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INVESTIGATING USER EMOTIONAL RESPONSES TO ECO-FEEDBACK DESIGNS

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ABSTRACT

Emotional responses to a product can be critical to 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 30 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. Results showed that taking immediate resource conservation actions such as turning off lights was correlated with negative emotions such as *guilt* and *embarrassment*. Users' evaluations of product aesthetics, usefulness and overall quality, however, were highly correlated with positive emotions, described as *satisfied*, *hopeful*, *interested* and/or *excited*. Two styles of eco-feedback design, quantitative and figurative, were compared. 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.

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 is comforting 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], easier to implement [8], and has 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 existing emotion assessment frameworks such as 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 would also investigate how different 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?*

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 categories of eco-feedback design 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 30 participants from varying backgrounds. The participants evaluated design ideas for four eco-feedback products and reported how they would feel and behave while using them.

BACKGROUND

1. Design for Sustainable Behavior

There is significant potential for energy and water savings in the US residential sector [14], and efficient technologies and renewable energy systems can play a key role in reducing consumption. However, their adoption is not widespread, and product use is subject to the "rebound effect" [15], wherein more efficient technologies may inadvertently encourage more intensive usage and thus offset the overall environmental benefit. There is an urgent need to develop products that people will use in a more environmentally aware manner. Consequently, there is a growing interest in the research area of design for sustainable product use [4], also known as design for sustainable behavior [5].

Shu, et al. presented a comprehensive review of various design frameworks which seek to reduce resource consumption during product use [8]. 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. Techniques on the product-in-control end, also known as *smart design* or *intelligent design* [18,19], involve automatically taking actions to ensure behavior changes, sometimes without user knowledge or consent. Other techniques including *behavior steering* or *behavior enabling*, in which users are encouraged by constraints or affordances embedded in a design [20] to behave in certain ways.

A substantial number of studies investigate the effectiveness of these techniques alongside user perceptions of the resulting designs. Montazeri, et al. [21] created napkin dispensers that displayed the quantity of napkins used, and validated in a field study each design's effectiveness at reducing consumption. 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 [22] and consumer preferences for sustainable product features [23,24].

2. Users' Emotions and Design

The emotional connections between users and products are recognized as indicators and moderators for delightful product experiences [25]. Strategies and methodologies have been developed to design products to elicit intended feelings, i.e. Kansei Engineering [26], or to design pleasurable products [27]. In addition, existing research has recognized the important role emotions play in marketing [28]. Pleasant surprise and interest are both strong indicators of customer satisfaction [29]. Emotions can also 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 [30].

A product's emotional engagement with a user is also important when it comes to design for sustainable behavior [31]. Dillahunt, et al. [32] 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. However, there is very little understanding of what precisely those users would describe themselves as feeling. Therefore, we believe it is important to understand possible spectrums of user emotions evoked by sustainable products and to investigate links between these emotions and users' pro-environmental behavior.

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* and *Proud*, and ten verbal descriptors of negative emotion such as *Afraid* and *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 [33]. 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 [34]. These methods are easy to implement, and a well-designed self-reporting scale can be valid and reliable [35].

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 [36]. Some common practices include observing facial expression [37] or vocal cues [38], measuring heart rate, skin conductivity or respiration [39], and detecting brain activities using electroencephalogram (EEG) [40] or functional magnetic resonance imaging (fMRI) [41]. These methods are considered more objective compared to self-reporting methods. However, their implementations are usually more complicated and the gathered data are usually more open to interpretation.

To gauge user emotions, researchers have asked people to recall their emotional experience with products [42], or used a diary method to track emotions over the course of using a product [43]. To collect feedback on provisional product ideas, design representations such as line drawings [44] or prototypes [45] have been used to elicit user emotions. Scenario-based design is an approach that captures the essence of the product *use* by creating a story or context for a product experience [46], and has been used to gather user feedback on the experience of using a product in the early design stage [47].

In this study, sketches were used as design representations and scenarios of users interacting with eco-feedback products were created to elicit user emotions. We explored multiple quantitative emotion assessment methods, including self-reporting, skin conductivity measurement and facial expression detection when designing this study. Self-reporting was chosen to measure users' emotions because we found it more meaningfully interpretable and more effective at distinguishing between subtly different emotions, in the context of our study, whereas skin conductivity, for example, often measures no noticeable change between wildly different scenarios.

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 from diverse demographic background. 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.

1. Study Participants

Thirty adult participants were recruited via the MIT Behavior Research Lab, a dedicated facility on campus that maintains a pool of potential research participants for campus researchers across departments. 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. More details of the participants' demographic distribution can be found in Results section 1. Each participant received a $15 Amazon gift card as compensation. The Behavior Research Lab served as the setting for the experiment itself.

2. Design Prompts

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

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

These four products were selected based on design literature [9,48,49] and were created and 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 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 the impact of a product's resource usage on environmental sustainability. Simple GIF animations were created for the electricity meter and water faucet designs to show the information the products would display during use. For example, the GIF animations of the water faucet designs showed the water flowing out of the faucet and the number of liters of water used ticked up; in the meantime, 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. Table 1 presents the sketches of each version of the four eco-feedback products.

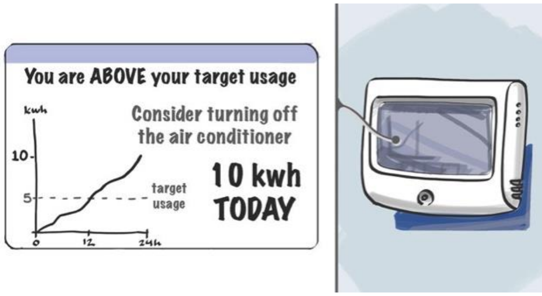
3. Usage Scenarios

For each product, users were presented with an *actionable* scenario in which they could take immediate actions to conserve electricity or water. The scenarios were constructed such that there was a tradeoff of convenience for the sustainable action. For example, when evaluating the water faucet designs, participants were asked to imagine that they were washing dishes after dinner; they started to soap the dishes after rinsing them, and noticed the water usage increasing on the faucet display. They were asked how likely they were to take actions to conserve resources, for example, turning off the faucet. A 1-7 scale was provided where 1 was "definitely not" and 7 was "definitely". The responses to this question will be referred to as the "certainty of taking immediate resource conservation action" in the rest of this paper. The scenarios were presented in neutral language in order to reduce social desirability bias that participants might be inclined to respond that they would always take the sustainable action [50].

Additionally, a *conserving* and a *wasteful* scenario was created for each product, respectively. 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. In the water faucet example, the user in the conserving scenario would "turn off the faucet while soaping the dishes to save water"; in the wasteful scenario, the user would "let the water run during the whole time while cleaning the dishes". These scenarios were described in written form, and accompanied by sketches of the designs. The sketches of products in each scenario are summarized in Table 1. Participants were asked to report their emotions (how they would feel) in the conserving and wasteful scenarios, respectively.

The actionable scenario and the conserving and wasteful scenarios of the figurative water faucet design, along with the questions asked to the participants, are provided in APPENDIX I as an example.

