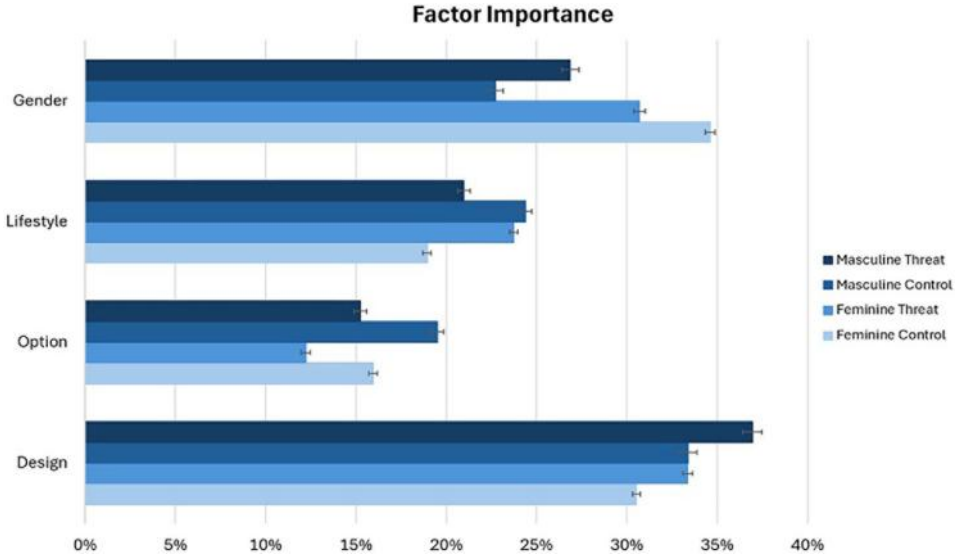

Fig. 10 Factor preferences (importance) for the four participant groups; error bars show ± one standard error

masculine threat group than by the masculine control group with preferences of −26% and −17%, respectively.

The hypothesis testing results found all factor-level interactions of masculine control versus threat significant ($p < 0.05$). Therefore, Tukey's multiple comparisons were performed for design, lifestyle, option variant, and gender styling to determine which factor-level pairs were significantly different ($p < 0.05$). Factor-level pairs of the design factor are significantly different except for the masculine threat and masculine control "basic" pairing, whose adjusted p-value is 0.98. The factor-level pairs of the gender styling factor are also significantly different, but the option variant factor-level pairs are not.

4.2.3 Feminine Control Versus Masculine Control. The feminine control and masculine control groups had similar preferences for the gender styling and lifestyle levels. The gender styling and lifestyle levels had the highest and lowest preferences, respectively, of all nine levels. Within the design factor, both groups preferred the "basic" designs more than the "Eco" or "Uni-Eco" designs. The "Uni-Eco" design was least preferred by both groups but was also preferred much less by the masculine control group than by the feminine control group with preferences of −17% and −8%, respectively.

The hypothesis testing results found all factor-level interactions of feminine control versus masculine control significant ($p < 0.05$) except the gender styling factor with a p-value of 0.90. Therefore, Tukey's multiple comparisons were performed only for the design, lifestyle, and option variant factors to determine which factor-level pairs were significantly different ($p < 0.05$). Only the Eco design pair of the design factor was not significantly different. Both factor-level pairs of lifestyle were not significantly different (p-value of 0.49), but both factor-level pairs of option variant were significantly different, with p-values <0.01.

4.2.4 Feminine Threat Versus Masculine Threat. The feminine threat and masculine threat groups had different levels of preferences within all four factors. The gender styling factor had the highest level of preferences collectively, with the "feminine" designs having the highest preference for both compared to the "masculine" designs. The lifestyle and option variant levels had the lowest preferences for both groups. Within the design factor, both groups preferred the "basic" designs more than the "Eco" or "Uni-Eco" designs. The "Uni-Eco" design was least preferred by both groups but was preferred much less by the masculine threat group than by the feminine threat group, with preferences of −26% and −9%, respectively.

The hypothesis testing results found all factor-level interactions of feminine threat versus masculine threat significant ($p < 0.05$). Tukey's multiple comparisons were then performed to determine which factor-level pairs were significantly different ($p < 0.05$). All factor-level pairs are significantly different with p-values <0.01, except for the lifestyle factor levels and the "basic" level of the design factor.

4.3 Interaction Effects. To see if the other three factors (lifestyle, option, and gender) strongly influenced the participants' preferences for the three design factor levels (basic, Eco, and Uni-Eco), interaction plots were created of the factor pairs that were found to be significant in the factor preference section. Figures 11 and 12 display these interactions.

