Investigating User Emotional Responses To Eco-Feedback Designs

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ABSTRACT

Emotional responses to a product can be critical in influencing how the product will be used. This study explores the emotions that arise from users' interaction with eco-feedback products, and investigates links between emotions and users' resource conservation behaviors. In-lab experiments were conducted with 68 participants of varying backgrounds. Each participant was shown sketches of four conceptual designs of eco-feedback products and reported how they would feel and behave in different scenarios using the products. Two styles of eco-feedback design, quantitative and figurative, were compared to each other and were compared to neutral designs which had little or no feedback information. Results showed that taking resource conservation actions such as turning off lights was highly correlated with negative emotions towards wasting resources, such as guilt, upset, embarrassment, and annoyance. Users' evaluations of aesthetics, usefulness, and overall quality of eco-feedback products, however, were highly correlated with positive emotions towards resource conservation, described as satisfied, proud, interested, and joyful. Figurative designs were observed to evoke much stronger emotions among younger participants than older ones. Ultimately, we hope our findings are useful to the designers of eco-feedback products.

1 INTRODUCTION

It is well established that products are capable of evoking powerful emotions in users [1]: the soft glow of a bedside lamp creates a cozy feeling, a space heater comforts on a cold winter day, and solar panels on a roof provide a sense of power and pride. These user emotions provide positive experiences that foster user well-being [2] and are essential to the products' success [3]. In this study, we apply an emotional design strategy to the realm of design for sustainable behavior [4,5]. More specifically, we examine eco-feedback designs [6] which aim to promote pro-environmental behavior in users by making them aware of their resource consumption and its consequential environmental impact. Compared to other strategies of designing for sustainable user behavior such as "behavior steering" (which encourages behavior change via embedded product constraints or affordances) and "smart" designs (which automatically take actions to enforce behavior change), eco-feedback has the advantages of being less intrusive [7] and easier to implement [8], with higher potential to raise users' environmental awareness [9]. In eco-feedback designs, users are in control of product usage [10], so whether these designs effectively encourage sustainable behaviors relies on how users perceive and feel about the designs. Therefore, we explore how user emotions elicited by the eco-feedback designs are linked to the effectiveness of the designs in spurring sustainable user behaviors.

In a previous study, we investigated eco-feedback designs in a range of styles, from more quantitative (e.g. displaying the power consumption of an appliance in Watts), to more emotionally evocative (e.g. displaying a wilting sunflower) [11]. Results suggested that designs which were both quantitatively clear and emotionally evocative were also the most appealing. However, it was not clear from this study which particular user emotions were evoked by these designs, or what roles different emotions might play in influencing user behavior. To fill this gap, our current study strives to better understand specific user emotions associated with eco-feedback designs and to investigate how they are linked to users' perception of the designs and their behavior change. Three main questions explored in this study are:

1. *What are the emotions that arise from users' interactions with eco-feedback products?*

We are interested in identifying a spectrum of emotions that builds on validated emotion assessment frameworks including the Positive and Negative Affect Schedule [12] and the Consumption Emotion Set [13]. Some expected emotions include *interest*, *satisfaction*, *worry* and *guilt*. We anticipate that the emotions will largely depend on the specific product usage scenario.

2. *What role do emotions play in influencing users' sustainable behavior and their perceptions of eco-feedback products?*

We seek to understand how a user's emotions influence their behavior with respect to conserving resources. We want to evaluate whether emotionally rich eco-feedback products can better promote sustainable behavior, and identify the specific emotions that are most effective in encouraging behavior change. We will also investigate how emotions can impact users' perceptions of eco-feedback designs.

3. *How can we design eco-feedback products to evoke strong and appropriate emotions in users to encourage sustainable behavior?*

In our previous study [11], quantitative and figurative design representations were compared on the strength of emotional responses they evoked in users. In this work, these eco-feedback designs were further evaluated. We expected that designs using figurative metaphors (such as animals) as reminders of environmental sustainability would be more emotionally evocative than designs showing strictly quantitative information (such as the total amount of resources consumed).

To address these questions, an in-lab experiment was conducted with 68 participants of varying backgrounds. Participants evaluated design concepts for four eco-feedback products and reported how they would feel and behave while using them.

2 BACKGROUND

2.1 Design for Sustainable Behavior

There is great potential for energy and water savings in the US residential sector [14], and encouraging people to use products in an environmentally aware manner could contribute to consumption reduction. Consequently, there is a growing interest in research into designing for sustainable product use [15], also known as design for sustainable behavior [5].

Prevailing techniques for designing for sustainable product use fall on a spectrum from users-in-control to products-in-control [5,10]. The typical users-in-control technique is *eco-feedback* [16,17], in which users are reminded of their resource use. Providing information and feedback are intervention strategies that have been proven to be effective in encouraging household energy conservation [18] and water conservation [19]. Eco-feedback designs incorporate these strategies to provide real time feedback information on resource usage. Techniques on the product-in-control end, also known as *smart design* or *intelligent design* [20,21], involve automatically taking actions to ensure behavior changes, sometimes without user knowledge or consent. Other techniques include *behavior steering* or *behavior enabling*, in which users are encouraged to behave in certain ways by constraints or affordances embedded in a design [22].

A substantial number of studies investigated the effectiveness of these techniques alongside user perceptions of the resulting designs. Montazeri, et al. [23] created napkin dispensers that displayed the quantity of napkins used and validated each design's effectiveness at reducing consumption in a field study. Cor and Zwolinski [7] tested four coffee makers intended to encourage electricity conservation. They found that the eco-feedback design (which reported energy consumed while making coffee) and the goal setting design (which provided a target value for energy consumption) were perceived as more useful and less intrusive than a written-information design (which offered instructions for turning off the coffee maker) or a smart design (which switched off the coffee maker automatically). Sohn, et al. [9] evaluated ten water faucet and sink designs intended to encourage water conservation. Immediate user reactions suggested that displaying water usage information raised more awareness and was perceived as more effective for encouraging water conservation than applying physical constraints that reduced water use. Other studies have investigated users' motivations for adopting sustainable behaviors [24], the influence of products' environmental impact information on consumers' preference judgement of product attributes [25,26], and consumer preferences for sustainable product features [27].

2.2 Users' Emotions and Design

The emotional connections between users and products are recognized as indicators and moderators for delightful product experiences [28]. Strategies and methodologies have been developed to design products to elicit intended feelings, i.e. Kansei Engineering [29], or to design pleasurable products [30]. In addition, existing research has recognized the important role emotions play in marketing [31]. Pleasant surprise and interest are both strong indicators of customer satisfaction [32]. Emotions can impact consumers' decision making by influencing assessment of any risks associated with adopting new products or services, as well as assessment of the monetary value of goods [33]. Neurological evidence has been found that the emotion-related regions of brain are activated when consumers make complex tradeoffs between a product's form and function [34].

An individual's environmental concerns and beliefs can be emotionally charged [35]. Emotions such as anticipated regret or guilt are linked to consumers' decision-making such as the selection of sustainable products and services [36] and ecological behaviors such as recycling and use of public transportation [37]. Therefore, engaging users emotionally is potentially an effective way for products to encourage sustainable behavior in users [38]. Dillahunt, et al. [39] designed an interactive virtual polar bear as a motivator for conserving energy. It was found that people who were more emotionally attached to the polar bear exhibited greater concern for the environment. But still there is little understanding of what precisely users would describe themselves as feeling in the context of using such product. In the psychology domain, studies have been conducted to illustrate the role of emotions (affect and arousal) in influencing and/or changing people's behavior [40]. And yet few guidelines have been developed specifically in the context of product design that look at eliciting user emotions to encourage sustainable behavior. To bridge these gaps, it is important to understand the possible spectrum of user emotions evoked by sustainable products and to investigate links between these product emotions and users' pro-environmental behavior.

2.3 Measuring Users' Emotions

The prevailing method to measure human emotions is self-reporting. The Positive and Negative Affect Schedule (PANAS) is a tool that measures the intensity of both positive and negative affect of a person [12]. It contains two ten-item scales, ten verbal descriptors of positive emotion such as *Excited* or *Proud*, and ten verbal descriptors of negative emotion such as *Afraid* or *Irritable.* Along these lines, Richins investigated a set of 175 emotion words that are specifically related to a consumer's consumption experience [13]. He further narrowed the list down to a Consumption Emotion Set (the CES), which contains the most representative 34 emotion descriptors. Another popular instrument to measure emotions is the Self-Assessment Manikin (SAM), which uses non-verbal pictorial assessment to measure the pleasure, strength, and dominance that are associated with a person's emotions [41]. Similarly, Desmet developed the Product Emotion Measurement Instrument (PrEmo), which is a set of cartoon figures that help users to express emotions related to owning or using a product [42]. These methods are easy to implement, and a well-designed self-reporting scale can be valid and reliable [43].

Another way to assess emotions that is gaining in popularity is measuring physiological responses of the human body, a group of methods enabled by the rapid growth of sensing technology [44]. Some common practices include observing facial expression [45] or vocal cues [46], measuring heart rate, skin conductivity or respiration [47], and detecting brain activities using electroencephalogram (EEG) [48] or functional magnetic resonance imaging (fMRI) [49]. These methods are considered more objective compared to self-reporting methods. However, their implementations are usually more complex and expensive, and the gathered data are usually more open to interpretation.

To gauge user emotions, researchers have asked people to recall their emotional experiences with products [50] or use a diary to track emotions over the course of using a product [51]. To collect feedback on provisional product ideas, design representations such as line drawings [34] or prototypes [52] have been used to elicit user emotions. Scenario-based design is an approach that captures the essence of a product's use by creating a story or context for the experience [53]. It has been used to gather feedback in the early design stage of the experience of using a product [54].

In this study, sketches were used as representations of eco-feedback designs and scenarios of user-product interaction were created to elicit user emotions. We explored multiple quantitative emotion assessment methods, including self-reporting, skin conductivity measurement and facial expression detection when preparing for this study. Self-reporting was chosen because we found it more meaningfully interpretable and more effective at distinguishing between subtly different emotions in this context, whereas the other methods often measured no noticeable change between different scenarios.

