Design Science

Revealing insights of users' perception: an approach to evaluate wearable products based on emotions

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Abstract

The wearable product market is growing rapidly and is full of products with similar functions and features. Engaging users at an emotional level may be the key to differentiating a product and encouraging long-term use. While researchers have proposed various design approaches to realize design qualities for wearable devices, emotional needs are often extracted by analysis-heavy methods and disconnected in the design process. To bridge this gap, we developed a new approach that uses a two-axis interactive collage tool for users to compare and evaluate wearable products with targeted emotion-related descriptive words. This approach enabled designers to explore how users perceive products and identify types of emotions that were associated with users' preferences for and perception of the product's form and visible characteristics. The example study demonstrated this approach by exploring the relationships between product characteristics and design goals, such as user comfort, user delight, and perceived product usefulness. The results showed that products that resemble clothing were perceived as more delightful and comfortable. The approach can be further used to explore other design concepts or goals.

Key words: wearable design, product evaluation, product perception, design for emotions

1. Introduction

Tech-enabled wearable products have experienced increased use in recent years and have the potential to improve life in a variety of dimensions. In the last few years, some major brands, such as Apple, Sony, and Samsung, have introduced new sensors and communication technologies (e.g. Apple Watch, Sony's SmartWear, Samsung Gear, etc.). However, these competing products have very similar specifications, in terms of functions and features. Designers find it challenging to differentiate a product in such a space. Creating a specific emotional connection with customers may drive product adoption, retention, and continued use.

Evoking the emotion of *delight* shows promise in achieving such a connection, especially for a simple function such as monitoring task performance (e.g. a step counter). Hassenzahl (2004) found that the satisfaction level of the design for an MP3 player cover depended not only on the perceived usability but also on the hedonic attributes. The study by Bartl, Gouthier & Lenker (2013) showed that customers experiencing delight exhibited higher levels of product loyalty and purchase intention. In addition to user delight, the feeling of *comfort* may

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play a role in establishing a positive emotional connection. The study by Cahour, Lorant & Sanchiz (2002) argued that the acceptance of a tool depended on its performance as well as the emotional comfort that users would feel or perceive. Thus, creating delight and comfort for users can promote long-term customer relationships of a wearable product and potentially secure a competitive position in the market.

While it is possible to intuitively design a product to have an emotional connection, such as in industrial design approaches, a more systematic approach is needed to measure this emotional connection due to the indefinite relationship between an emotion and its behavioural expression. Section 2.1 discusses past attempts at measuring this connection and Section 2.2 describes some existing methods of designing wearable devices. In this article, we proposed an approach with an online tool, a two-axis interactive collage, to understand how users perceive various wearable products both cognitively and emotionally. We developed this collage tool based on the work of Guyton, who demonstrated the collage activity as an effective method to establish product semantics to inspire sustainability concerns (Guyton 2006), and the addition of a connection to perception by She & MacDonald (2014), who used the collage to trigger the five senses in designers. To test and demonstrate the approach, we created an example study in which participants evaluated various wearable products under the target emotion-related or perception-related criteria. Within the same evaluating interface, participants reported their perception, preference, and related emotions of the products in an integrated manner. Though emotions can be further evoked with physical interaction with products, this project focuses on the visual perception of form, functions, and features through a static online photographic representation, which usually happens as an exploratory phase in online shopping or before visiting a retail store.

Using this collage approach, we explored whether wearables that were positioned by participants as more closely resembling clothes evoked more user comfort and user delight. This clothing metaphor was inspired by the work of Dunne & Smyth (2007), which incorporated device wearability (see Section 2.2 for details). Wearing clothes can involve both physical and social comfort and we tested to see if users transferred the feeling of being comfortable and delightful from wearing clothes to wearing electronic devices. We also analysed how participants associated emotion-related descriptive words with perceived user delight, user comfort, and product usefulness as well as user preference.