4.3.1 Feminine Control Condition. Figure 11 (left) illustrates the interaction among design level, option variant (1 or 2), and lifestyle for women in the control condition. A significant design × option variant interaction was observed. Preference for option variant 1 increased markedly at the *Eco* level but declined at *Uni-Eco*, while option variant 2 decreased steadily across design levels, yielding a crossover pattern. Leisure framing produced slightly higher preferences than luxury framing across all levels. Preference for option variant 1 increased at the Eco level and declined at Uni-Eco, particularly under leisure framing.

4.3.2 Feminine Threat Condition. Figure 11 (right) shows the interaction among design level, option variant, and lifestyle for women in the threat condition. Overall preference declined across the design spectrum from basic to Uni-Eco, indicating reduced appeal for sustainable and inclusive designs when gender identity was threatened. A significant design × option variant interaction reflected a steeper decline for option variant 2 than for option variant 1, particularly at the Uni-Eco level. A marginal design × lifestyle crossover suggested that luxury framing enhanced preference for basic designs but reduced it for sustainable ones. The combination of option variant 2 with luxury framing yielded the lowest ratings across all groups. These findings imply that identity threat heightened sensitivity to design cues associated with sustainability and luxury, leading to lower evaluations of more prosocial or premium sustainable variants.

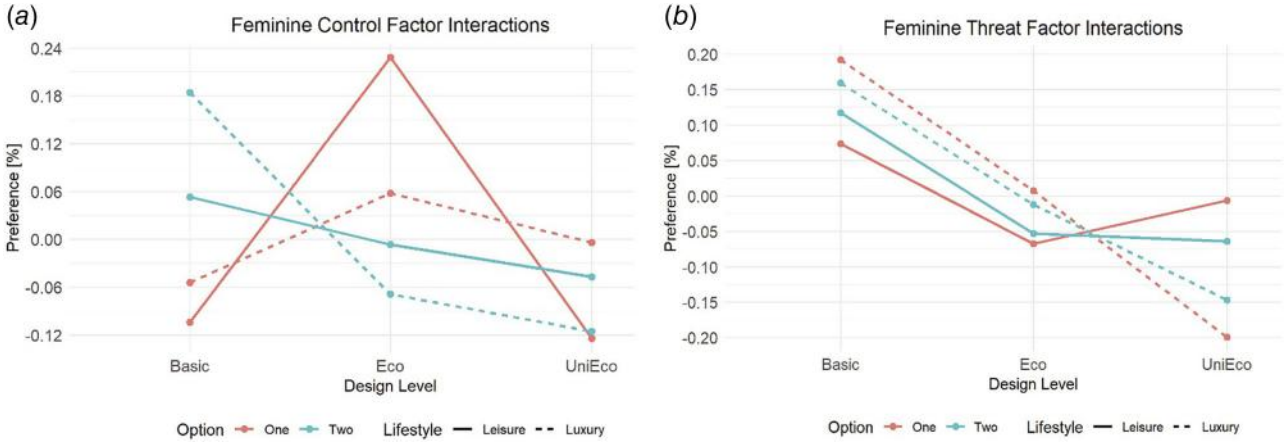

Fig. 11 Smartwatch design preferences of the feminine control (left) and feminine threat (right) groups by the levels of factor design, lifestyle, and option variant

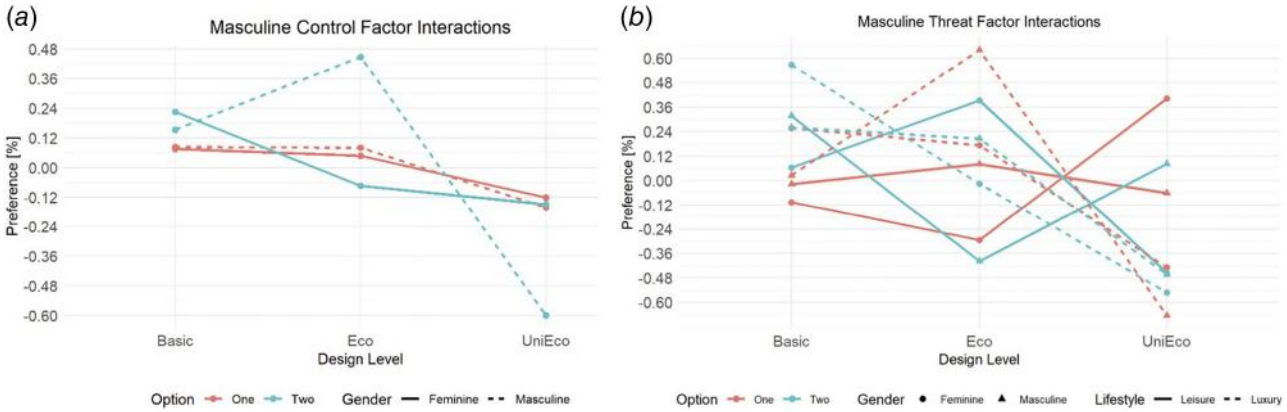

Fig. 12 Smartwatch design preferences of the masculine control (left) masculine threat (right) group by the levels of factor design, option variant, and gender styling