3 METHODS

Overview: Four eco-feedback products were created for this experiment to encourage electricity or water conservation behavior in users. Two versions of each product were sketched by a professional industrial designer. In-lab experiments were conducted with participants of diverse demographics and backgrounds. The participants evaluated the designs and reported how they would feel and behave if they were using these products. Detailed usage scenarios were described to the participants to help reveal more realistic emotions.

3.1 Design Prompts

The four products meant to encourage electricity or water conservation in the study were:

- *an **Electricity Meter** that monitors home electricity usage*
- *a **Light Switch** that reminds people to turn off the lights when leaving a room*
- *a **Water Faucet** that monitors the day's cumulative water usage*
- *a **Washing Machine** with a selectable water-saving mode*

These four products were selected based on design literature [9,55,56] and were evaluated in a previous study by the authors [11]. The designs were modified slightly to make the intention of encouraging resource conservation behavior clearer. For example, a target usage value was added to the electricity meter display to set a goal for electricity conservation.

Two versions of each product that provided feedback information were created: a *Quantitative* design that displayed the resource consumption information in the form of text or a chart, and a *Figurative* design that used a drawing of an animal as a reminder of resource usage's impact on environmental sustainability. In addition, a *Neutral* design was created for each product, with either no specific instruction on resource conservation (the electricity meter) or no feedback information at all (the light switch, water faucet, and washing machine designs). These neutral designs served as a baseline control group for user emotions and actions. Figure 1 presents the sketches of each version of the four eco-feedback products.

Animated GIFs were created for the electricity meter and water faucet designs to demonstrate the information they would display during use. For example, GIF animations of the water faucet designs showed water flowing out of the faucet as the number of liters of water used ticked up; the quantitative water faucet design showed the bar chart growing and the figurative water faucet design showed the water level in the fish tank dropping.

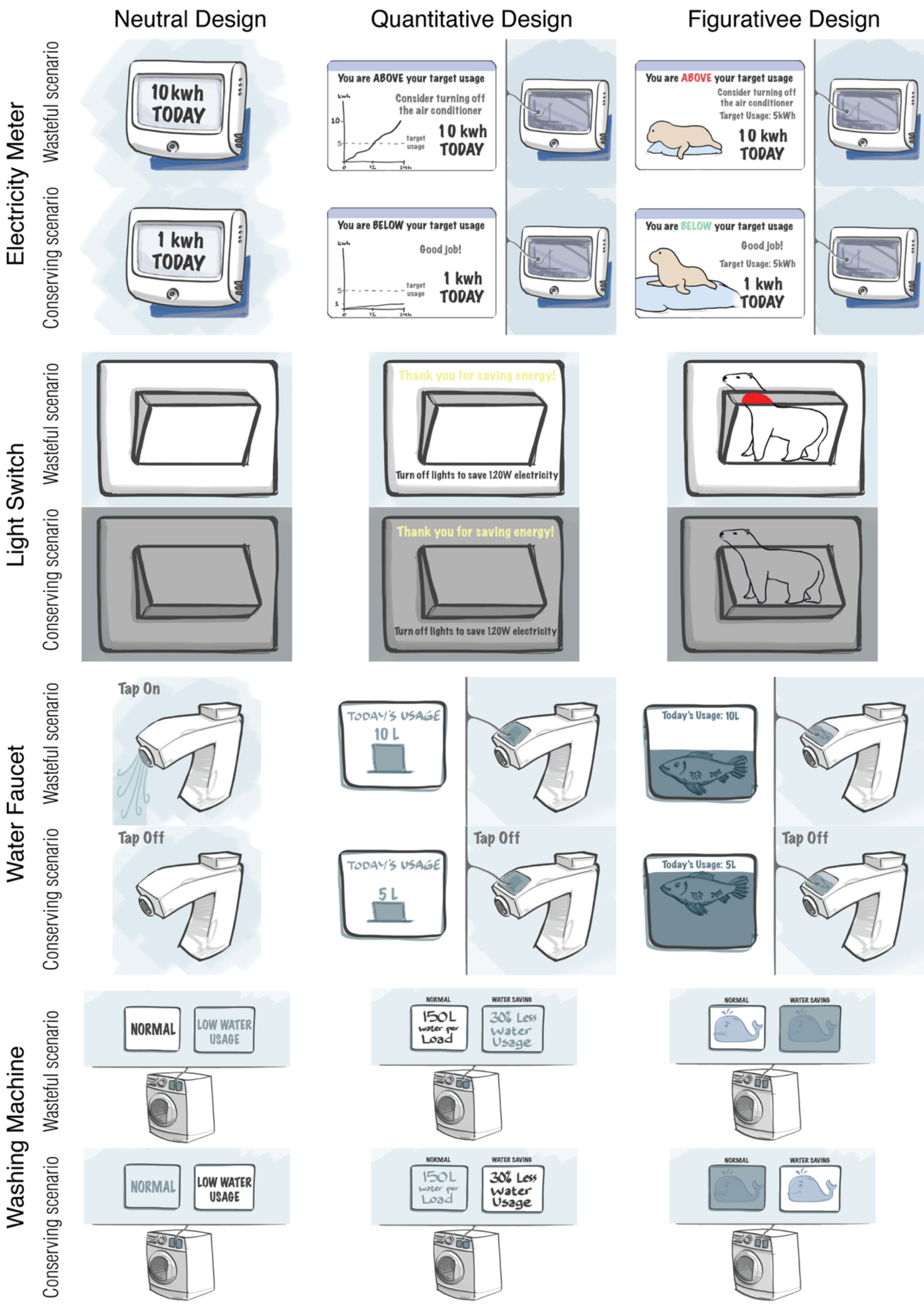

Figure 1 The neutral, quantitative and figurative designs of four eco-feedback products in a conserving scenario and a wasteful scenario

3.2 Usage Scenarios

For each product, users were first presented with an *actionable* scenario in which they could take actions to conserve electricity or water. The scenarios were constructed such that there was a tradeoff of convenience for the sustainable behavior. For example (see Figure 2), for the water faucet designs, participants were asked to imagine that they were washing dishes after dinner and noticed the water usage increasing on the faucet display. They were asked how likely they were going to turn off the faucet to save water. A 1-7 scale was provided where 1 was “definitely not” and 7 was “definitely” taking action. The responses to this question will be referred to as the “certainty of taking resource conservation action” in the rest of this paper. The scenarios were presented in neutral language to reduce social desirability bias that might incline participants to respond that they would always take the sustainable action [57].

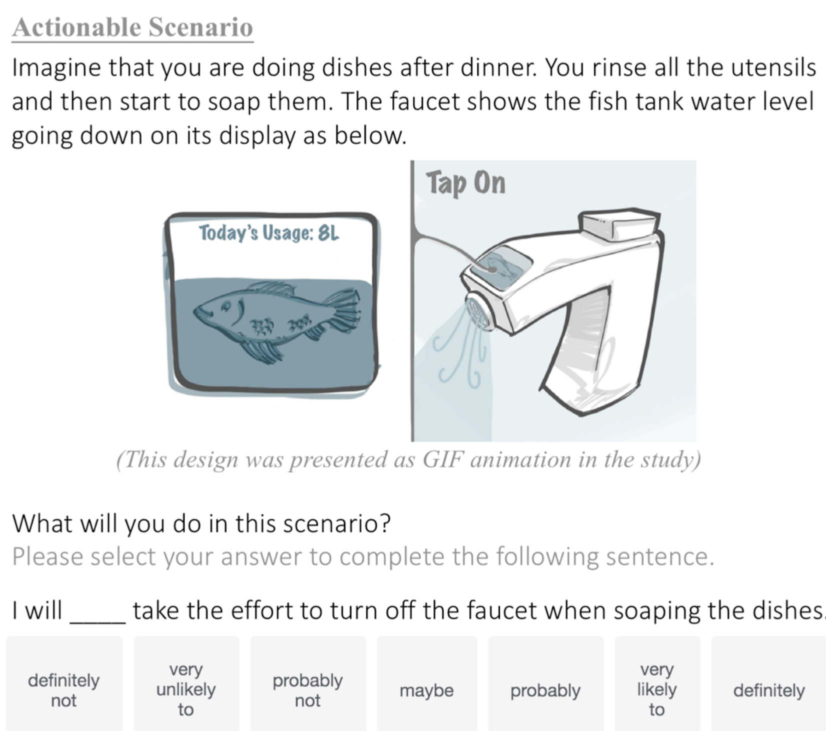

Figure 2 Actionable product usage scenario of figurative water faucet design

Additionally, a *conserving* and a *wasteful* scenario was created for each product. In the conserving scenario, participants were asked to imagine that they used the product sustainably or followed the directives of the product to conserve resources. In the wasteful scenario, participants were asked to imagine that they failed to use the product sustainably, thus wasting water or electricity.