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

<table>
<tr><th></th><th></th><th>Electricity Meter</th><th>Light Switch</th><th>Water Faucet</th><th>Washing Machine</th></tr>
<tr><td rowspan="2">Quantitative Designs</td><td>Wasteful Scenario</td>
<td></td>
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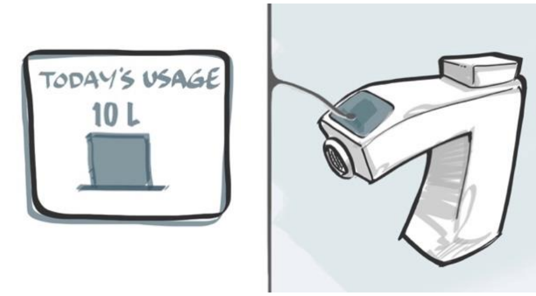
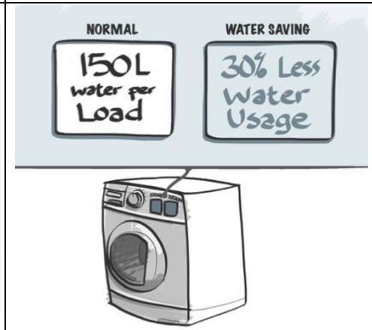
<td></td>
<td></td></tr>
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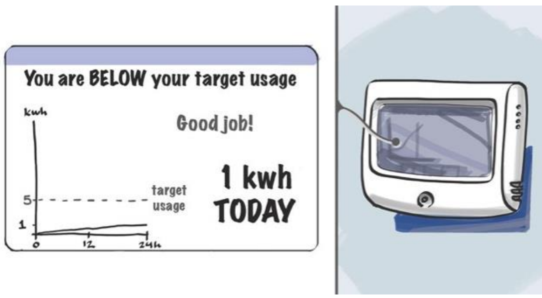
<td></td>
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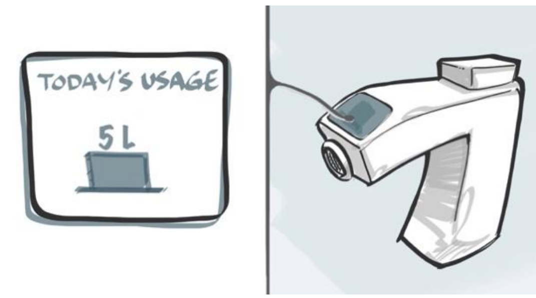
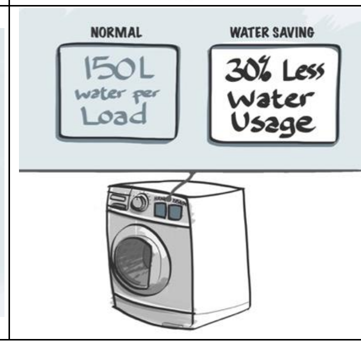
<td></td>
<td></td></tr>
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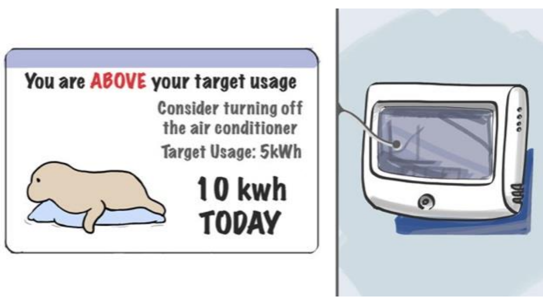
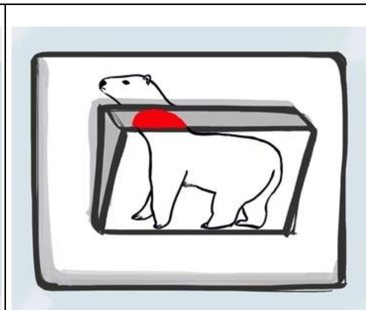
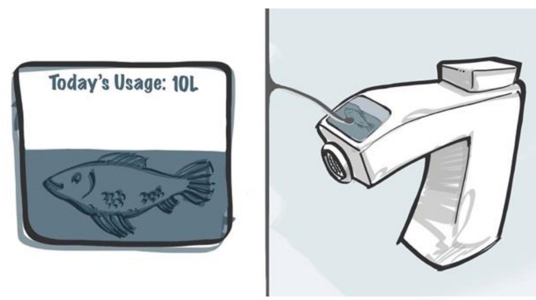
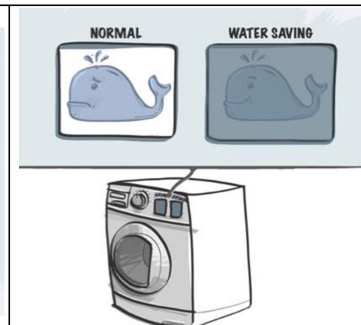
<td></td>
<td></td>
<td></td>
<td></td></tr>
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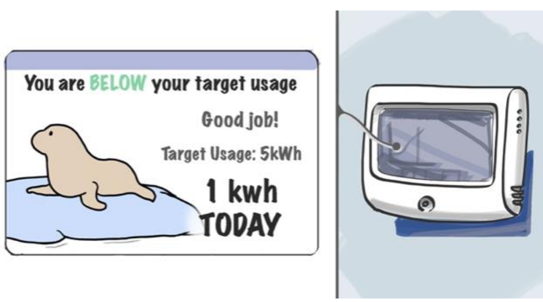
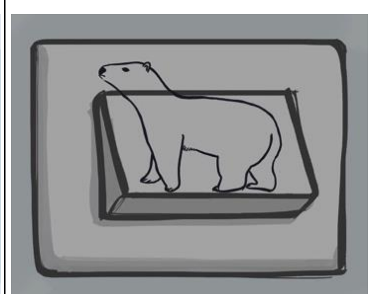
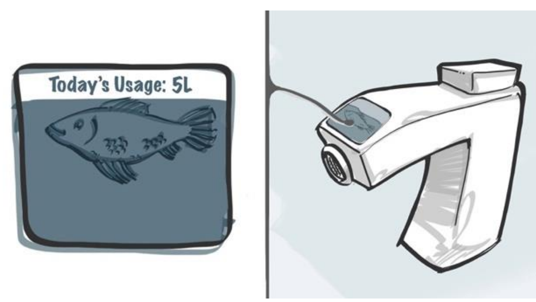
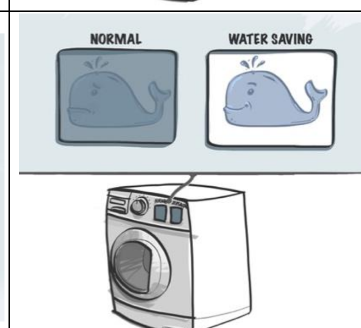
<td></td>
<td></td>
<td></td>
<td></td></tr>
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4. *Emotion Evaluation*

Participants self-reported their emotional reactions in both the conserving and the wasteful scenario 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 to the usage scenarios. The emotions were intended to span the positive and negative, and were meant to include words associated with a user's consumption experience and resource conservation behavior. The number of emotions was set so that the list was sufficient for the product usage scenarios and also concise enough to avoid survey fatigue.

Participants reported to what extent 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 the participants' positive and negative affect, the details of which will be described in Results section 2. The sequence in which the 15 emotions were presented was randomized in the survey.