4.3.3 Masculine Control Condition. Figure 12 (left) depicts the interaction among design, option variant, and gender styling for men in the control condition. A significant design × option variant interaction was observed, with option variant 2 showing a sharp peak in preference at the Eco level and a substantial decline at Uni-Eco, while option variant 1 remained relatively flat. A corresponding design × gender styling effect indicated that masculine styling increased preference for moderately sustainable designs but decreased it for highly sustainable ones, whereas feminine styling produced stable ratings across design levels. The three-way pattern suggests that affirmed men were most favorable toward Eco designs that paired sustainability with masculine form language, supporting the notion that sustainability cues are most appealing when they align with familiar esthetic conventions rather than overt inclusivity.

4.3.4 Masculine Threat Condition. Figure 12 (right) displays the interaction among design, option variant, gender styling, and lifestyle for men in the threat condition. Preferences were highly variable, showing multiple crossovers across design levels. A significant design × option variant effect was observed, with option variant 1 increasing in preference across design levels while option variant 2 peaked at Eco and declined sharply at Uni-Eco. A strong design × gender styling interaction revealed that masculine-styled designs received the highest ratings at the Eco level but the lowest at Uni-Eco, whereas feminine-styled designs remained low throughout. Luxury framing further intensified these differences. The three-way pattern suggests that under gender identity threat, men polarized in their evaluations: ecodesign expressed through masculine esthetics was rewarded, but Uni-Eco designs were penalized. These patterns are consistent with H1 and H4.

4.3.5 Cross-Group Patterns. Across groups, ecodesign received higher average ratings than basic or Uni-Eco designs. Men exhibited larger shifts in preference between Eco and Uni-Eco levels, particularly under threat, whereas women's preference profiles were more stable across identity conditions. Leisure framing yielded higher ratings than luxury across groups. Uni-Eco designs showed the largest declines under masculine threat.

4.4 Summary of Hypotheses. Table 2 outlines the outcomes of each hypothesis that was tested in this study.

Across conditions, ecodesigns yielded the highest average preference ratings, while Uni-Eco designs were evaluated positively only in control groups. Under gender identity threat, men showed reduced preference for Uni-Eco designs.

5 Discussion

5.1 Overview of Key Findings. The results indicate that gender identity is associated with differences in user preference for user preference for ecodesign and universal-ecodesign product variants. Men under gender identity threat reported significantly lower preference for ecodesign and universal-ecodesign product variants, whereas women's preferences remained relatively stable across conditions. Across participants, ecodesign variants received the highest average ratings, while Uni-Eco variants

Table 2 Hypothesis outcome summary

Hypothesis		Supported?	Evidence summary
H1	Men who are primed to have their gender identity affirmed will have a higher preference for smartwatches designed using a combined universal and ecodesign principle approach than men who are primed to have their gender identity threatened	Yes	Threatened men rated sustainable and Uni-Eco designs lower than affirmed men ($p < 0.01$)
H2	Women who are primed to have their gender identity threatened will have a similar preference for smartwatches designed using a combined universal and ecodesign principle approach as women who are primed to have their gender identity affirmed	Yes	No significant difference between affirmed and threatened women ($p > 0.05$)
H3	Men who are primed to have their gender identity affirmed will have a similar preference for smartwatches designed using a combined universal and ecodesign principle approach as women who are primed to have their gender identity affirmed	Partial	Uni-Ecodesign increased overall preference by ~12% versus basic designs
H4	Men who are primed to have their gender identity threatened will have a lower preference for smartwatches designed using a combined universal and ecodesign principle approach than women who are primed to have their gender identity threatened	Yes	Significant three-way interaction; threatened men showed lowest preference for Uni-Eco designs

showed greater variability across identity conditions. These findings support H1 and H2 and partially support H3 and H4. Together, the results suggest that both the intensity of sustainability cues and the salience of gender identity are related to product perception.

5.2 Comparison With Prior Research. The observed patterns are consistent with prior evidence that sustainable behavior is socially constructed as feminine, producing a "green-feminine stereotype" that discourages some men from engaging with pro-environmental actions [1]. As in earlier behavioral studies, gender identity threat reduced men's engagement with sustainability cues, consistent with prior interpretations that identity threat may increase avoidance of gender-incongruent behaviors [4,21].