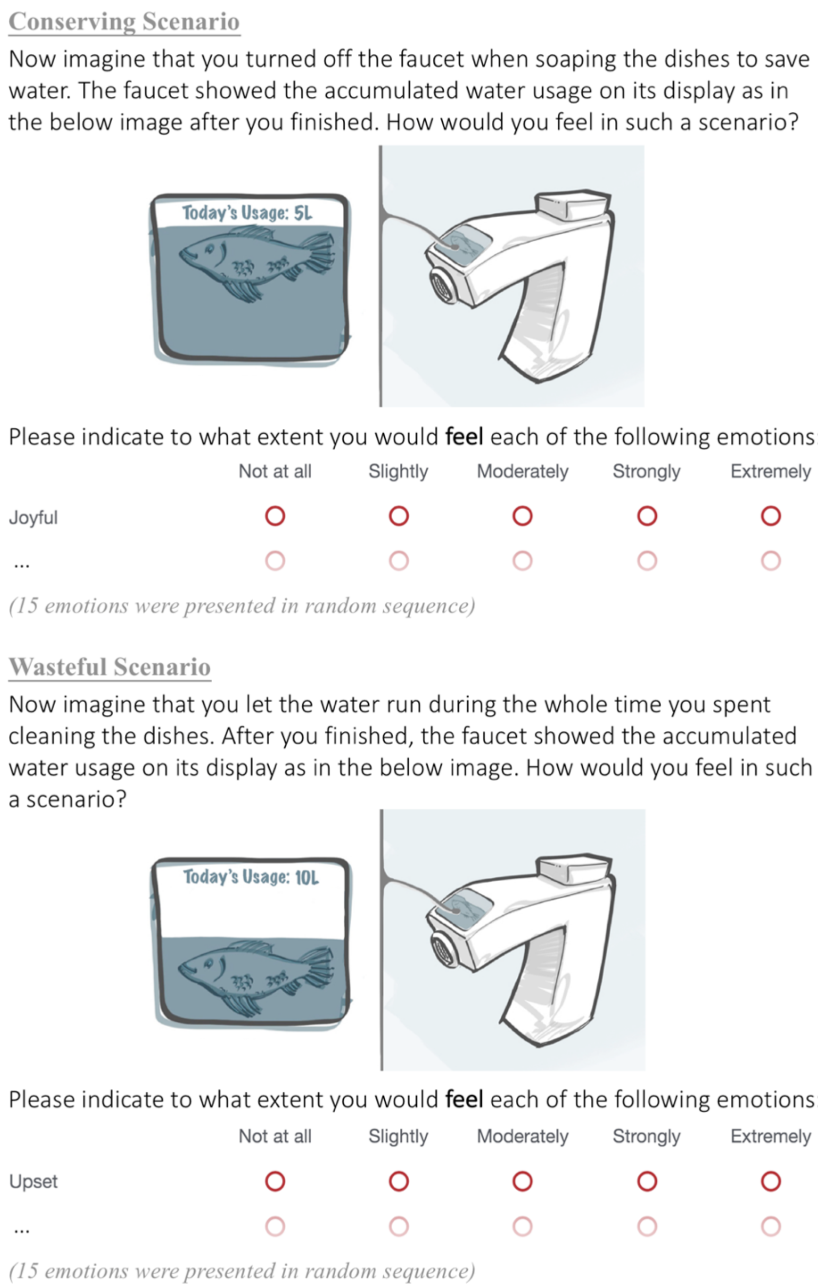

Figure 3 Conserving and wasteful product usage scenarios

In the water faucet example (Figure 3), the user would turn off the faucet to save water in the conserving scenario, and let the water run in the wasteful scenario. These scenarios were described in written form and were accompanied by sketches of the designs summarized in Figure 1. Participants were asked to report their emotions (how they would feel) in both the conserving and the wasteful scenarios.

3.3 Emotion Evaluation

Participants self-reported their emotional reactions in both the conserving and wasteful scenarios with verbal emotion descriptors. Fifteen emotions were evaluated: *interested*, *excited*, *proud*, *joyful*, *satisfied*, *hopeful*, *warmhearted*, *surprised*, *upset*, *worried*, *annoyed*, *embarrassed*, *guilty*, *skeptical*, and *bored*. These emotion labels were chosen from the PANAS [12] and the CES [13] word sets, and were pilot tested for their appropriateness for the usage scenarios. The emotions were intended to span positive and negative options, and to include words associated with a user's consumption experience and resource conservation behavior. The number of emotions was formulated such that it was sufficient for describing the product usage scenarios but also concise enough to avoid survey fatigue. The sequence in which the 15 emotions were presented was randomized in the survey.

Participants reported the extent to which they would feel each emotion on a 1-5 scale: 1 - Not at all, 2 - Slightly, 3 - Moderately, 4 - Strongly, and 5 - Extremely. For mathematical convenience, the responses of 1-5 were later mapped to a 0-4 scale, thus the response of "not at all" would correspond to an emotional intensity of 0. Then the emotional responses were normalized using participants' positive and negative affects, the details of which will be described in section 4.2.

3.4 Design Evaluation

In addition, participants evaluated each design on its *Aesthetics*, *Usefulness* for encouraging resource conservation behavior, their *Willingness to Use* it, and its *Overall Quality*. 1-5 Likert scales were provided for the evaluations. These criteria were created based on selected measures of Garvin's eight dimensions of product quality [58]. Only measures that the participants could reasonably judge by looking at the design sketches were chosen, and were tailored to the features of the eco-feedback designs.

These evaluations were subjective assessments from individual respondents and approximated how users perceived each design. The results reflected whether the users perceived an eco-feedback design to be attractive and provided clues on whether the designs would be well accepted. Eliciting user feedback to provisional design ideas in the early design stage is important as it can help eliminate risks in product development and increase the chances of product success. We followed established methodology by presenting all designs in a consistent style to allow fair comparison [59].

3.5 Experimental Setup

The experiment was conducted with individual participants. Seventy-one adults were recruited via the MIT Behavioral Research Lab, a dedicated facility on campus that maintains a pool of potential research participants for researchers across the institution. Participants could be of any background and were not limited to students or staff working on campus, and thus their age and level of education could cover a broad range. Each participant received a $15 Amazon gift card as compensation. The Behavioral Research Lab served as the setting for the experiment itself.

Participants were divided into three experimental groups: a *control group* that viewed only neutral designs, a *quantitative group* that viewed only quantitative designs, and a *figurative* *group* that viewed only figurative designs. The experiments were conducted in two stages. Stage 1 took place in February 2018. Thirty participants were recruited and tested with only the quantitative and figurative designs, the results of which are reported in our previous publication [60]. Stage 2 took place in June 2018 with an additional 41 participants. All three groups of designs were tested in this second stage. Minor adjustments were made to the experimental process between the two stages as described next.

3.6 Experimental Process

The entire process took about 45 minutes. The main steps of the experiment were:

a) **Introduction** Participants were introduced to the scope of the study and the process of the experiment. Informed consent was obtained.

b) **Practice Questions** To familiarize participants with the emotion evaluation questions, two practice questions were asked: one reporting their current moods and another reporting emotions in a described scenario. Any ambiguity in the questions was clarified at this point.

c) **Pro-Environmental Attitude** Participants completed the New Ecological Paradigm (NEP) scale [61] in which they indicated if they agreed or disagreed with 15 environment-related statements. The summation of responses to all 15 statements represented participants' pro-environmental attitude. The results were used to check if participants' product usage behavior was influenced by their environmental awareness.

d) **Current Moods** Participants reported their current moods with the PANAS [12], which has ten positive and ten negative emotion descriptors. The summed scores of the positive and negative emotion descriptors were a participant's positive and negative affect, respectively. The results were used to normalize participant's emotional responses when using the products.

e) **Product-Related Emotions & Design Evaluation** Participants were presented with four eco-feedback products in a random sequence. For each product, the participants reported what they would do and how they would feel in usage scenarios as described in section 3.2 and 3.3. Then they evaluated the design as described in section 3.4.

f) **Demographics Questions** Data including age, gender, education level, and occupation were collected.

g) **Post-Experimental Interview** Semi-structured interviews were conducted asking open ended questions including how much the participants liked the designs and why; what kind of emotions they would feel when using the products and why; and how they would behave (take actions to conserve resources or not) and why. Notes were taken by researchers during the interviews and were summarized to provide insights into how and when the participants would feel certain emotions, and how emotions were linked to participants' behavior and their evaluations of the designs.

Questions from step c) to f) were presented in a survey created with Qualtrics, an online survey tool. The participants answered the questions on a computer by themselves. The researchers were out of view to reduce social desirability bias on their responses, though at least one researcher was nearby in case the participant had questions. The entire experiment was video recorded.

Two rounds of pilot studies were conducted. The first round was with five students and focused on the question wording, especially the emotion evaluation questions. The second round focused on testing the experimental process and was conducted with three graduate students. The design prompts and the questions were adjusted based on the feedback from the pilot studies.

In stage 1 of the experiment, the sequence of the experimental steps was exactly as described above. In stage 2, the sequence was adjusted and step c) was moved after step e) in case of any potential priming effect of the pro-environmental attitude questions on participants' responses to the usage scenarios. This adjustment did not significantly influence the results, as will be described in section 4.1.

4 RESULTS

4.1 Study Participants

Thirty and forty-one participants took part in the study in stages 1 and 2, respectively. Three participants in stage 2 reported noticeably inconsistent emotions in step e (survey) and step g (interview) of the experiment. We considered their data unreliable and excluded them from the dataset, leaving 68 participants for further analysis.

No significant differences were observed between the two stages in participants' certainty of taking resource conservation actions or in their pro-environmental attitude scores (see APPENDIX I). This suggested that the adjustment of the experimental sequence didn't make significant impact on the study results and asking pro-environmental attitude questions (experiment step c) prior to the design evaluation questions (step e) didn't induce a significant priming effect. Therefore, we combined the stage 1 and stage 2 data.

Among the 68 participants whose data were kept for further analysis, 37 were female and 31 were male. They varied in age from 21 to 65. The gender and age information was available prior to the experiments and was used to evenly assign participants to the experimental groups. Participants with different levels of education were also distributed evenly in the experimental groups. Twenty-five participants were current college or graduate students; the rest had various occupations including researcher, manager, clinician, preschool teacher, accountant, driver, carpenter, and others. Participants' demographic distributions within each experimental group are summarized in Table 1.