5. *Experimental Process*

The experiment was conducted on individual participants. Participants were divided into two experimental groups: the *quantitative design group* and the *figurative design group*, in which the participants only review the quantitative designs or the figurative designs, respectively. 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. Each question had a short list of five emotion descriptors. Any ambiguity in the questions was clarified at this point.
c) **Pro-Environmental Attitude** Pro-environmental attitudes of the participants were evaluated with the New Ecological Paradigm (NEP) scale [51]. The results were used to check if the participants' product usage behavior was influenced by their environmental awareness.
d) **Current Moods** Participants reported their current positive and negative affect with the PANAS [12], which has ten positive and ten negative emotion descriptors. 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 and reported what they would do and how they would feel in usage scenarios as described in Methods section 3 and 4. The sequence in which the four products were presented was randomized, and so was the sequence of presenting the conserving or wasteful scenarios. In addition, the participants evaluated each design on its *Aesthetics*, *Usefulness* for encouraging resource conservation behavior, *Willingness to Use*, and *Overall Quality*. These criteria were created based on selected measures of Garvin's eight dimensions of product quality [52]. Only criteria that the participants could reasonably making judgement about by looking at the design sketches were chosen, and they were tailored to the features of the eco-feedback designs. Example questions can be found in APPENDIX I.
f) **Demographics Questions** Information including age, gender, level of education, occupation, and household yearly income was 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.

Questions in step c), d), e) and f) were presented in a survey designed with Qualtrics. The participants answered the questions on a computer by themselves, though a researcher was nearby in case the participant had questions. The entire experiment was video recorded. Pilot studies were conducted prior to the experiments. The first round of pilot studies was with five students and the focus was on the wording of the questions, especially the emotion evaluation questions. The second round of pilot studies 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 each round of pilot studies.

RESULTS

1. *Study Participants*

Nineteen females and eleven males participated in the study. They varied in age from 21 to 65. The gender and age information were available prior to the experiment and were used to evenly assign the participants to the two experimental groups. Significant opinion differences towards the designs were observed between younger and older participants (for more details see Results section 3). Therefore, we categorized the participants into a younger group and an older group. The cut-off age was chosen to be 40 years old, which lay in the biggest age gap among participants. Table 2 summarizes the demographic distribution of the participants.

Table 2 Demographic distribution of study participants

	Quantitative Design Group		Figurative Design Group	
	Female	Male	Female	Male
Younger (<40 years old)	8	1	7	2
Older (>40 years old)	2	4	2	4

The majority (sixteen participants) had a bachelor's degree or equivalent level of education; seven had some college or lower level of education; and seven had a master or doctoral degree. Ten are current college or graduate students; the rest had various occupations including researcher, manager, clinician, accountant, carpenter, and more. Participants with different level of education were also distributed evenly in the two experimental groups.

Participants' positive and negative affect assessed with the PANAS represented their mood states in the studies. Their distributions are plotted in Figure 1. Analysis of variance (ANOVA) was conducted to compare between the experimental groups, the age groups, and between females and males. No significant differences were found between the experimental groups (positive affect F-value = 0.041, p-value = 0.840; negative affect F-value = 0.071, p-value = 0.792), or between the age groups (positive affect F-value = 2.067, p-value = 0.162; negative affect F-value = 0.299, p-value = 0.589). Compared to female participants, male participants appeared to have significantly higher positive affect (F-value = 14.010, p-value < 0.001) but not significantly different negative affect (F-value = 2.686, p-value = 0.112).

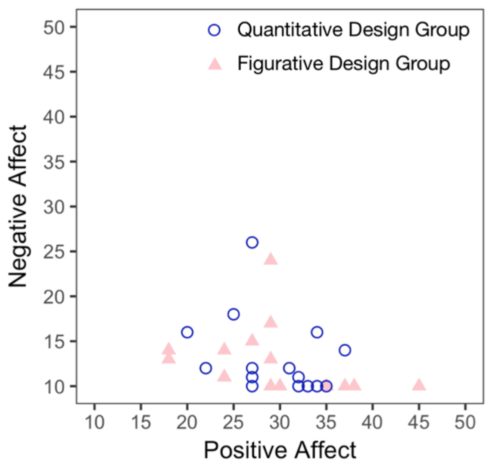

Figure 1 Participants' positive and negative affect in the study
Note: The positive affect and negative affect were two independent variables and each could vary in the range of 10 to 50.

The pro-environmental attitude scores of the participants varied from 42 to 69, with 56.5 as the median (the possible range of the pro-environmental attitude scores was 15 to 75). No significant difference was found between the experimental groups (F-value = 0.046, p-value = 0.831), the age groups (F-value = 0.131, p-value = 0.720), or genders (F-value = 0.492, p-value = 0.489).

2. *Spectrum of Emotions*

It was observed that participants' positive affect was significantly correlated with multiple positive emotions regarding using the products. Similarly, negative affect was significantly correlated with multiple negative emotions regarding using the products. To rule out the impact of participants' positive and negative affect (their emotional states in the study) on their emotional reactions towards the designs, normalizations were applied to the product related emotions using the positive and negative affect as references. After normalization, the emotions varied in a range between 0-10, where 0 representing not feeling an emotion at all and 10 indicating feeling an extremely strong emotion. The normalizations largely reduced the correlations. See APPENDIX II for more details of the correlation analyses and the normalization.

Though the intensity of emotions with respect to using an eco-feedback product varied across the participants and was influenced by the types of products and the styles of design, the trend was consistent that more positive emotions arose in the conserving scenarios and more negative emotions arose in the wasteful scenarios. Therefore, emotions towards different products and in different experimental groups were pooled together, and an overall distribution of user emotions was generated as in Figure 2.

The three emotions with the highest mean values in the conserving scenarios were *satisfied* (mean ± sd: 3.1 ± 1.9), *proud* (2.4 ± 1.9) and *interested* (2.1 ± 1.6). The top emotions in the wasteful scenarios were *guilty* (3.6 ± 2.6), *upset* (2.4 ± 2.0), *embarrassed* (2.4 ± 2.4), *annoyed* (2.3 ± 2.0) and *worried* (2.2 ± 1.9). *Skeptical* (0.8 ± 1.3) was the dominant negative emotion in the conserving scenarios; and *interested* (1.1 ± 1.4) was the dominant positive emotion in the wasteful scenarios.

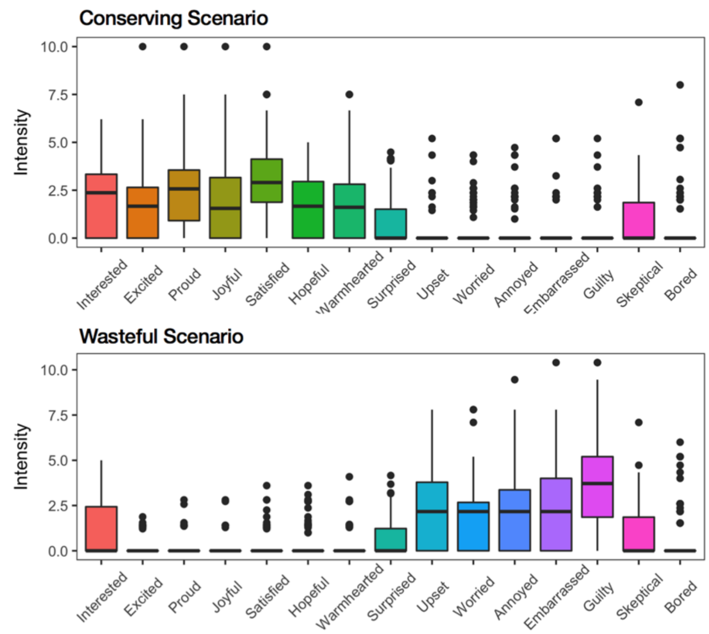

Figure 2 Intensity of emotions in the conserving (above) and wasteful (below) scenarios.