2. Background

2.1. Emotional design

The value of meeting basic task-related needs has decreased. Kano developed a model in 1984, which categorizes product features into must-be, the-more-the-better, and delighting (Kano *et al.* 1984; Berger 1993). MacDonald *et al.* (2006) further explored the feature classification methods of the Kano model and categorized the delighting features as the product attributes on which users received extra usefulness and satisfaction. Ealey & Troyano-Bermúdez (1996) found it harder to predict customers' preferences when the automobile market was full of similar vehicles so that customers could barely distinguish one from another, suggesting that a vehicle that created "delight and surprise" could

potentially overcome this (Ealey & Troyano-Bermúdez 1996). A study by Bauer, Falk & Hammerschmidt (2006) demonstrated that customers reacted positively to emotional service aspects during online shopping, and the appeal of the website strongly related to the judgement of its functionality and usability.

Emotional design is an active field of research and has many analysis-rich approaches within the context of user-centred design and user experience design. Since the late 1900s, Nagamachi has advocated the Kansei engineering approach to handle consumers' emotional requirements in various design domains (Nagamachi 1995, 2002). The Kansei approach addresses the three following issues: (1) how to capture consumers' emotions to identify design requirements; (2) how to build the relationship between products and the consumers' emotional needs; and (3) how to design products to better fulfil emotional needs. Kansei researchers have proposed many methods to capture/document emotions, for example, physiological pattern tracking (e.g. heart rate), interview, card sorting and semantic differential. Among these methods, semantic differential is the most widely used one in Kansei engineering (Huang, Chen & Khoo 2012). Semantic differential relies on a non-interactive process with a single focal product and a selection of Kansei adjectives (descriptors of emotions) to represent emotions in the psychological realm (Osgood 1962; Huang *et al.* 2012).

In addition to methods that rely on verbal words, Desmet et al. invented a non-verbal tool that uses cartoon characters to represent emotions and used it to identify the emotional responses to the products (Desmet 2003; Desmet, Porcelijn & Van Dijk 2007). Desmet *et al.* (2007) visualized the focal products (cell phones) and associated emotional responses in a two-dimensional space, where the distance reflected the similarities of the products.

2.2. Wearable design

Wearable technology includes electronic devices embedded with sensors and micro-controllers, and they can be incorporated into clothing or worn on the body as implants or accessories (O'Donovan *et al.* 2009; Guler, Gannon & Sicchio 2016). One common approach to designing wearables is to realize a set of design qualities and to understand how the qualities shape user experience. Schirra & Bentley (2015) interviewed five participants who used a smartwatch for at least four months about the factors of purchase decisions and issues related to everyday usage. They identified several design considerations, including aesthetic dissimilarity, causal or sporty form, and colour. Lyons (2015) conducted a similar study with 50 respondents to understand factors that influenced buying and using a smartwatch, finding that style (formal/casual/sporty), similarity to a regular wristwatch, and size were the most important. Lyons also found that colour was one of the decisive design qualities for choosing a watch, and that sleek and simple watches were preferred over flashy ones. Maier *et al.* (2015) developed low-fidelity prototypes based on the existing smartphone technology after discussions with the focus group and tested the wearable technology acceptance to support the elderly. Dunne & Smyth (2007) conducted a study to investigate how sensory stimuli generated by wearing a device affected its wearability in terms of comfort and cognitive attention. They summarized physical, mental, emotional and social comfort as wearability and explored elements of clothing comfort, such as pressure, texture, moisture, etc. They concluded that wearability yielded conscious

consequences and was essential for users to accept the wearable devices. Yet, this study did not involve an experiment or specific features for design.

Wearable technology research does not focus on the emotional connection as a primary design goal for wearable devices. For example, emotion is not mentioned in the study by Maier *et al.* (2015) about assistive technology for the elderly, in which positive feeling could be a key factor in adoption. Additionally, most studies do not involve a comprehensive representation of the alternative products or designs, but rather focus on exploring single product configuration. Reflecting on design qualities without being exposed to other available options causes evaluation in a vacuum, which is unrealistic given the large number of wearables.