Table 1 Demographic distributions of study participants

	Control Group	Quantitative Group	Figurative Group
Total number of participants	14	26	28
Gender			
Female	7	14	16
Male	7	12	12
Age			
Mean ± SD	38.4 ± 10.6	38.0 ± 14.1	37.3 ± 15.1
Education Level			
Some college or lower	3	6	5
Bachelor's degree or equivalent	6	11	15
Master or doctoral degree	5	9	8

The positive and negative affect, assessed with the PANAS, represented participants' mood states in the studies. The positive affect varied between 18-45 and the negative affect varied between 10-26 (possible ranges were 10-50). No significant differences were found between experimental groups with ANOVA tests (positive affect F-value = 0.019, p-value = 0.981; negative affect F-value = 0.571, p-value = 0.568). Participants' pro-environmental attitude scores varied from 35 to 75, with 57 as the median (possible range was 15 to 75). Again, no significant differences were found between groups (ANOVA F-value = 0.185, p-value = 0.831).

4.2 Spectrum of Emotions

Participants' reported emotions about using products were significantly correlated with their positive and negative affects. To rule out the impact of participants' mood on their emotional reactions, the positive and negative affects were used to normalize product related emotions. The normalizations largely reduced the correlations (see APPENDIX II). After normalization, emotions varied in a range between 0-10, where 0 represented not feeling an emotion at all and 10 indicated feeling an extremely strong emotion.

Though the intensity of emotions with respect to using an eco-feedback product varied across participants and was influenced by the types of products, the trend was consistent that more positive emotions arose in conserving scenarios and more negative emotions arose in wasteful scenarios. The distributions of user emotions in each experimental group (with four products pooled together) are summarized in Figure 4.

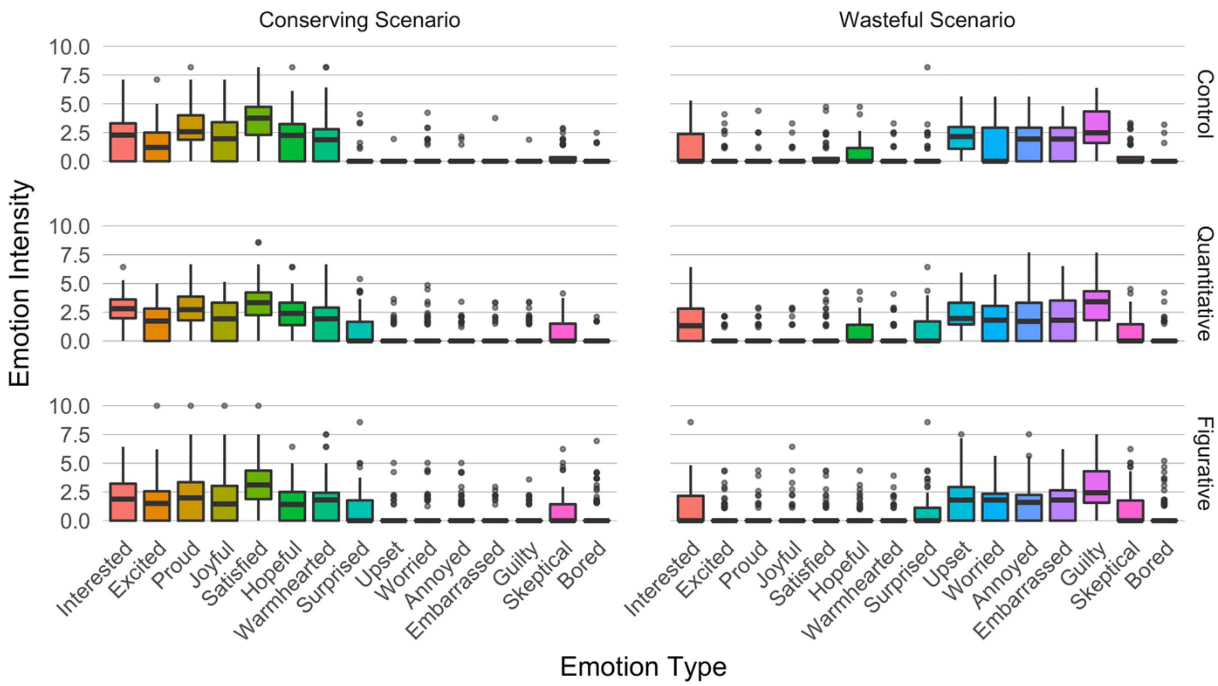

Figure 4 Distributions (boxplots) of intensity of 15 emotions of using the products in the conserving (left) and wasteful (right) scenarios

Overall, the emotions with the highest mean values in conserving scenarios were *satisfied* (mean ± sd: 3.3 ± 1.8)*, proud* (2.5 ± 1.8), and *interested* (2.2 ± 1.7)*.* The strongest emotion in wasteful scenarios was *guilty* (2.9 ± 1.8)*,* followed by *upset* (2.0 ± 1.6)*, embarrassed* (1.9 ± 1.7), *annoyed* (1.9 ± 1.7) and *worried* (1.7 ± 1.5). *Skeptical* (0.6 ± 1.1) was the dominant negative emotion in conserving scenarios; and *interested* (1.2 ± 1.5) was the dominant positive emotion in wasteful scenarios.

It was expected that participants in the control group would not have strong emotional reactions in the product usage scenarios, since the neutral designs they saw had little or no feedback information. However, contrary to this expectation, they did report strong emotions. In interviews, all but one control group participant reported that they would feel positive emotions in conserving scenarios and/or negative emotions in wasteful scenarios. Seven participants expressed that they would feel *good* or *happy* to conserve resources, six indicated that they would feel *satisfied*, three said they would be *proud* of themselves, and two reported being *excited* about conserving. Six participants indicated they would feel *guilty* about wasting, three would be *annoyed* with themselves if they forgot to or could not conserve resources, two would be *upset,* one would feel *frustrated*, and two would feel *bad* about wasting. There was one participant who indicated that the designs were "generic" and thus would not evoke any particular emotions in him. At the same time, the emotions reported by control group participants were not necessarily directly linked to the designs but were more a reflection on their past experience of consuming resources or their own attitude toward resource conservation.

In the quantitative and figurative groups, the reported emotions were not only linked to resource consumption or conservation, but also linked to the designs. In the interviews, seven quantitative group participants mentioned that they were pleased to see the "thank you" note or the "good job" note on designs and thus were motivated to conserve resources, and half of the figurative group participants said that seeing sad animal images made them feel *upset* or *guilty* while happy animal images made them feel *joyful* or *satisfied*. In addition, participants in quantitative and figurative groups reported feeling *surprised* or *skeptical* noticeably more frequently than control group participants (see Figure 4). They found information or graphics presented in the designs surprising, such as the "150 L water per load" message on the washing machine button, which was an unexpectedly large volume of water used by a traditional washing machine; or the stylistically decapitated polar bear on the light switch. Also, they could be skeptical about how accurate these devices were at tracking resource usage, or how the resource usage targets were set.

4.3 Designs and Emotions

To simplify the comparison of emotions between groups, principal component analysis was conducted on emotions in the conserving and wasteful scenarios. The first principal components (PCs) in the conserving and wasteful scenarios could explain 75% and 66% of their respective variances, which were high. And thus, they were used as representations of the emotions in each scenario. The PC in conserving scenarios was highly correlated with positive emotions such as *satisfied*, *proud*, *interested,* and *joyful*; the PC in wasteful scenarios was highly correlated with negative emotions including *guilty*, *upset*, *embarrassed,* and *annoyed*. Factor loadings and percentage of variance of the first principal components are summarized in Table 2.

Notable differences in opinion were observed between younger and older participants in the figurative group. During the interviews, five participants didn't link the polar bear image or the seal on an iceberg image to global warming and thus didn't link the animal figures to the consumption of energy. All five were among the older half of the participants. Seven participants didn't like the animal images' cartoonish style because they were juvenile; six of these were in the older half. This led us to explore the differences in emotional responses between older and younger participants. We were mindful that age might not be the primary underlying reason for these difference. There may exist other factors that might explain the differences, such as the participants' experiences or whether environmental education was part of their school curriculum. Therefore, we segmented the participants based on their generational cohorts [62].

Table 2 Factor loadings and the percentage of variance of the emotions' first principal components in conserving and wasteful scenarios

	Conserving Scenario	Wasteful Scenario
Interested	0.356	0.225
Excited	0.301	0.055
Proud	0.414	0.028
Joyful	0.354	0.025
Satisfied	0.503	0.047
Hopeful	0.318	0.079
Warmhearted	0.321	0.037
Surprised	0.136	0.131
Upset	0.014	0.419
Worried	0.045	0.345
Annoyed	0.022	0.380
Embarrassed	0.019	0.383
Guilty	0.026	0.563
Skeptical	0.078	0.116
Bored	0.021	0.039
Percentage of variance	74.8%	66.3%

Note: A factor loading represents the correlation between a principal component and an original variable; the higher the factor loading, the stronger the correlation.

We divided the participants into two age groups using 37 years old as a cutoff: the younger group represented the Millennials cohort, and the older group represented the Generation X and Baby Boomer cohorts. The age cutoff was close to participants' median age (35 years old). Therefore, each age group had enough people for meaningful statistical comparison (control, quantitative, and figurative groups each had 7, 15, and 16 participants in their younger groups, and 7, 11, and 12 participants in their older groups). We not only compared emotions between the experimental groups, but also between the younger and older age groups.