Within the design cognition literature, these findings align with studies showing that users infer meaning and value from visual design cues as strongly as from performance attributes [52,53]. The sensitivity of preference to design principle approach and gender styling under threat suggests that form language and perceived social meaning may mediate the relationship between sustainability intent and user response. This pattern complements prior research demonstrating that subtle framing effects can shift sustainable design evaluations [34,35].

The relative stability of women's preferences mirrors earlier social psychology findings that feminine identity expression is less constrained by gender norms [2,5]. In this context, women appear to evaluate sustainable and inclusive design features based on functional or esthetic quality rather than gender signaling.

5.3 Interpreting the Role of Universal Design. Integrating universal design principles with ecodesign produced mixed results. While universal design aims to promote equity, accessibility, and long-term usability [9,41,42], its visual cues may not always be perceived as neutral. Under conditions of identity threat, men evaluated universal-ecodesign variants less favorably than standard ecodesign, suggesting that certain perceptual cues associated with inclusivity may be interpreted differently across identity conditions.

This finding expands earlier research on product semantics, which has shown that perceived meaning can override functional intent [50,51]. In design contexts where sustainability or accessibility is visually emphasized, users may subconsciously categorize these cues as belonging to particular social identities, shaping emotional and cognitive responses. It is important to note that this study evaluates perceptual responses to sustainability-oriented design cues rather than lifecycle-validated environmental performance.

5.4 Broader Implications for Sustainable Product Design. From a design theory perspective, these findings underscore the importance of understanding how users' self-concept interacts with design semantics. Beyond optimizing environmental performance, designers may also consider how sustainability is framed and communicated. In practice, this means that designers should integrate universal design features in ways that appear adaptable and performance-driven, rather than socially coded.

In engineering education and practice, emphasizing co-creation and inclusive esthetics may help reframe sustainability from a gendered behavior to a collective responsibility. Recent studies on human-centered and sustainable design processes [38,48] point to the need for design tools that account for social perception as part of early-stage concept evaluation. The results provide preliminary empirical evidence that such frameworks may be beneficial.

5.5 Theoretical Contributions. This work connects social identity theory and design cognition, illustrating how stereotype activation interacts with perceptual design features. It extends prior human factors and cognitive engineering research by introducing gender identity threat as a contextual variable influencing design evaluation. The findings add to evidence suggesting that ecodesign design outcomes may be influenced by alignment between environmental messaging and users' identity frameworks.

5.6 Practical Implications. The findings suggest several considerations for sustainable product development. Sustainability cues that emphasize performance, durability, or technical innovation may reduce the likelihood of gendered interpretation. In addition, universal design features may be most effective when integrated through functionally grounded and visually neutral design language. Moderate sustainability cues were more consistently preferred than highly emphasized inclusive variants across groups. Finally, iterative user testing across identity-relevant subgroups may help identify unintended perceptual effects before product launch. Incorporating perceptual evaluation methods into engineering design education may also increase awareness of how social framing influences product reception.

5.7 Limitations and Future Work. Although the experiment used a balanced sample and controlled manipulations, the results are limited by the use of rendered stimuli and self-reported preference data. Future research could employ physiological or behavioral measures to triangulate user engagement with sustainable designs. Expanding beyond gender identity to include other dimensions of social identity, such as cultural or generational factors, would provide a more comprehensive understanding of inclusivity

in design perception. Additionally, the study focuses on a single product category; future research should examine whether these effects generalize across other product types.

6 Conclusions

This research examined how gender identity influences user preference for smartwatch variants incorporating ecodesign and universal design principles. Using a behavioral priming and conjoint analysis experiment with 197 participants, the study found that men under gender identity threat evaluated ecodesign and universal-ecodesign variants less favorably, while women's preferences remained stable. Sustainability cues in ecodesign principle-driven products were consistently preferred across all groups, whereas the most inclusive Uni-Eco designs elicited polarized responses, particularly among threatened men.

These findings support H1, H2, and H4, and partially support H3, suggesting that perceptions of sustainability vary across social identity conditions and design framing. The results extend prior work on the "green-feminine stereotype" [1] by applying it to design evaluation contexts. They also contribute to design cognition literature by highlighting how visual semantics and identity cues interact to shape product meaning and preference [35,50].

From a practical standpoint, this study illustrates the need to frame sustainability as a universal value rather than a gendered trait. Integrating universal design and ecodesign principles through neutral, performance-oriented esthetics can promote inclusivity without reinforcing stereotypes. The findings support the continued development of design frameworks that merge perceptual, behavioral, and technical dimensions to foster equitable engagement with sustainable technologies. Future research should explore how other identity dimensions, such as culture, profession, or generational cohort, affect responses to sustainability and inclusivity cues. Expanding this approach to physical prototypes, immersive environments, and cross-cultural samples will strengthen understanding of how design meaning evolves under real-world social contexts.

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.

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