2.3. Collage tool design

Our approach uses a two-axis collage tool. The tool was specifically developed from the work of Guyton, who demonstrated the collage activity as an effective way to establish product semantics for sustainable products and to inspire sustainability concerns (Guyton 2006). In this study, we used the collage activity in a novel way as an evaluation tool.

The authors have previously used this collage activity to prime designers into particular mindsets and to help them brainstorm design features that communicate sustainability to the customers (She & MacDonald 2014). She and MacDonald asked the experiment participants to arrange eight images of dish sponges on a white background with two axes: one tracked preference, from "dislike" to "like", and the other tracked environmental impact, from "high impact" to "low impact". Participants then matched the product images with sensory descriptors, such as dim, smooth, soft, musty, and disgusting. While participants physically interacted with the product images and sensory words, they repeatedly made judgements about perception and preference. In this practice, the collage activity served as a psychological priming method; the activity activated specific cognitive orientations as well as relevant cognitive procedures. A follow-up study further validated that the collage activity enhanced students' design abilities to generate more effective features in terms of the environmental friendliness as judged by novice users (Liao & MacDonald 2018).

Instead of establishing product semantics, we now use this collage activity as an instrument for users to express their preference by creating a two-axis map based on provided criteria. First, participants arrange product images on a grid with a set of labelled axes drawn, as illustrated in Figure 1(a). The axes are labelled at their extremities with words that are emotional or descriptive, such as "Like/Dislike" or "Comfortable/Not comfortable". Second, participants describe their selections by choosing words from a given list for each product image. This activity allows participants to evaluate multiple products holistically under various criteria, with different combinations of axes. As mentioned in Section 2.1, Desmet *et al.* (2007) plotted the focal products with respect to associated emotional responses in a two-dimensional space to reflect the relationship between the products and the emotions; we anticipated that a direct input from users in a two-dimensional space would be more accurate and intuitive.
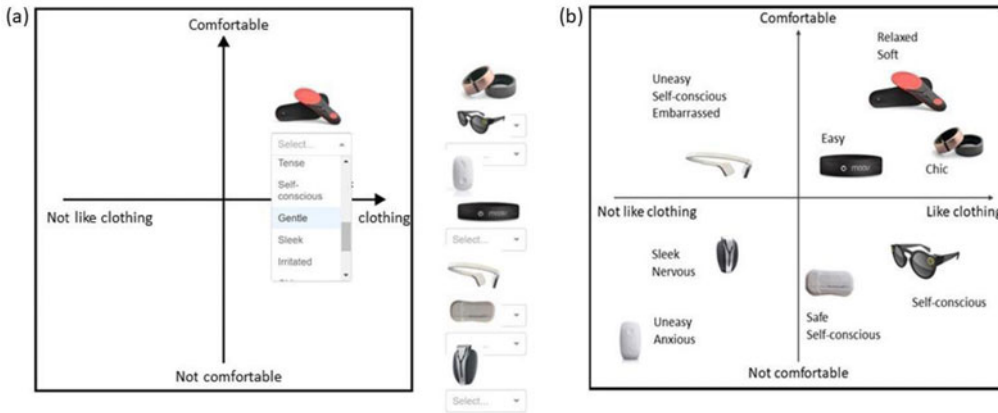
Figure 1. (a) Collage tool in use: users evaluate products by placing product images on the grid and express their perceived emotions by selecting descriptive words from the drop-down menu; (b) collage output.

3. Exploratory questions

We applied the approach with the two-axis collage tool and explored the relationship between emotions and perception of wearable devices guided by the following exploratory questions.

Question 1: *Are wearable devices that resemble clothing perceived as more comfortable?* Being comfortable means physical ease and relaxation. As described in Section 1, Dunne & Smyth (2007) found that wearability, including clothing comfort, such as pressure, texture and moisture, was essential for users to accept wearable devices. Looking like apparel or clothing can remind users of the experience of wearing clothing and evoke the feeling of being comfortable.

Question 2: *Are wearable devices that resemble clothing perceived as more delightful?* Having users feel comfortable and relaxed can potentially let them reduce anxiety and experience delight. A low-tech or low-key aesthetic is expected to positively influence users' acceptance or emotions.