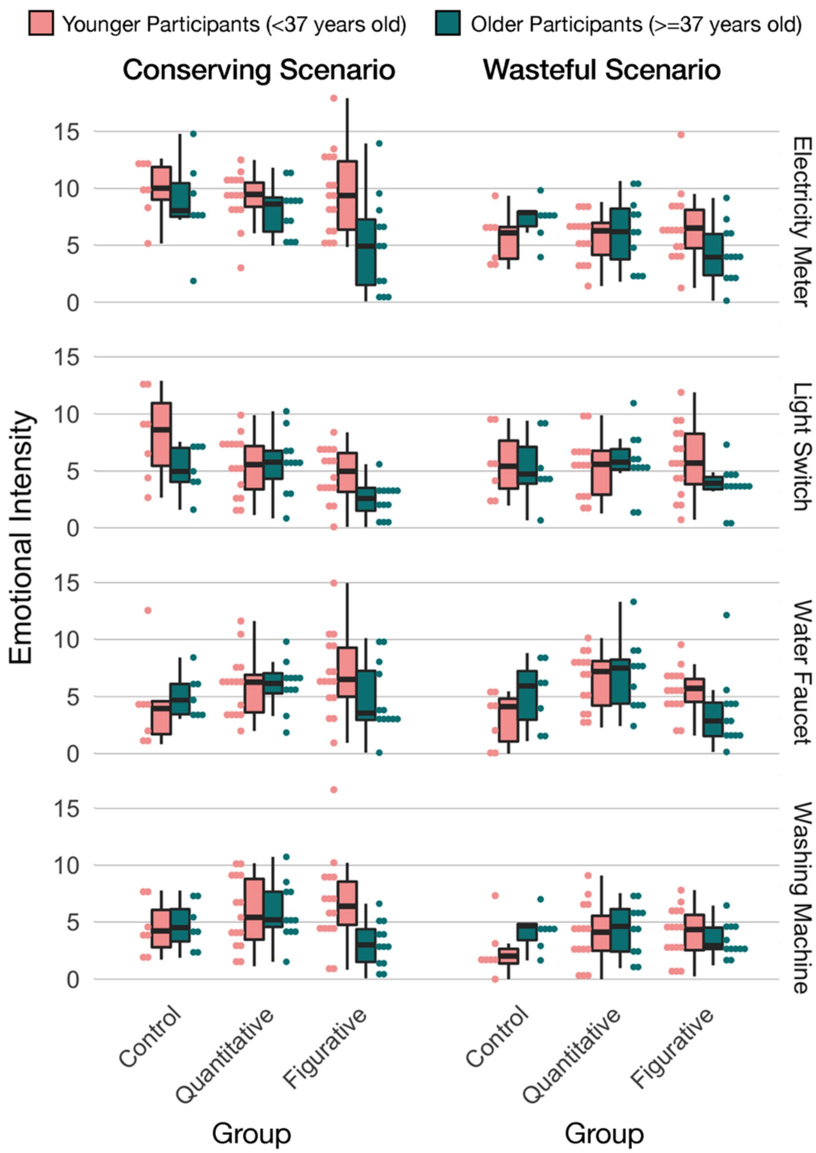

Figure 5 Comparing principal components of emotions in conserving and wasteful scenarios, between experimental groups and between age groups
Note: This graph uses both boxplots and dotplots to illustrate the distributions of the emotion principal components. The boxplots show the overall distributions and make it easier to compare distributions between groups, while the dotplots provide more details with raw data.

Figure 5 shows the distribution of the PCs of emotions towards the four products within each experimental group and each age group. Analysis of variance (ANOVA) was conducted to detect if there were any significant differences between groups (Table 3). The emotions towards all four products were pooled together for the analysis. Benjamini & Hochberg (BH) method was applied to adjust the p-values to reduce false detection in multiple comparisons.

Table 3 ANOVA of emotions between experimental groups and between age groups

		Conserving scenario	Wasteful scenario
Between younger & older participants	**in control group**	0.747 (0.652)	3.360 (0.102)
	in quantitative group	0.104 (0.817)	0.652 (0.421)
	in figurative group	23.165 (<0.001)	13.409 (0.001)
Between experimental groups	**among younger participants**	0.202 (0.817)	2.549 (0.102)
	among older participants	10.290 (<0.001)	8.405 (0.001)

Note: ANOVA results are presented as *F-value (adjusted p-value)*. Results significant on 0.05 levels are highlighted in grey.

In the figurative group, the intensity of emotions of older participants were significantly lower than that of the younger participants. The differences between age groups within the control group and within the quantitative group were not significant. In addition, significant differences were detected between older participants in different experimental groups. Further pairwise comparisons showed that older participants' intensity of emotions was significantly lower in the figurative group, compared to either the control group or the quantitative group, in both the conserving and wasteful scenario (conserving scenario: F-value = 8.276 and 19.441, adjusted p-value = 0.008 and <0.001; wasteful scenario: F-value = 9.629 and 14.850, adjusted p-value = 0.004 and <0.001, compared to control group and quantitative group, respectively). No significant differences were detected between the three experimental groups among the younger participants, taking all four products into consideration.

To detect if any other demographic factors or the environmental attitude of participants had influence on the emotion intensity, linear regressions were conducted between the emotion PCs and participants' age, gender, education level, and pro-environmental attitude scores (see APPENDIX III). Positive links were found between the participants' pro-environmental attitude scores and their emotion PCs in both conserving and wasteful scenario, indicating the emotions revealed in the study to a certain extent reflected participants' pro-environmental attitudes. Age was linked with the emotion PCs, consistent with the above ANOVA analysis. Gender and education level were not found to be significantly linked with emotion PCs.

4.4 Resource Conservation Action and Design Evaluations

In this section, we compare between experimental groups on users' reported certainty of taking resource conservation action and their evaluation on designs. Results of the four design evaluation criteria: aesthetics, usefulness, willingness to use, and overall quality, were highly correlated with each other (Pearson correlation coefficients ranging from 0.48 to 0.74). Therefore, we choose to present only the overall quality ratings to save space. The distributions of the certainty of conserving resources and the design quality evaluations are summarized in Figure 6.

ANOVA was conducted to compare between groups, the results of which also presented in Figure 6. Significant differences were detected between water faucet designs in users' certainty of turning off the faucet and their overall quality evaluations. In addition, significant differences were found between the quality evaluations on light switch designs. Further pairwise comparisons were conducted when significant differences were detected.

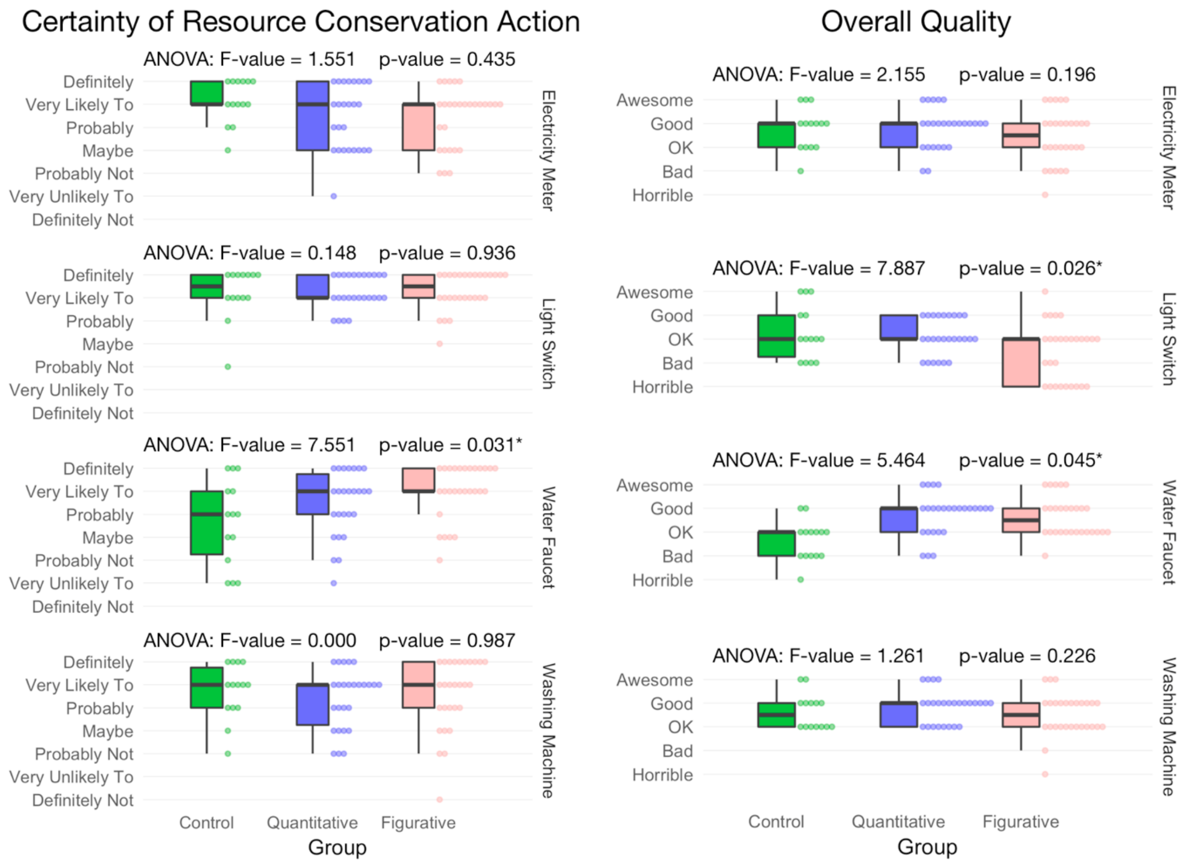

Figure 6 Certainty of taking resource conservation action (left) and users' evaluation on designs' overall quality (right)

Note: ANOVA results are presented as *F-value (p-value adjusted with* BH method*)*. Adjusted p-values smaller than 0.05 are highlighted with *. Similar to Figure 5, this graph uses both boxplots and dotplots to illustrate the result distributions. The boxplots show the overall distributions, while dotplots show the raw data.

With regard to light switch designs, the figurative design with the polar bear image had marginally lower overall quality ratings compared to both the neutral design (F-value = 4.513, adjusted p-value = 0.060) and the quantitative design (F-value = 5.543, adjusted p-value = 0.060). During the interviews, half of the control group participants commented that the neutral light switch was a simple design and looked common. Four quantitative group participants thought the information about energy consumption was useful, however, five quantitative group participants indicated that the information was not helpful as they didn't have a clear intuition for how much 120W of electricity is. In addition, eleven quantitative group participants commented that the text reminder was too small and thus might not attract attention. Comments on the figurative light switch design were polarized. Twenty participants said that the graphic of a decapitated polar bear was too violent and thus inappropriate. Among those, four thought the design was manipulative and would drive people away and another six commented that the design would make them not want to turn on the light at all. At the same time, six participants considered the design to be humorous and a compelling way to attract attention and encourage people to turn off lights. The certainty of turning off light switches was high regardless of the design, as two-thirds of the participants indicated that turning off light was a regular habit.