In addition to video recording, notes were taken by a researcher during post-experimental interviews and were summarized to provide insights into how and when the participants would feel certain emotions:

In general, the participants expressed *excitement* about the eco-feedback technologies and indicated that they would be *interested* to learn how much electricity or water they consumed. However, some of them were concerned about how accurate these devices tracking resource usage and therefore were *skeptical* of the feedback information. Participants were *surprised* by the large quantity of electricity or water consumed in the described product-using scenarios. It was also pointed out that the users would feel *bored* if they saw the designs every day.

In the conserving scenarios where the participants succeeded in saving resources, participants reported feeling *joyful* and *satisfied* because they contributed to the environmental sustainability and/or saved money on a lower water/utility bill; they would also be *proud* of themselves because they remembered/took the effort to behave sustainably. *Warmhearted* and *hopeful* feelings would arise when they were convinced that a simple action or small effort of theirs could effectively reduce their electricity/water consumption.

In the wasteful scenarios, participants reported being *upset* and *worried* by their large consumption, and would feel *embarrassed* and *guilty* if they forgot to/could not conserve resources. They would also feel *upset* because of the sad animal images in the figurative designs, and would feel *guilty* if they associated their behaviors with the harm to the environment and the wildlife. They could be *annoyed* by the products if the products kept reminding them of their electricity/water usage over and over again, or they could be *annoyed* with themselves when they did not/could not behave as expected.

Other words participants used to describe their feelings include *curious*, *relieved*, *concerned*, *confused*, *anxious*, *frustrated*, *irritated and depressing*.

3. Designs & Emotions

It was expected that figurative designs would evoke stronger emotions compared to quantitative designs, which was indicated by the results of the previous study of the authors [11]. However, this current study did not show the same trend. Overall, the average emotions in the quantitative design group were larger than those in the figurative design group (see APPENDIX III). From the interviews, it was revealed that quantitative designs often made the participants feel strongly because the numbers of energy/water consumption made them realize that a lot of energy or water would be wasted, or that they could easily save a lot of resources with some simple actions. In the washing machine example, a few participants commented that they were surprised by the "150 L water per load" message because 150 L was a large quantity (when in fact, 150L is a typical amount of water used by a traditional washing machine). At the same time, they would feel positive if they could save 30% of that water, which was a significant amount.

Notable opinion differences were observed between the two age groups, especially towards the figurative designs. Participants in the older group in general didn't associate the polar bear or the seal on an iceberg with global warming, and thus didn't link the animal figures to the consumption of energy. In contrast, participants in the younger group in general recognized the symbolic meaning of arctic animals and considered them to be appropriate reminders to conserve energy. In addition, the cartoonish image style was criticized by the older participants, but was well accepted among the younger participants. Accordingly, significant differences were observed between their emotional reactions towards the figurative designs. Therefore, we not only compared emotions between the two experimental groups, but also the younger and older age groups.

To simplify the comparison, principal component analysis was conducted with emotions in the conserving and wasteful scenarios, respectively. The most significant principal component (PC) in each scenario could explain more than 70% of the variances, and thus were used as representatives of the emotions in each case. The PC in the conserving scenario was highly correlated with positive emotions such as *satisfied*, *proud* and *joyful*; the PC in wasteful scenario was highly correlated with negative emotions including *guilty*, *embarrassed* and *upset*. See APPENDIX IV for more details on the principal component analysis. Figure 3 shows the distributions of the principal components of emotions towards the four products within each experimental group and each age group.

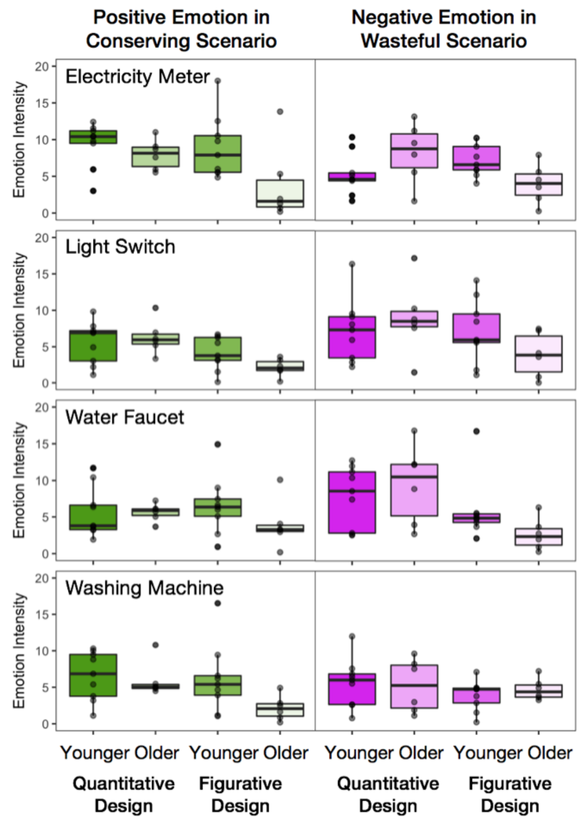

Figure 3 Comparing principal components of emotions in conserving and wasteful scenarios respectively, between experimental groups and between age groups

It can be observed that older participants in the figurative design group generally reported less intense emotions in both conserving and wasteful scenarios. Analysis of variance (ANOVA) was conducted to detect if this difference was significant (Table 3). The emotions towards all four products were pooled together for the analysis. The Benjamini & Hochberg (BH) method was applied to adjust the p-values to reduce false detection in multiple comparisons. It appeared that the intensity of emotions of older participants in the figurative design group were on average significantly lower than that of the younger participants in the same experimental group, and were on average significantly lower than that of older participants in the quantitative design group. The difference between the age groups towards the quantitative designs was not significant. Nor were the emotions of younger participants in the two experimental groups different.

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

F-value (adjusted p-value)		Conserving scenario	Wasteful scenario
Between younger & older participants	in quantitative design group	0.172 (0.693)	1.830 (0.242)
	in figurative design group	11.563 (0.002)	7.182 (0.019)
Between quantitative & figurative design groups	among younger participants	0.157 (0.693)	0.289 (0.593)
	among older participants	19.474 (<0.001)	15.146 (0.001)

No significant differences were found between the two experimental groups regarding design evaluations. The older participants in the figurative design group generally gave lower scores for the *Aesthetics*, *Usefulness*, and *Overall Quality* of the design. However, these differences were not statistically significant.

4. *Designs & Resource Conservation Behaviors*

Figure 4 summarizes participants' reported certainty of taking immediate conservation actions with the four eco-feedback products. The electricity meters on average had the lowest certainty. Participants commented that they would take more factors into consideration before following the electricity meter's instructions to conserve electricity. For example, if it were an extremely hot summer day, they would not turn off the air conditioner even if the electricity meter information suggested they do so to conserve energy. The light switches on average had the highest certainty. Many participants reported that turning off lights was a habit they had already developed and therefore they would turn off the lights regardless of the designs. For the water faucet designs, some participants reported that feedback information would make them more aware of their water usage and thus encourage them to reduce waste. However, other participants commented that they would not be willing to sacrifice the convenience of keeping water running and thus would be less likely to change the way they wash dishes. For the washing machine, some participants expressed concerns about detergent residue that might be left in the clothes, and thus were reluctant to use the water saving mode.