Question 3: *Do users perceive wearable devices that they like as more useful?* Besides user comfort and user delight, the perceived usefulness (functionality) and users' preference are considered important factors for purchase intention and product retention, so the relationship between these two factors is well worth exploring.

4. Collage evaluation approach

Derived from the physical collage activity explained in Section 2.3, we implemented the new interactive tool for users to evaluate various products and to express their preference. The details of the interactive collage activity are further described in the following sections.

4.1. Selecting stimuli products for collage activity

To select images for the collage, we benchmarked wearable devices available for purchase and selected eight products for the collage that either resemble apparel or have a novel look and have various methods of attachment; see

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Table 1. Pictures, schematics, and descriptions of the products for collage activity

No.	Product picture	Schematic	Description
1			This is a shoe insole. It can function as a navigation device for the blind individuals or as a fitness tracking system—for example, counting steps taken, calories burned, and monitoring and remembering workout routines.
2			This device is worn as a ring on the finger. It has a 3-axis accelerometer to detect motion, and an optical heart rate sensor to track heart rate, active minutes, and calories burned.
3			This device is worn as a pair of sunglasses. It records a 10-second video from user's perspective and syncs to Snapchat, a messaging app for phones.
4			This device attaches to the upper back via a reusable silicone adhesive. It easily fixes the posture by strengthening the core back muscles and raising awareness. It provides personalized training program and real-time posture feedback via the mobile phone.
5			This device is worn as a headband. It monitors heart rate during workouts. It also gives exercise coaching.
6			This device is worn as a headband. It tracks mental activity that helps reduce stress and settle the mind. The device uses 7 sensors that are applied to the occipital lobes.
7			This device attaches to the skin via an adhesive. It is a body-worn sensor that naturally conforms to the contours of the human body. It gathers raw kinematics and electrophysiological data to monitor the wellbeing of the patient after medical treatment.
8			This device clips on belt, pocket, bra, etc. It tracks activity, steps, and calories in order to monitor health. It helps to understand what, where, and who causes you to be stressed, calm, or productive.

Table 1. Additionally, the products existing in the market are not as prevalent as smartwatches or fitness wristbands yet, so we expect users' previous experiences will not bias the evaluations. Before the collage activity, we asked participants to review all the products with schematics of how they were attached to the human body as well as brief descriptions of their functions, summarized in Table 1. The online experiment introduced each product in Table 1 on a separate screen in a randomized order.

Table 2. Axis labels for collage activity

	Question 1	Question 2	Question 3
Horizontal-axis label	Not like clothing/Like clothing	Not like clothing/Like clothing	Dislike/Like
Vertical-axis label	Not comfortable/Comfortable	Not delightful/Delightful	Not useful/Useful

Table 3. Lists of descriptive words

Comfortable	Not comfortable	Delightful	Not delightful
Relaxed	Awkward	Delicious	Uncomfortable
Quiet	Unpleasant	Joyful	Disgusting
Soft	Uneasy	Admirable	Harsh
Sleek	Self-conscious	Blissful	Bitter
Gentle	Embarrassed	Joyous	Miserable
Safe	Irritated	Playful	Dreadful
Calm	Anxious	Sweet	Full
Chic	Tense	Ecstatic	Hateful
Easy	Scared	Festive	Awful
Secure	Nervous	Eager	Fearful

4.2. Axis labels

The axis labels were determined regarding the exploratory questions (Section 3). Vertical axis directly related to the targeted perception and emotions of each question (Table 2), and we used the same horizontal-axis labels ("Not like clothing/Like clothing") so that participants could cognitively load as much as they wanted (e.g. opinion, features, etc.) on it.