As for the water faucet, providing feedback on water usage made the participants much more likely to conserve water. In interviews, around two-thirds participants in both quantitative and figurative groups indicated the feedback information on the faucet was useful and made them aware of their water usage, which would be neglected easily otherwise. Pairwise comparisons showed that participants' certainty of turning off water faucets was significantly higher in the figurative group than in the control group (ANOVA F-value = 8.263, adjusted p-value = 0.019). Also, both the quantitative and figurative water faucet designs had higher quality ratings than the neutral design (F-value = 14.447 and 13.506, adjusted p-value = 0.001 and 0.001, respectively). The fish image on the figurative water faucet design was much better accepted than the polar bear image on the light switch design, seemingly because the metaphorical link between fish and water was considered more direct than the link between polar bear and electricity. In addition, even though the GIF animation indicated that using too much water would eventually drain the water tank of the fish, it didn't directly show any image of the fish being harmed, and thus was considered milder.

Linear regressions were conducted between the certainty of conservation action, design evaluations, and participants' demographic factors, pro-environmental scores and emotion principal components (see APPENDIX III). Pro-environmental attitude was not directly linked to either the certainty of conservation action or design evaluations. Age was negatively linked with the aesthetics rating, consistent with the observation that older participants in general appreciated the cartoon styled drawings less. Education level appeared to be significantly linked with all four design evaluations – the higher a participant's education level was, the lower they tended to rate the designs. Additionally, certainty of conservation actions was significantly linked to the emotion PC in wasteful scenarios, and almost all design evaluations were significantly linked to emotion PC in conserving scenarios. Next, we'll elaborate on these links between resource conservation behavior, design evaluation, and user emotions.

4.5 Links between User Emotions, Resource Conservation Behaviors and Perceptions of Eco-Feedback Products

To identify links between user emotions regarding using eco-feedback products and users' resource conservation behaviors, Pearson correlations were calculated between the emotion principal components and the certainty of resource conservation actions. In addition, correlations were calculated between the emotion PCs and the four design evaluations. To reduce false detections of significant correlations, BH adjustment was applied to the p-values. The correlation results are summarized in Table 4.

Table 4 Correlation between principal component of emotions, and certainty of conservation actions and design evaluations

Correlations between		Control Group	Quantitative Group	Figurative Group
Emotion PCs in Conserving Scenario	**Action**	0.365 (0.028)	0.142 (0.149)	0.060 (0.531)
	Aesthetics	0.085 (0.658)	0.327 (0.002)	0.353 (<0.001)
	Usefulness	0.154 (0.641)	0.290 (0.005)	0.367 (<0.001)
	Willingness To Use	-0.066 (0.658)	0.202 (0.049)	0.121 (0.257)
	Overall Quality	0.06 (0.658)	0.337 (0.002)	0.303 (0.002)
Emotion PCs in Wasteful Scenario	**Action**	0.535 (<0.001)	0.442 (<0.001)	0.234 (0.033)
	Aesthetics	0.119 (0.708)	0.097 (0.408)	0.207 (0.047)
	Usefulness	-0.011 (0.935)	0.185 (0.150)	0.256 (0.033)
	Willingness To Use	0.109 (0.708)	0.134 (0.292)	0.061 (0.520)
	Overall Quality	0.050 (0.891)	0.080 (0.421)	0.163 (0.108)

Note: Pearson correlation results are presented as *correlation coefficient (adjusted p-value)*. Correlations significant on 0.05 levels are highlighted in grey.

In the control group, the certainty of participants taking actions to reduce electricity/water waste was significantly positively correlated with both the emotion PC in conserving scenarios (representing positive emotions such as *satisfied*, *proud*, *interested* and *joyful*) and the emotion PC in wasteful scenarios (representing negative emotions such as *guilty*, *upset*, *embarrassed* and *annoyed*). This was consistent with the interview results that in situations where the participants had strong intensity to take actions to conserve resources, they would express positive emotions towards saving and express negative emotions towards wasting; and in situations where they didn't feel the necessity of conserving resources, they wouldn't feel as strongly about wasting or conserving. Actually, it was observed that the feeling of *satisfied* in the wasteful scenario was significantly negatively correlated with the certainty of conservation action in the control group (correlation coefficient = -0.53, adjusted p-value < 0.001), indicating positive emotions towards consumption instead of conservation. No significant correlations were found between the emotion PCs and the design evaluations in the control group, confirming the observation that the emotions in the control group were not directly evoked by the designs (see section 4.2).

In the quantitative and figurative groups, the correlations between certainties of conservation actions and the emotion PCs were still statistically significant in wasteful scenarios, however no longer significant in conserving scenarios. There were presumably multiple reasons behind this phenomenon. First, as described earlier, figurative designs significantly reduced emotions in some participants (see section 4.3), however, did not significantly reduce the certainty of taking actions and in some scenarios even increased the certainty (see section 4.4). This could potentially explain the decreasing of correlations between emotions and certainty of taking conservation actions. Secondly, in actionable scenarios (where participants answering questions of how likely they were going to take actions to conserve resources), the participants were presented with product sketches (or GIF animations) corresponding to those in wasteful scenarios. This might explain why certainty of taking actions had stronger correlations with the negative emotions in wasteful scenarios than with the positive emotions in conserving scenarios.

More interestingly, significant correlations were found between emotion PCs and design evaluations in the quantitative and figurative groups, demonstrating strong links between user emotions and their perceptions of the designs. In general, design evaluations were significantly correlated with positive emotions in conserving scenarios in both quantitative and figurative groups, suggesting the importance of fostering positive emotions in eco-feedback designs: if a product made the users feel good about conserving resources, they might be more engaged with the product in the long run. In the figurative group, the negative emotions in wasteful scenarios were also significantly correlated with the evaluation on products' aesthetics and usefulness on encouraging sustainable behavior. One potential explanation was that, participants who appreciated the drawing style of the figurative designs (that is, gave them higher aesthetics ratings) would be more likely to empathize with the animal images presented on the designs (with stronger feelings of *guilty*, *upset,* etc. when seeing images of sad animals), and also thought these emotions were effective in encouraging resource conservation behavior (gave higher useful ratings). However, it should be noted that correlations between positive emotions and design evaluations were much stronger, even in the figurative group. As revealed by the post-study interviews, if a product made the users feel bad, the users might avoid interacting with the product in order to keep away negative feelings.

5 DISCUSSION

Key findings of the study are highlighted below and discussed in response to the original research questions:

1. *What are the emotions that arise from users' interactions with eco-feedback products?*

In this study we took a discrete emotion perspective [63,64], treating emotions as distinguishable units and providing study participants with emotion labels to rate. We chose commonly used labels such as *proud* and *guilty,* assuming these could be recognized and consciously reported. Our analysis also relied upon a dimensional model of emotions [65] and used positive affect and negative affect measurements of participants to normalize the intensity of their emotional responses.

By providing study participants with product usage scenarios, we successfully revealed not only visceral emotions towards the appearance of the designs, but also behavioral emotions towards using the products, and reflective emotions towards the consumption and conservation of resources [1]. In the control group where participants seeing designs with little or no feedback information, their reported emotions mostly came from past experience of consuming or conserving electricity and water, and reflected their attitudes towards resource conservation. In a scenario where a user successfully conserved resources, positive emotions such as *satisfied* and *proud* tended to dominate. In a scenario where a user failed to conserve resources, feelings such as *guilty*, *embarrassed,* or *upset* were likely to arise.

In the quantitative and figurative groups where the designs were embedded with feedback information on resource consumption and explicitly encouraged conservation behaviors, the revealed user emotions were a mix of these behavioral and reflective emotions and emotions directly elicited by the designs. Eco-feedback information could enhance positive emotions towards saving and negative emotions towards wasting. For example, users may empathize with the animals in the figurative designs, experience negative emotions when seeing sad or dying animal images, and experience positive emotions when "saving" the animals and seeing happy animal images. These emotions seem likely to have been generated by a combination of both bottom-up and top-down processes [66]: emotions could either be triggered directly by visual stimuli in the sketches (such as a decapitated polar bear) or arise via higher-level cognitive interpretations drawing upon stored knowledge (such as the fact that greenhouse gas emissions accelerate global warming and thus endanger wildlife). In this experimental setting it was difficult to tease out how much each process might have been involved in the generation of a particular response.

Eco-feedback products generally made people curious about their resource consumption, even though users could also be *skeptical* about the accuracy of feedback information. Additionally, the quantitative designs and figurative designs were more likely to make participants feel *surprised* compared to the neutral designs. On one hand, this validated the use of neutral designs in the control experimental setting; on the other hand, this indicated that the eco-feedback designs would be eye-catching and would attract users' attention. This is actually important, as when users are interacting with products in their daily lives, they may not think about resource consumption and thus unintentionally waste resources. Whether a design can successfully attract users' attention in the first place is the premise of whether it can effectively encourage sustainable behavior. If a design can introduce cognitive dissonance in users by catching them in surprise, there is a chance that the users might change their behavior to resolve the dissonance [67].

2. *What role do emotions play in influencing users' sustainable behavior and their perceptions of eco-feedback products?*

Human behavior is a product of complex interactions between the cognitive and the affective systems of our brains [68]. There are multiple mechanisms by which emotion can shape behavior [69]: sometimes rapid, automatic affective responses directly influence immediate decision making and behavioral choice, while at other times emotions influence behavior less directly, by providing feedback, promoting learning, or altering guidelines for future behavior.