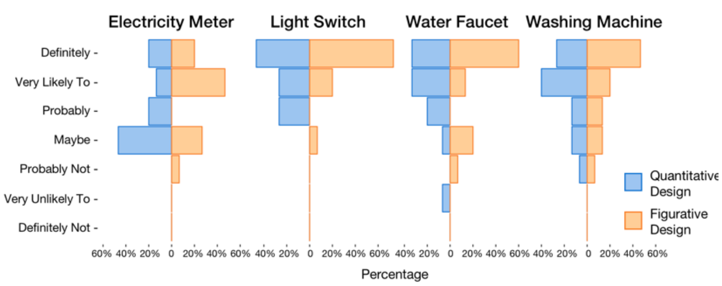

Figure 4 Comparing certainty of immediate conservation actions between two experimental groups

Overall, the certainties of taking immediate conservation actions were not significantly different between the figurative design group and the quantitative design group (ANOVA F-value = 1.885, p-value = 0.172). No difference was observed between the age groups as well (ANOVA F-value = 0.145, p-value = 0.704). To rule out the potential influence of participants' pro-environmental attitude on their certainty of taking immediate conservation actions, the Pearson correlation between these two was calculated and appeared to be insignificant (correlation coefficient = 0.127, p-value = 0.165).

5. *Links between User Emotions, Resource Conservation Behaviors and Perceptions of Eco-Feedback Products*

To identify the links between user emotions regarding using eco-feedback products and users' resource conservation behaviors, Pearson correlations were calculated between the intensity of emotions and the certainty of taking immediate conservation actions. In addition, correlations were calculated between the emotions and the four product evaluations: *Aesthetics*, *Usefulness*, *Willingness to Use*, and the *Overall Quality*. To reduce false detections of significant correlations, BH adjustment was applied to the p-values. The correlation analysis results are summarized in Table 4.

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

		Action	Aesthetics	Usefulness	Willingness To Use	Overall Evaluation
Conserving Scenario	Interested	-0.078 (0.521)	0.256 (0.024)	0.338 (0.002)	0.176 (0.203)	0.330 (0.002)
	Excited	0.048 (0.691)	0.283 (0.017)	0.315 (0.003)	0.193 (0.175)	0.304 (0.004)
	Proud	0.081 (0.521)	0.216 (0.075)	0.256 (0.024)	0.165 (0.238)	0.326 (0.002)
	Joyful	0.079 (0.521)	0.200 (0.107)	0.208 (0.097)	0.178 (0.203)	0.249 (0.026)
	Satisfied	0.156 (0.213)	0.255 (0.024)	0.273 (0.015)	0.235 (0.074)	0.323 (0.002)
	Hopeful	-0.023 (0.864)	0.293 (0.017)	0.343 (0.002)	0.074 (0.585)	0.348 (0.002)
	Warm-hearted	0.107 (0.384)	0.124 (0.408)	0.166 (0.193)	0.090 (0.516)	0.198 (0.101)
	Surprised	-0.217 (0.073)	0.268 (0.023)	0.074 (0.528)	-0.004 (0.975)	0.215 (0.068)
	Upset	-0.154 (0.213)	0.110 (0.408)	0.028 (0.785)	-0.206 (0.143)	0.003 (0.975)
	Worried	-0.090 (0.489)	0.178 (0.155)	0.085 (0.484)	-0.099 (0.501)	0.113 (0.471)
	Annoyed	-0.174 (0.17)	-0.138 (0.364)	-0.183 (0.152)	-0.379 (0.001)	-0.165 (0.194)
	Embarrassed	0.000 (0.999)	-0.095 (0.456)	-0.025 (0.785)	-0.070 (0.585)	-0.018 (0.874)
	Guilty	-0.055 (0.666)	0.005 (0.961)	-0.096 (0.469)	-0.094 (0.513)	-0.042 (0.763)
	Skeptical	-0.142 (0.241)	0.079 (0.555)	-0.027 (0.785)	-0.126 (0.394)	0.073 (0.705)
	Bored	-0.285 (0.016)	-0.302 (0.017)	-0.389 (<0.001)	-0.138 (0.394)	-0.298 (0.005)
Wasteful Scenario	Interested	-0.213 (0.074)	0.109 (0.408)	0.136 (0.278)	-0.05 (0.675)	0.151 (0.233)
	Excited	-0.127 (0.276)	0.046 (0.697)	-0.043 (0.740)	-0.123 (0.394)	0.037 (0.763)
	Proud	-0.144 (0.241)	-0.115 (0.408)	-0.147 (0.249)	-0.254 (0.051)	-0.065 (0.705)
	Joyful	-0.02 (0.864)	-0.109 (0.408)	-0.082 (0.484)	-0.122 (0.394)	-0.069 (0.705)
	Satisfied	-0.135 (0.263)	-0.076 (0.555)	-0.044 (0.74)	-0.003 (0.975)	0.021 (0.874)
	Hopeful	-0.171 (0.170)	0.182 (0.154)	0.084 (0.484)	-0.055 (0.675)	0.162 (0.194)
	Warm-hearted	-0.131 (0.269)	0.033 (0.768)	-0.034 (0.785)	-0.074 (0.585)	0.040 (0.763)
	Surprised	0.019 (0.864)	0.112 (0.408)	0.156 (0.223)	0.129 (0.394)	0.162 (0.194)
	Upset	0.258 (0.034)	0.057 (0.651)	0.183 (0.152)	0.102 (0.501)	0.099 (0.533)
	Worried	0.218 (0.073)	0.056 (0.651)	0.105 (0.42)	0.072 (0.585)	0.068 (0.705)
	Annoyed	0.204 (0.085)	0.101 (0.433)	0.123 (0.322)	0.035 (0.786)	0.057 (0.729)
	Embarrassed	0.306 (0.010)	-0.058 (0.651)	0.136 (0.278)	0.022 (0.865)	0.044 (0.763)
	Guilty	0.390 (<0.001)	0.045 (0.697)	0.174 (0.173)	0.105 (0.501)	0.106 (0.502)
	Skeptical	-0.054 (0.666)	-0.018 (0.871)	-0.130 (0.295)	-0.310 (0.008)	-0.063 (0.705)
	Bored	-0.238 (0.054)	-0.107 (0.408)	-0.093 (0.469)	-0.052 (0.675)	-0.049 (0.763)

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

It is interesting to see that the certainty of participants taking immediate actions to reduce electricity/water consumption was significantly positively correlated with the intensity of negative emotions (*guilty*, *embarrassed* and *upset*) in the wasteful scenarios. However, the rated *Usefulness* of the products was not significantly correlated with these negative emotions. Instead, it was significantly positively correlated with positive emotions (*hopeful*, *interested*, *excited*, *satisfied* and *proud*) in the conserving scenarios. These seemingly inconsistent results suggest a more complex phenomenon, that negative emotions might be effective in enforcing one-time sustainable behavior, however, might discourage users in the long run. The post-study interviews revealed that if a product made the users feel bad, the users would avoid interacting with the product in order to keep away negative feelings. Instead, if a product made the users feel good, they would be willing to use it more often to conserve resources.

The *Aesthetics* and *Overall Quality* of the designs were significantly correlated with multiple positive emotions, again suggesting the importance of fostering positive emotions in eco-feedback designs. The *Willingness to Use* products was correlated with *annoyed* in the conserving scenario and with *skeptical* in the wasteful scenario, with both correlations significant and negative. This indicated that if a user was annoyed by the designs or did not trust the information provided by the designs, he/she would be less willing to use the products.

In addition, *bored* in both conserving and wasteful scenarios was negatively correlated with the certainty of taking conservation actions as well as all design evaluations. Four of these correlations were statistically significant. On one hand, this suggested that *bored* was a strong indicator of negative perceptions of a design. On the other hand, it indicated that if a user was not engaged with an eco-feedback design (felt bored with it), the design would not be effective in promoting sustainable behaviors.