4.3. Descriptive words

The words in the collage activity describe basic emotions, perception, and design characteristics. For emotional words, we retrieved terms both from the founding research in psychology that described primary and secondary emotions (Plutchik 1984; Shaver *et al.* 1987; Smith 2015) and from the manuals in psychiatric practice and personality tests (Hoffman Institute Foundation 2015) to ensure that words people use daily to self-report feelings were included. We also incorporated aesthetic words from visual design (Augustin, Carbon & Wagemans 2012), and perception-related words from a study of sustainable design (She & MacDonald 2014). This collection of 473 words was decreased to 40 words that relate to the collages' vertical-axis labels (see Table 3) by computing the vector distances between the axis labels and the words using the Global Vectors for Word Representation (GloVe) algorithm (Pennington, Socher & Manning 2014). GloVe represents each word as a vector and is trained on aggregated global word–word co-occurrence statistics from a corpus.
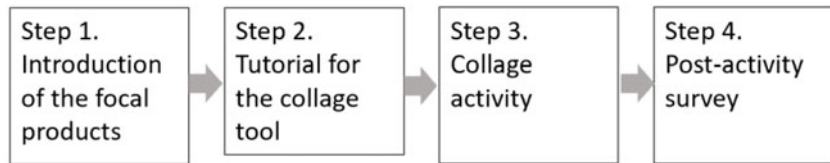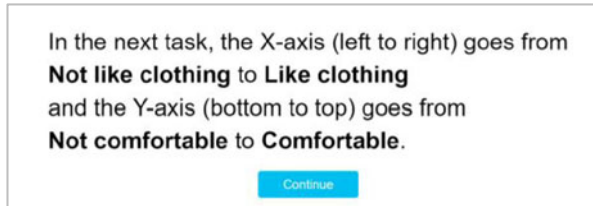
Figure 2. Overview of experimental procedure.

Figure 3. Reminder of the provided criterion before each collage activity.

4.4. Tool development

We coded the two-axis interactive collage tool using Google's Firebase, as shown in Figure 1. This tool allows participants to drag and drop products on the grid and click on the drop-down menu to choose descriptive words. A real-time database records the grid x and y positions of the products and the words selected. The link to this tool is https://product-drag-drop.firebaseapp.com.

5. Study procedure

Four-hundred participants were recruited on Amazon Mechanical Turk (AMT). Criteria for selecting participants followed the recommendations by Mason & Suri (2012) and Kittur, Chi & Suh (2008). The criteria included physically locating in the United States and a greater than 60% approval rate for previous AMT tasks. The experimental procedure is shown in Figure 2.

The participants were first introduced to the focal products with the product pictures, schematics, and brief descriptions about how the products were attached and functioned. The products were presented in sequence in a randomized order. The full list of products is in Table 1. Second, they received a tutorial on the collage tool. Then in Step 3, the participants were given the prompt:

> *"You will evaluate the visual appearance of the wearable devices you just reviewed based on three provided criteria by using this tool. Note that you need to evaluate all eight products (place them on the grid and select at least one word) before you continue or submit your work."*

Participants performed three collage activities based on three provided criteria in Table 2. Before each collage activity, participants were reminded of the specific criterion (axis labels) that they evaluated on, as illustrated in Figure 3. Finally, they answered questions on their wearable use and purchases.
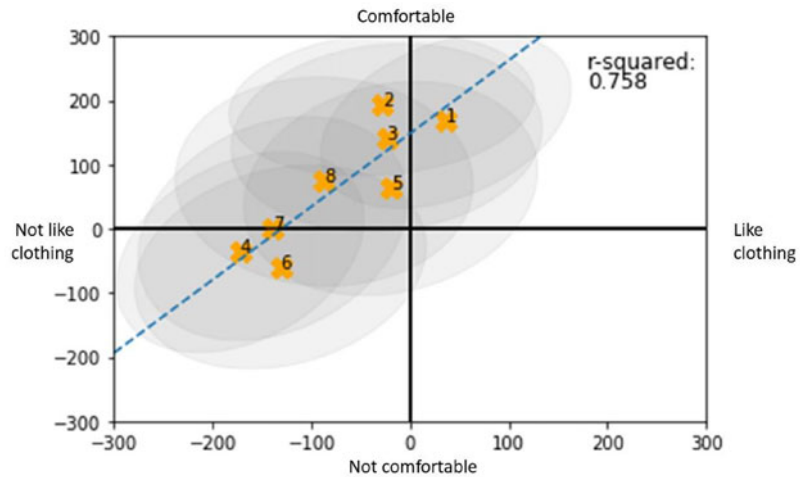
Figure 4. Average positions for axis "Not comfortable/Comfortable".