In this study, the reported certainty of taking conservation action was used as a measure of product usage behavior. Since tradeoffs for convenience were included in the actionable scenarios, we collected responses spanning from "definitely" to "definitely not" taking conservation actions. In all experimental groups, significant correlations were found between certainty of taking conservation action and negative emotions in wasteful scenarios. This result is consistent with the negative-state relief model which suggests that experiencing negative feelings such as guilt gives people strong motivation to take action to relieve such feelings [70]. In addition, negative emotions could potentially enrich the user experience [71]. Therefore, it could be effective for a product to elicit negative emotions to encourage resource conservation behaviors.

Nevertheless, we acknowledge that negative feelings could backfire. If the negative emotions evoked by a design are not aligned with users' intentions of conserving resources, they may avoid further interaction with the design. The figurative design of the light switch in our study provides an example. It showed a polar bear that was stylistically decapitated by turning the light switch on. The majority of participants who saw this design reported that they would "definitely" turn off the light to avoid the guilty feeling of "killing" the polar bear. However, more than half of the participants did not like the design and would not want to use it because the negative feeling was too strong. This is consistent with the point of view from existing literature that designers should avoid making users feel guilty [72].

On the contrary, the evaluations of designs' *Aesthetics*, *Usefulness*, and *Overall Quality* in both the quantitative and figurative groups were significantly correlated with positive emotions in conserving scenarios. These design evaluations were reported by individual respondents and represented how they perceived the designs. The significant correlations suggest that positive reinforcement and using positive emotions to reward users would be a favorable strategy to attract users and keep them engaged in sustainable behaviors in the long run (as long as liking a product is correlated with actually using it, a sensible proposition beyond the boundary of this study).

A designer might read the result that emotions in a wasteful scenario correlate extremely significantly with users' stated intent to do better next time as "emotion in a wasteful scenario encourages users to conserve", a prompt that they could then explore and iterate on. The correlations between emotions in a conserving scenario and product quality could provide another prompt that "positive emotions in a conserving scenario makes users like a design". This heuristic hopefully serves as an example of how the results of this study can influence design practice.

Nonetheless, it should be noted that all data were self-reported. Discrepancies may exist between what people say, and how they actually feel or what they actually do, regardless of our effort to minimize such discrepancies. A participant may or may not turn off a water faucet in a real-life scenario even if they have said that they would do so. Further studies could be conducted with physical products or prototypes to investigate the gap between users' stated intention to conserve resources and their actual product-use behavior.

3. *How can we design eco-feedback products to evoke strong and appropriate emotions in users to encourage sustainable behavior?*

Two styles of eco-feedback designs were compared in this study: quantitative designs that emphasize objective resource usage information, and figurative designs that use animal figures as reminders of environmental sustainability. In addition, we created a group of neutral designs which provided little or no feedback information. In a previous study conducted with university students [11], designs with animal figures were evaluated as more "emotionally evocative" than quantitative designs. However, in this study, the intensity of emotional reactions towards the two design styles was not significantly different among participants in the younger age group. This is likely because the emotions evaluated in the previous study were more on the visceral level which was concerned with the appearance of the designs. However, the user emotions revealed in this work also include the behavioral level and reflective level that was concerned with using the products and conserving resources.

Additionally, we observed that figurative designs evoked much stronger emotions in younger participants (below 37 years old) than in older participants (aged 37 years old and up): the figurative designs actually seem to suppress emotions in the older participants. This discrepancy could be explained by the differences between two generations observed in interviews: while the use of arctic animals as symbols of global warming and environmental sustainability was well-known among the younger participants, it was not common knowledge to all older participants; and the cartoonish drawing styles were better accepted by the younger than by the older. This finding provided important lessons for designing emotionally evocative eco-feedback designs for different audiences: a cartoonish design could well fit into a school environment to educate children about resource conservation; it could also fit into a college dorm to initiate discussion about environmental sustainability among students; but it might be less appropriate for a formal workplace where more serious designs are expected. This finding points out the challenge of designing more inclusive eco-feedback designs for a general population.

Among the four products tested, the eco-feedback water faucet appeared to significantly increase the reported certainty of users conserving water and had significantly higher ratings on overall quality compared to the faucet without feedback information. A few features of the eco-feedback water faucet that users liked were pointed out in the post-study interviews. First, eco-feedback information was embedded in the faucet in a noticeable way that users would unlikely miss when using it (while users could choose to not interact or forget to interact with an electricity meter or an light switch). Secondly, the eco-feedback information was presented in a concise and neutral manner in the water faucet. Compared to the electricity meter design, the water faucet did not set any target usage. This provided users with flexibility in terms of how much resources to use and avoided the potential mental accounting effect of goal setting: if the usage was lower than the target, users might feel they could use more and thus result in more wasting than saving. Lastly, the fish image in the figurative design was in general considered good metaphorical symbol of water conservation. While the message of saving water was clearly conveyed, the graphic itself was not as violent or depressing as some other figurative designs might be. These observations pointed to the importance of keeping a balance between eye-catching and unobtrusive, being instructive but not manipulative, and providing trustworthy information in eco-feedback designs.

6 CONCLUSION AND FUTURE WORK

This study has improved our understanding of emotions that arise from users' interactions with eco-feedback products. It was found that higher certainties of users taking actions to conserve resources were linked to stronger negative emotions towards wasting such as *guilty*, *upset, embarrassed,* and *annoyed*; however, users' perception of the designs' aesthetics, usefulness and the overall quality were more correlated with positive emotions towards resource conservation, such as *satisfied*, *proud, interested,* and *joyful.* This suggests that evoking negative emotions in users may be an effective strategy for spurring immediate sustainable behaviors while fostering positive emotions may be more important for engaging users with eco-feedback products in the long term. Longitudinal studies that observe users' interaction with eco-feedback products for longer periods of time could help to confirm these hypotheses and to reveal how user emotions may evolve over time.

Two styles of eco-feedback designs, the quantitative (which emphasized the quantitative resource usage information) and the figurative (which used animal figures as reminders of environmental sustainability), were tested and compared to neutral designs (which had little or no feedback information). It was found that older participants (aged 37 years old and up) overall had very different emotional reactions towards figurative designs compared to younger participants (below 37 years old). This result is helpful for forming guidelines to design more inclusive eco-feedback products, or design eco-feedback products for different generational cohorts.

In this study, preliminary design ideas presented in forms or sketches and GIF animations were used to evaluate users' emotional reactions towards the designs. In addition, detailed usage scenarios were created to help participants report realistic emotions and behaviors. While further studies with physical products or prototypes should be explored to understand user emotions, we believe the method we established is useful to designers and design researchers in the early stage design as it enables the evaluation of many different ideas in a short amount of time.

This study investigated the individual users' perceptions of eco-feedback designs and the product usage scenarios tested in the study were mostly private settings. Future work could also consider eco-feedback in public settings. Community perception of eco-feedback designs in shared spaces and group emotions towards using such designs are interesting topics that could be explored in the future.

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APPENDIX I Comparison Between Experimental Stage 1 and Stage 2

The experiments were conducted in two stages: stage 1 in spring 2018 and stage 2 in summer 2018. Distribution of gender, age, and education level of the participants in each stage and each experimental group were summarized in the table below.

Appendix Table 1 Demographic distributions of study participants within each experimental stage and experimental group

	Control Group	Quantitative Group	Figurative Group
Stage 1	-	**Total: 15** Female: 10; Male: 5 Age: 37.6 ± 15.7 EL1: 4; EL2: 7; EL3: 4	**Total: 15** Female: 9; Male: 6 Age: 35.8 ± 16.9 EL1: 3; EL2: 9; EL3: 3
Stage 2	**Total: 14** Female: 7; Male: 7 Age: 38.4 ± 10.6 EL1: 3; EL2: 6; EL3: 5	**Total: 11** Female: 4; Male: 7 Age: 38.6 ± 12.5 EL1: 2; EL2: 4; EL3: 5	**Total: 13** Female: 7; Male: 6 Age: 38.9 ± 14.1 EL1: 2; EL2: 6; EL3: 5

Note: Age distributions were reported as mean ± sd; EL stands for education level, EL1 – some college or lower degree; EL2 – bachelor's degree or equivalent, EL3 – master or docotoral degree.

Constraint by the pool of participants that were available at the Behavioral Research Lab, the demographic distributions were not exactly the same in the two stages of the experiment. To test if participants' age, gender, and education level were linked to their pro-environmental attitude scores or their certainty of taking conservation actions, we first ran linear regressions:

$$Y \sim Group_Q + Group_F + Age + Gender + EL2 + EL3$$

where Y could be either the certainty of taking conservation action with any of the four products or the pro-environmental attitude score; $Group_Q$ and $Group_F$ were dummy variables for quantitative and figurative groups; $EL2$ and $EL3$ were dummy variables for the education level. No significant coefficients were found for age, gender, or education level in any of these regression analyses, indicating no significant influences of the demographic factors.

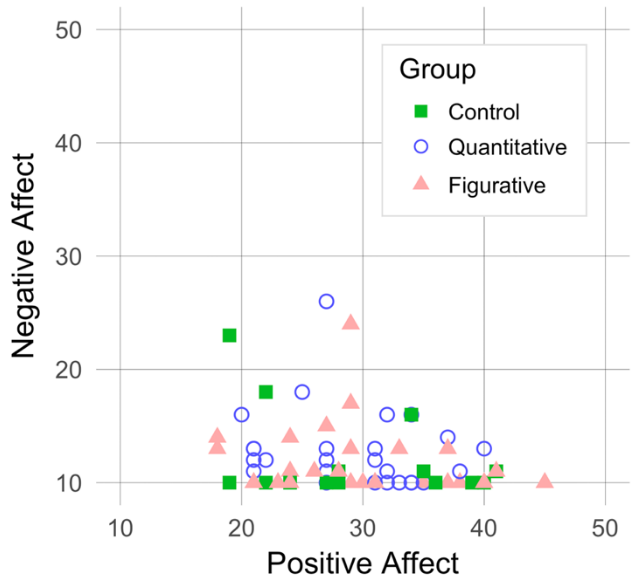
Next, to test if asking pro-environmental attitude questions before evaluating the designs (step e of the experiment) had any priming effect on participants' responses to the questions of how likely they were to take actions to conserve resources, analysis of variance (ANOVA) was conducted between certainty of taking resource conservation actions in stage 1 and stage 2, for each design and within quantitative group and figurative group. In addition, ANOVA was conducted to compare the pro-environmental attitude scores between stage 1 and stage 2 participants within each of the two experimental groups. The results were summarized in the below table. No significant differences (on 0.05 level) were detected.