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?*

For this study we used a discrete emotion perspective [53,54], 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 [55] and used positive affect and negative affect measurements of participants to normalize the intensity of their emotional responses.

We found that the emotions a user had in response to an eco-feedback product varied depending on the usage scenario. In a scenario in which a user successfully conserved resources with an eco-feedback product, positive emotions such as *satisfied* and *proud* tended to dominate. In a scenario where a user failed to conserve resources, the eco-feedback design was linked to feeling *guilty*, *embarrassed* or *upset*. Eco-feedback products generally made people curious about their resource consumption, though some users were *skeptical* about the accuracy of the usage feedback presented by such products.

By providing study participants with product usage scenarios, we aimed to reveal not only the visceral emotions we had asked for in our previous study, but also behavioral and reflective emotions [1]. In other words, the emotions that participants reported were not only concerned with the aesthetics or the appearance of the designs, but also with their imagined use of the product, and with their personal values, such as being environmentally sustainable. These emotions seem likely to have been generated by a combination of both bottom-up and top-down processes [56]: 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). Unfortunately, in this experimental setting it was hard to determine how much each process might have been involved in the generation of a particular response.

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 [57]. There are multiple mechanisms by which emotion can shape behavior [58]: 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 immediate conservation action was used as a measure of influencing product usage behavior. Since tradeoffs for convenience were included in the actionable scenarios, we collected responses spanning from "definitely" to "very unlikely to" take conservation actions. The certainty of taking conservation actions was mainly correlated with negative emotions including *guilty*, *embarrassed* and *upset* in the wasteful scenario. This finding suggested that if a user felt bad about wasting resources, they were more likely to conserve resources; and if an eco-feedback design made the users feel *guilty*, *embarrassed*, or *upset*, the design might be more effective in promoting immediate sustainable behaviors.

However, the evaluations of the designs' *Aesthetics*, *Usefulness*, and the *Overall Quality* were more significantly correlated with the positive emotions such as *satisfied*, *hopeful*, *interested* and *excited*. The post-experimental interviews revealed that participants would avoid interacting with a design if it made them feel bad. The figurative design of the light switch was an extreme example. It showed a polar bear that was stylistically decapitated when the light switch was on. The majority of the 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, many of them did not like the design and would not want to use it because they would "not be able to turn on the lights at all" and that would be annoying; or they would need to desensitize themselves from the negative feelings. This finding supports the point of view from existing literature that designers should avoid making users feel guilty [59]. Instead, creating positive reinforcement by using positive emotions to reward the users would be a more favorable strategy to attract users to the designs and to encourage sustainable behaviors.

In addition, the significant correlations between the emotions and the design evaluations suggested the importance of keeping a user interested in using an eco-feedback product, providing trustworthy information, and limiting intrusiveness to avoid irritating users.

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

Two styles of eco-feedback designs were compared in this study: quantitative designs that emphasize the objective resource usage information, and figurative designs that use animal figures as reminders of environmental sustainability. In a previous study conducted with university students [11], the 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 under 40 years old. This is likely because that the emotions evaluated in the previous study were more on the visceral level that was concerned with the appearance of the designs. However, the user emotions revealed in this work were more on the behavioral level that was concerned with using the products. Therefore, the visual display of the designs had less influence on the intensity of user emotions. Instead, a large number showing resource consumption such as "150L water per load" of laundry could evoke strong emotions. A thank-you note or a compliment such as "good job" for conserving resources displayed by an eco-feedback product could also be emotionally evocative.

Additionally, we observed that figurative designs evoked much stronger emotions in younger participants than in the older participants. This discrepancy could be explained by the differences between two generations: while the use of animals as symbols of global warming and environmental sustainability was well-known among the younger generation, it was less of a common knowledge among the older generation; 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 the whole population.

CONCLUSIONS & FUTURE WORK

From this study, we gained better understanding of the emotions that would arise from users' interactions with eco-feedback products. We found that higher certainties of users taking immediate actions to conserve resources were linked to stronger negative emotions such as *guilty*, *embarrassed* and *upset*; however, users' perception of the designs' aesthetics, usefulness and the overall quality were more correlated with positive emotions such as *satisfied*, *hopeful*, *interested* and *excited.* This suggests that evoking negative emotions in users may be an effective strategy for spurring immediate sustainable behaviors, however, 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 designs, quantitative and figurative, were tested. It was found that participants in younger and older age groups had very different emotional reactions towards designs that use animal figures as reminders of environmental sustainability. 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. This enabled the evaluation of many different ideas in a short amount of time. In addition, detailed usage scenarios were created to help the participants report realistic emotions and behaviors. Still, further studies with more realistic products should be explored to understand user emotions. In this study, in-lab experiments were conducted with individuals to allow in-depth interviews with the users. However, the number of participants was limited. In future work, studies with a larger population of participants could be conducted to further investigate these questions.

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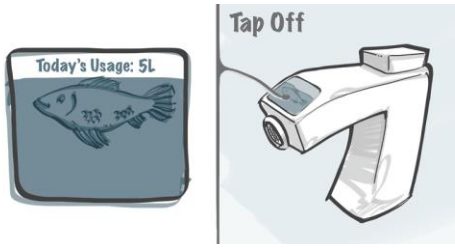
APPENDIX I Example Product Usage Scenarios and Action, Emotion, and Design Evaluation Questions

Product Introduction

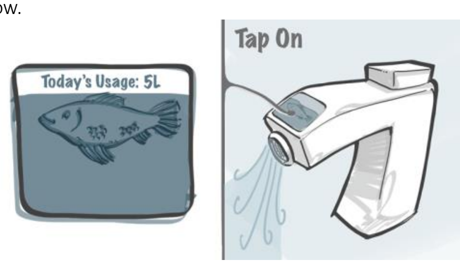
Below is a water faucet design. It monitors the accumulated water usage of the day and displays that information on its screen. The more water is used, the lower the fish tank water level will be on the display. Imagine that your kitchen sink has a water faucet like this.



(This design was presented as GIF animation in the study)

Actionable Scenario

Imagine that you are doing dishes after dinner. You rinse all the utensils and then start to soap them. The faucet shows the fish tank water level going down on its display as below.



(This design was presented as GIF animation in the study)

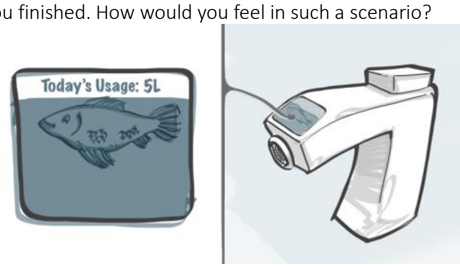
What will you do in this scenario?
Please select your answer to complete the following sentence.

I will ____ take the effort to turn off the faucet when soaping the dishes.

definitely not	very unlikely to	probably not	maybe	probably	very likely to	definitely

Conserving Scenario

Now imagine that you turned off the faucet when soaping the dishes to save water. The faucet showed the accumulated water usage on its display as in the below image after you finished. How would you feel in such a scenario?