6. Data and analysis

We collected 351 valid responses, as determined by the response time, which was required to be within one standard deviation (SD) of the mean response time of 7.0 minutes. Based on the results of the post-activity survey, 44% of the participants are female and 54% are male. Forty-three percent of them have ages between 26 and 34 and 36% have ages between 35 and 54. Sixty-three percent of participants reported previously using or buying a wearable product, and the most popular choice was Fitbit. Regardless of whether or not they currently own a wearable device, 43% of participants reported considering buying a wearable device.

The final positions of products were recorded as well as the descriptive words. The average x and y positions were calculated to represent aggregated rating results of products by 351 judges. The boundary of the collage is from -300 to 300. The numeric values indicate relative positions of the products on each category but do not have specific meanings.

6.1. Evaluating user comfort

Figure 4 shows average x- and y-values for each product (see Table 1 for the index of each product) for axes "Not comfortable/Comfortable" and "Not like clothing/Like clothing". The light grey ellipse indicates the confidence region with two SDs from the average position along both axes. The positive linear trend ($R^2 = 0.758$) of the average x- and y-values indicates that wearables that are more like clothing are positioned on the grid as more comfortable. The correlation coefficient of the x- and y-values of the products is 0.335 (p-value $= 3.44e - 123$). Regarding exploratory question 1, this result indicates that wearable devices resembling clothing are perceived as more comfortable.

6.2. Evaluating user delight

Figure 5 shows average x- and y-values for each product for axes "Not delightful/Delightful" and "Not like clothing/Like clothing". The positive linear
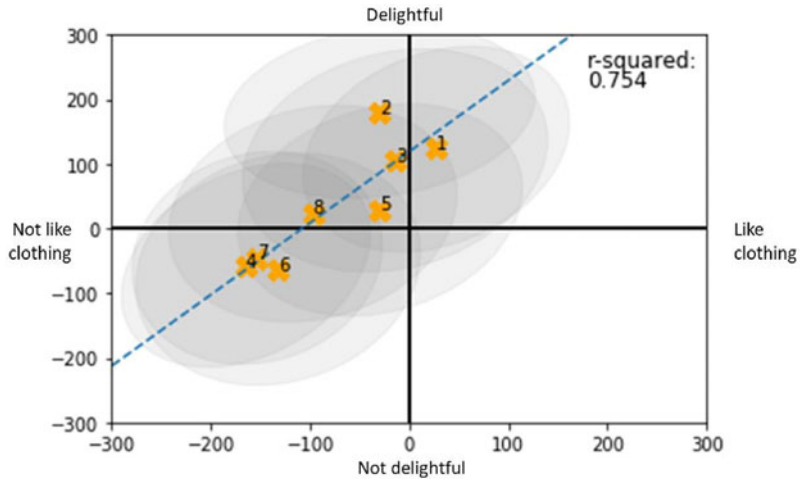
Figure 5. Average positions for axis "Not delightful/Delightful".
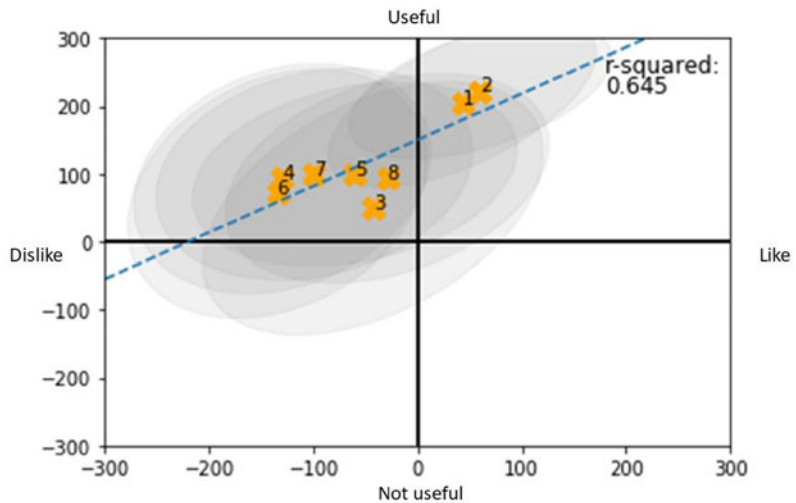
Figure 6. Average positions for axis "Not useful/Useful".