Appendix Table 2 Comparing two experimental stages with ANOVA

F-value (p-value)		**Quantitative Group**	**Figurative Group**
Certainty of Taking Resource Conservation Action	**Electricity Meter**	2.358 (0.138)	0.027 (0.87)
	Light Switch	0.315 (0.580)	4.179 (0.051)
	Water Faucet	1.314 (0.263)	0 (1)
	Washing Machine	1.721 (0.202)	1.18 (0.287)
Pro-Environmental Attitude Scores		0.065 (0.801)	0.340 (0.565)

APPENDIX II Normalizing Emotions in Product Usage Scenarios using Positive and Negative Affect

Study participants' positive and negative affect was measured before they evaluated the eco-feedback products. The positive affect and negative affect were two independent variables and each could vary in the range of 10 to 50. Their distributions can be found in the below figure.



Appendix Figure 1 Participants' positive and negative affect

Positive emotions (*interested*, *excited*, *proud*, *joyful*, *satisfied*, *hopeful,* and *warmhearted*) and the emotion *surprised* that participants would feel in both conserving and wasteful scenarios were observed to be significantly positively correlated with the positive affect. Negative emotions (*upset*, *worried*, *annoyed*, *and skeptical*) were observed to be significantly positively correlated with the negative affect in both conserving and wasteful scenarios; in addition, negative emotions in the wasteful scenarios were also significantly positively correlated with the positive affect (see Appendix Table 3). Based on these observation, the following equations were used to normalize the emotions:

$$Normalized\{PE_i\} = \frac{PE_i}{PA_i/\max(PA_i)}$$

$$Normalized\{NE_i\} = \frac{NE_i}{\sqrt{\left(\frac{PA_i}{\max(PA_i)}\right)^2 + \left(\frac{NA_i}{\max(NA_i)}\right)^2}} \times \sqrt{2}$$

where PE_i were any positive emotions (PE) or the emotion *surprised* of participant i, NE_i were any negative emotions (NE) of participant i; PA_i and NA_i were the positive affect (PA) and negative affect (NA) of participant i; $\max(PA_i)$ and $\max(NA_i)$ were the largest positive affect and largest negative affect among all participants. The maximum values were included so that the positive emotions and negative emotions would be on comparable scales after normalizations. After normalization, the correlations between emotions and affects were largely reduced (see Appendix Table 3).

Appendix Table 3 Pearson correlation between participants' positive/negative affect and their reported emotion intensity in product usage scenarios before and after normalization

	Before Normalization				After Normalization			
	Positive Affect		Negative Affect		Positive Affect		Negative Affect	
	Conserving Scenario	Wasteful Scenario	Conserving Scenario	Wasteful Scenario	Conserving Scenario	Wasteful Scenario	Conserving Scenario	Wasteful Scenario
Interested	0.391 (<0.001)	0.319 (<0.001)	-0.006 (0.917)	-0.061 (0.600)	0.094 (0.263)	0.185 (0.056)	0.076 (0.459)	-0.012 (0.898)
Excited	0.333 (<0.001)	0.192 (0.003)	0.012 (0.914)	-0.036 (0.759)	0.132 (0.111)	0.096 (0.263)	0.057 (0.524)	-0.01 (0.900)
Proud	0.373 (<0.001)	0.197 (0.002)	-0.033 (0.766)	-0.153 (0.038)	0.085 (0.303)	0.147 (0.104)	0.033 (0.732)	-0.152 (0.134)
Joyful	0.282 (<0.001)	0.201 (0.002)	0.061 (0.600)	-0.145 (0.049)	0.058 (0.487)	0.144 (0.104)	0.127 (0.157)	-0.142 (0.134)
Satisfied	0.28 (<0.001)	0.149 (0.019)	-0.016 (0.909)	-0.054 (0.615)	-0.101 (0.263)	0.035 (0.699)	0.06 (0.524)	-0.026 (0.809)
Hopeful	0.404 (<0.001)	0.213 (0.001)	-0.020 (0.887)	0.009 (0.914)	0.175 (0.056)	0.112 (0.197)	0.033 (0.732)	0.058 (0.524)
Warmhearted	0.264 (<0.001)	0.189 (0.003)	0.057 (0.615)	-0.119 (0.127)	0.043 (0.634)	0.14 (0.106)	0.100 (0.272)	-0.107 (0.254)
Surprised	0.187 (0.003)	0.214 (0.001)	0.010 (0.914)	-0.029 (0.795)	0.058 (0.487)	0.156 (0.103)	0.059 (0.524)	-0.020 (0.838)
Upset	0.037 (0.609)	0.256 (<0.001)	0.190 (0.010)	0.190 (0.010)	0.016 (0.789)	0.135 (0.11)	0.138 (0.134)	0.062 (0.524)
Worried	-0.038 (0.609)	0.200 (0.002)	0.237 (0.001)	0.185 (0.010)	-0.09 (0.278)	0.096 (0.263)	0.157 (0.134)	0.089 (0.326)
Annoyed	0.025 (0.734)	0.173 (0.006)	0.158 (0.034)	0.267 (<0.001)	-0.019 (0.781)	0.061 (0.487)	0.105 (0.254)	0.140 (0.134)
Embarrassed	0.073 (0.274)	0.187 (0.003)	-0.047 (0.655)	0.078 (0.428)	0.033 (0.699)	0.064 (0.487)	-0.055 (0.529)	-0.019 (0.838)
Guilty	0.015 (0.828)	0.163 (0.01)	-0.052 (0.615)	0.139 (0.059)	-0.024 (0.769)	-0.022 (0.774)	-0.059 (0.524)	-0.001 (0.992)
Skeptical	0 (0.995)	0.086 (0.198)	0.207 (0.006)	0.184 (0.01)	-0.056 (0.488)	0.024 (0.769)	0.134 (0.134)	0.115 (0.222)
Bored	0.093 (0.167)	0.178 (0.005)	-0.038 (0.757)	-0.088 (0.337)	0.06 (0.487)	0.123 (0.143)	-0.045 (0.622)	-0.090 (0.326)

Note: The correlation results are reported as *correlation coefficient (p-value)*. HB adjustments were applied to the p-values. Significant correlations on 0.05 levels are highlighted in gray.

APPENDIX III Linear Regression Analysis

Linear regressions were conducted between the emotion principal components and participants' pro-environmental attitude scores, age, gender, and education level. Further, linear regressions were conducted between the certainty of conservation action, design evaluations and emotion principal components, pro-environmental attitude scores, age, gender, and education level. The results are summarized in the table below. Coefficient estimation significant on 0.05 level are highlight in gray.

Group Q and Group F were dummy variables for quantitative and figurative groups. Attitude score and age were normalized to be centered around 0 with standard deviation of 1. Gender was a dummy variable (female = 1, male = 0). EL2 and EL3 were dummy variables for education level (EL2 – bachelor's degree or equivalent, EL3 – master or doctoral degree). *Emotion PC C* and *Emotion PC W* as independent variables were normalized emotion principal components in conserving and wasteful scenarios.

Appendix Table 4 Linear regression result summary

coefficient (p-value)	**Emotion PC C**	**Emotion PC W**	**Action**	**Aesthetics**	**Usefulness**	**Willingness To Use**	**Overall Quality**
(Intercept)	6.703 (<0.001)	5.461 (<0.001)	5.665 (<0.001)	3.039 (<0.001)	3.716 (<0.001)	3.996 (<0.001)	3.604 (<0.001)
Group Q	0.072 (0.895)	0.600 (0.175)	-0.199 (0.330)	0.111 (0.517)	0.492 (0.006)	0.070 (0.725)	0.277 (0.079)
Group F	-0.858 (0.115)	-0.128 (0.771)	0.117 (0.564)	-0.021 (0.900)	0.176 (0.323)	-0.263 (0.182)	-0.019 (0.901)
Attitude	0.642 (0.002)	0.558 (<0.001)	0.112 (0.154)	-0.123 (0.062)	-0.040 (0.561)	0.059 (0.436)	-0.085 (0.164)
Age	-0.681 (0.002)	-0.137 (0.425)	0 (0.997)	-0.15 (0.027)	-0.008 (0.914)	-0.045 (0.564)	-0.122 (0.051)
Gender	-0.110 (0.796)	-0.159 (0.642)	0.117 (0.458)	-0.100 (0.447)	-0.165 (0.233)	-0.110 (0.473)	-0.100 (0.411)
EL2	-0.086 (0.871)	-0.806 (0.061)	0.102 (0.610)	-0.206 (0.217)	-0.535 (0.002)	-0.144 (0.455)	-0.245 (0.112)
EL3	-0.504 (0.376)	-0.300 (0.514)	-0.075 (0.724)	-0.380 (0.033)	-0.737 (<0.001)	-0.522 (0.012)	-0.362 (0.028)
Emotion PC C	-	-	-0.033 (0.702)	0.27 (<0.001)	0.313 (<0.001)	0.064 (0.440)	0.239 (<0.001)
Emotion PC W	-	-	0.504 (<0.001)	0.070 (0.326)	0.052 (0.484)	0.082 (0.321)	0.019 (0.767)
R-squared	0.08	0.075	0.159	0.143	0.183	0.065	0.137
F value	3.263	3.037	5.504	4.861	6.508	2.011	4.624
p-value	0.002	0.004	<0.001	<0.001	<0.001	0.038	<0.001

Table Caption List

Figure Caption List