Please indicate to what extent you would feel each of the following emotions:

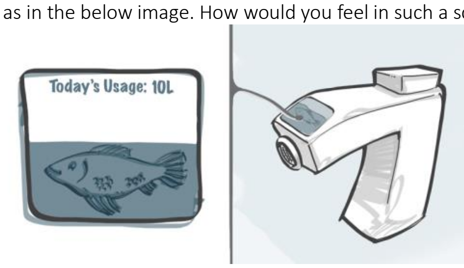
	Not at all	Slightly	Moderately	Strongly	Extremely
Upset	○	○	○	○	○
Skeptical	○	○	○	○	○
Joyful	○	○	○	○	○
Proud	○	○	○	○	○
Bored	○	○	○	○	○

(Rest of the 10 emotions were not included here to save space)

Optional comments: Please write in any other emotions (and their intensity) that you would have.

Wasteful Scenario

Now imagine that you let the water run during the whole time you spent cleaning the dishes. After you finished, the faucet showed the accumulated water usage on its display as in the below image. How would you feel in such a scenario?



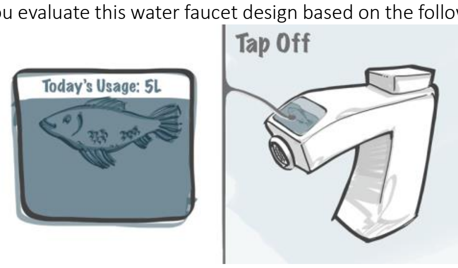
	Not at all	Slightly	Moderately	Strongly	Extremely
Annoyed	○	○	○	○	○
Hopeful	○	○	○	○	○
Guilty	○	○	○	○	○
Embarrassed	○	○	○	○	○
Worried	○	○	○	○	○

(Rest of the 10 emotions were not included here to save space)

Optional comments: Please write in any other emotions (and their intensity) that you would have.

Design Evaluation

How would you evaluate this water faucet design based on the following criteria?



(The design was presented as GIF animation here in the study)

Aesthetics - is this design aesthetically pleasing (does it look good)?

Not at all aesthetically pleasing	Slightly aesthetically pleasing	Moderately aesthetically pleasing	Very aesthetically pleasing	Extremely aesthetically pleasing

Usefulness - is this design an effective reminder to save water and would it encourage you to do so?

Not at all willing to use	Slightly willing to use	Moderately willing to use	Very willing to use	Extremely willing to use

Willingness to use - would you be willing to use this water faucet instead of a normal one?

Not at all willing to use	Slightly willing to use	Moderately willing to use	Very willing to use	Extremely willing to use

Overall evaluation - do you think this is a good design, all things considered?

This is a horrible design!	This is a bad design	This is an OK design	This is a good design	This is an awesome design!

Note: Only the sans-serif text above was present in the survey. The sequence of conserving and wasteful scenarios, and the order of the 15 emotions, were randomized for each participant.

APPENDIX II Normalizing Emotions in Product-Using Scenarios with Positive and Negative Affect

The positive and negative affect of the study participants was measured before they evaluated the eco-feedback products. Each can vary from 10 to 50. The positive emotions (*interested*, *excited*, *proud*, *joyful*, *satisfied*, *hopeful* and *warmhearted*) that the participants would have in both the conserving and wasteful usage scenarios were normalized with the positive affect; the negative emotions (*upset*, *worried*, *annoyed*, *embarrassed*, *guilty*, *skeptical*, and *bored*) in both scenarios were normalized with the negative affect; *surprised* was a neutral emotion and was not significantly correlated with either the positive or the negative affect, and thus was normalized with the root mean square of the positive and negative affect. The following equations were used for normalization:

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

$$Normalized\{NE_i\} = \frac{NE_i}{NA_i/\max(NA_i)}$$

$$Normalized\{Surprised_i\} = \frac{Surprised_i}{\sqrt{PA_i^2 + NA_i^2}\,/\max(\sqrt{PA_i^2 + NA_i^2})}$$

where PE_i, NE_i and $Surprised_i$ are any positive emotions (*PE*), any negative emotions (*NE*), and the emotion *surprised* of participant i, respectively; PA_i and NA_i are the positive affect (*PA*) and negative affect (*NA*) of participant i, respectively; $\max(PA_i)$, $\max(NA_i)$ and $\max(\sqrt{PA_i^2 + NA_i^2})$ are the largest positive affect, largest negative effect and largest root mean square among all participants, respectively. The maximum values were included so that the positive emotions and negative emotions would be on comparable scales after normalizations.

Appendix Table: Pearson correlation between participants' positive/negative affect and their reported intensity of emotions in product-using 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	0.395 (<0.001)	0.284 (0.010)	-0.093 (0.480)	-0.119 (0.388)	0.105 (0.460)	0.161 (0.237)	-0.001 (0.995)	-0.081 (0.571)
Excited	0.246 (0.033)	0.121 (0.331)	0.067 (0.562)	-0.143 (0.261)	0.012 (0.948)	0.100 (0.465)	0.135 (0.350)	-0.130 (0.362)
Proud	0.330 (0.002)	0.121 (0.331)	0 .000 (1.000)	-0.144 (0.261)	0.009 (0.948)	0.118 (0.460)	0.089 (0.552)	-0.142 (0.35)
Joyful	0.174 (0.142)	0.110 (0.379)	0.101 (0.45)	-0.148 (0.261)	-0.068 (0.690)	0.109 (0.460)	0.167 (0.292)	-0.148 (0.35)
Satisfied	0.163 (0.161)	0.061 (0.630)	0.067 (0.562)	-0.072 (0.562)	-0.220 (0.094)	0.019 (0.930)	0.161 (0.294)	-0.040 (0.841)
Hopeful	0.481 (<0.001)	0.232 (0.046)	-0.112 (0.420)	-0.039 (0.776)	0.276 (0.034)	0.187 (0.203)	-0.033 (0.841)	0.002 (0.995)
Warmhearted	0.309 (0.004)	0.179 (0.137)	0.002 (1.000)	-0.172 (0.181)	0.069 (0.690)	0.178 (0.209)	0.081 (0.571)	-0.173 (0.292)
Surprised	0.170 (0.145)	0.192 (0.12)	-0.007 (1.000)	0.031 (0.816)	0.040 (0.797)	0.128 (0.448)	0.004 (0.995)	0.031 (0.841)
Upset	-0.011 (0.904)	0.180 (0.137)	0.323 (0.002)	0.366 (<0.001)	0.006 (0.948)	0.303 (0.023)	0.195 (0.292)	-0.073 (0.584)
Worried	-0.108 (0.379)	-0.052 (0.652)	0.421 (<0.001)	0.265 (0.021)	-0.107 (0.460)	0.061 (0.691)	0.242 (0.233)	-0.116 (0.444)
Annoyed	-0.097 (0.442)	0.062 (0.63)	0.246 (0.034)	0.489 (<0.001)	-0.103 (0.460)	0.171 (0.209)	0.103 (0.483)	0.073 (0.584)
Embarrassed	0.093 (0.449)	0.146 (0.225)	-0.092 (0.480)	0.070 (0.562)	0.111 (0.460)	0.231 (0.083)	-0.110 (0.466)	-0.204 (0.292)
Guilty	-0.05 (0.652)	0.059 (0.630)	-0.080 (0.553)	0.206 (0.080)	-0.041 (0.797)	0.170 (0.209)	-0.101 (0.483)	-0.187 (0.292)
Skeptical	-0.063 (0.630)	0.019 (0.869)	0.215 (0.069)	0.228 (0.053)	-0.034 (0.825)	0.062 (0.691)	0.039 (0.841)	0.029 (0.841)
Bored	0.028 (0.815)	0.216 (0.067)	-0.106 (0.443)	-0.142 (0.261)	0.041 (0.797)	0.251 (0.056)	-0.139 (0.350)	-0.179 (0.292)

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 Average (St Dev) Emotions for Four Eco-Feedback Products in Each Experimental Group

			Interested	Excited	Proud	Joyful	Satisfied	Hopeful	Warmhearted	Surprised	Upset	Worried	Annoyed	Embarrassed	Guilty	Skeptical	Bored
Electricity Meter	**Conserving Scenario**	**Quantitative Design**	3.46 (1.25)	2.89 (1.46)	3.4 (1.86)	2.91 (1.15)	4.16 (1.66)	3.19 (0.8)	2.32 (1.3)	2.02 (1.44)	0.11 (0.42)	0.38 (0.82)	0.14 (0.56)	0.49 (1.42)	0.43 (0.9)	1.02 (1.2)	0.14 (0.56)
		Figurative Design	2.2 (1.93)	2.67 (2.9)	3.04 (2.57)	2.59 (2.92)	3.72 (2.98)	1.44 (1.38)	1.65 (1.36)	0.95 (1.33)	0.16 (0.61)	0.29 (0.77)	0.42 (1.26)	0.35 (1.34)	0.16 (0.61)	0.84 (1.88)	1.35 (2.11)
	Wasteful Scenario	**Quantitative Design**	2.28 (1.3)	0.09 (0.35)	0.09 (0.35)	0 (0)	0.33 (0.96)	0.79 (1.16)	0.37 (1.09)	0.53 (0.83)	3 (1.69)	2.64 (1.96)	2.79 (2.44)	2.18 (2.06)	3.08 (2.27)	0.7 (1.06)	0.91 (1.42)
		Figurative Design	1.55 (1.5)	0.21 (0.56)	0 (0)	0 (0)	0.08 (0.31)	0.19 (0.53)	0 (0)	0.49 (0.74)	2.42 (2.02)	2.58 (1.75)	1.48 (1.82)	1.95 (1.95)	3.68 (1.89)	1.6 (2.03)	0.8 (1.83)
Light Switch	**Conserving Scenario**	**Quantitative Design**	1.49 (1.56)	1.55 (1.42)	2.6 (1.38)	1.83 (1.55)	3.24 (1.28)	1.73 (1.66)	2.52 (2.01)	0.45 (1.12)	0 (0)	0.28 (0.77)	0.43 (0.9)	0 (0)	0 (0)	0.51 (1.07)	0.29 (0.76)
		Figurative Design	0.66 (1.16)	0.82 (1.38)	1.56 (1.48)	0.48 (0.9)	2.79 (1.78)	0.66 (1.09)	1.05 (0.92)	0.23 (0.62)	0 (0)	0 (0)	0.55 (1.18)	0 (0)	0 (0)	0 (0)	0.58 (1.42)
	Wasteful Scenario	**Quantitative Design**	0.47 (0.88)	0 (0)	0.18 (0.49)	0.28 (0.77)	0.24 (0.66)	0.56 (1.03)	0.46 (0.85)	0.42 (0.9)	3.07 (2.27)	2.39 (2.01)	3.71 (2.08)	3.28 (3.05)	4.78 (2.61)	0.65 (1.12)	0 (0)
		Figurative Design	0.29 (0.84)	0.1 (0.4)	0 (0)	0 (0)	0 (0)	0.22 (0.65)	0 (0)	0 (0)	2.23 (2.25)	1.92 (1.79)	1.98 (1.72)	2.86 (2.49)	3.64 (2.59)	0.84 (1.3)	0.28 (0.75)
Water Faucet	**Conserving Scenario**	**Quantitative Design**	2.7 (1.01)	1.69 (1.19)	1.77 (1.64)	1.75 (1.68)	2.7 (1.2)	2.04 (1.33)	1.31 (1.5)	1.37 (1.51)	0.85 (1.59)	0.74 (1.33)	0.61 (1.33)	0.78 (1.51)	1.44 (1.82)	0.99 (1.33)	0.14 (0.56)
		Figurative Design	1.76 (1.5)	1.27 (1.42)	2.11 (1.85)	2.26 (2.28)	2.82 (1.75)	1.8 (1.72)	1.93 (2.12)	0.89 (1.27)	0 (0)	0.6 (0.92)	0.13 (0.52)	0.29 (0.77)	0.29 (0.77)	0.37 (0.82)	1.07 (1.8)
	Wasteful Scenario	**Quantitative Design**	2.11 (1.39)	0.28 (0.58)	0 (0)	0.09 (0.36)	0.09 (0.36)	0.37 (0.82)	0.36 (0.81)	1.86 (1.36)	3.07 (2.26)	3.27 (2.07)	2.96 (1.86)	3.28 (2.82)	4.99 (3.56)	0.98 (1.12)	0.46 (0.96)
		Figurative Design	1.2 (1.4)	0.09 (0.33)	0.27 (0.75)	0.09 (0.33)	0.31 (0.66)	0.4 (0.9)	0.09 (0.33)	0.36 (0.63)	1.97 (2.15)	1.77 (2.15)	1.47 (2.17)	1.5 (2.35)	2.78 (2.32)	0.33 (0.87)	1.06 (1.73)
Washing Machine	**Conserving Scenario**	**Quantitative Design**	2.47 (1.3)	1.46 (1.29)	2.85 (1.48)	1.43 (1.5)	2.9 (1.65)	2.47 (1.58)	2.6 (1.87)	0.55 (0.87)	0.1 (0.37)	0.79 (1.43)	0.38 (0.86)	0.22 (0.84)	0.32 (0.84)	1.29 (1.41)	0.16 (0.61)
		Figurative Design	1.97 (1.6)	1.03 (1.55)	1.68 (1.83)	1.62 (2.17)	2.41 (1.99)	1.21 (1.58)	1.27 (2.05)	0.67 (1.25)	0.29 (1.12)	0.59 (1.3)	0.29 (1.12)	0 (0)	0 (0)	1 (1.39)	1.04 (2.4)
	Wasteful Scenario	**Quantitative Design**	0.65 (1.16)	0.09 (0.36)	0.28 (0.79)	0.19 (0.73)	0.56 (1.03)	0.58 (1.04)	0.47 (1.01)	0.62 (1.17)	1.9 (1.7)	1.78 (1.51)	1.61 (1.64)	2.27 (2.26)	3.71 (2.51)	0.81 (1.48)	0.32 (1.22)
		Figurative Design	0.41 (0.76)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0 (0)	0.28 (0.8)	1.63 (1.67)	0.99 (1.14)	2.04 (1.77)	1.72 (1.36)	2.51 (1.86)	0.67 (1.28)	1.2 (2.03)

Note: These statistics were calculated based on the normalized emotion intensities, which varied from 0-10. 0 represented not feeling an emotion at all and 10 indicated feeling an extremely strong emotion.

APPENDIX IV Principal Component Analysis of Emotions

Appendix Table: Factor loadings and the percentage of variance of the first principle components in the conserving scenario and the wasteful scenario, respectively

	Conserving Scenario	Wasteful Scenario
Interested	0.333	0.146
Excited	0.316	0.012
Proud	0.414	0.006
Joyful	0.357	0.006
Satisfied	0.496	0.020
Hopeful	0.305	0.040
Warmhearted	0.325	0.017
Surprised	0.163	0.085
Upset	0.014	0.407
Worried	0.049	0.355
Annoyed	0.031	0.368
Embarrassed	0.030	0.418
Guilty	0.032	0.592
Skeptical	0.104	0.113
Bored	0.036	0.058
Percentage of variance	71.7%	74.0%