trend ($R^2 = 0.754$) indicates that wearables that are more like clothing are positioned as more delightful. The correlation coefficient of the x- and y-values of the products is 0.327 (p-value $= 9.51e - 89$). This collage explores question 2, and the result shows that wearable devices resembling clothing are perceived as more delightful.

6.3. Evaluating product usefulness

Figure 6 shows average x- and y-values for each product for axes "Not useful/Useful" and "Dislike/Like". The positive linear trend ($R^2 = 0.645$) indicates that wearables that are more liked are positioned as more useful. Most products locate in the second quadrant, indicating most participants considered
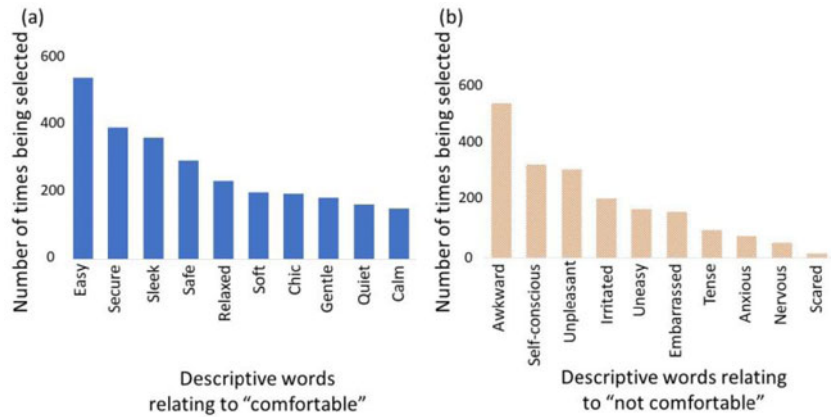
Figure 7. Number of times of the (a) comfortable-related (blue) and (b) not-comfortable-related (orange) words being selected on the collage with axis labels "Not comfortable/Comfortable".

these products useful but did not like them. The correlation coefficient of the x- and y-values of the products is 0.413 (p-value $= 2.72$e $- 176$). This result shows that users perceive wearable devices they like as more useful.

6.4. Choosing descriptive words

As described in Section 4.3, in the collage tool, participants arranged product pictures and identified related descriptive, emotion words and perception words from a given list. The positions of the descriptive words were recorded as the positions of the associated product pictures. In this section, we visualized the word selection in two ways: in Section 6.4.1, we plotted the number of times that the descriptive words were selected on the provided collages; in Section 6.4.2, we showed the most positive and negative words as rated by participants.

6.4.1. Number of times being selected

In the collage with axis labels "Not comfortable/Comfortable" and "Not like clothing/Like clothing", each word was selected 234 times on average with an SD of 141. Figure 7 shows the number of times that the descriptive words were selected for various products on this collage. The colour blue highlights the words that relate to the term "comfortable" and orange highlights the words that relate to "not comfortable" (see Table 2). The top five most frequently selected words on this collage include "Easy", "Awkward", "Secure", "Sleek" and "Self-conscious". The word "Easy" was selected 540 times in total, as the most frequently used positive word in this criterion. This result indicates that the ease to use or wear remains as a critical characteristic, especially for products that provide intimate body contact like wearable devices.

In the collage with axis labels "Not delightful/Delightful" and "Not like clothing/Like clothing", each word was selected 177 times on average with an SD of 153. Similarly, Figure 8 shows the number of times that the descriptive words were selected during product evaluation. The colour blue highlights the words relating to the descriptive word "delightful" and orange relates to "not

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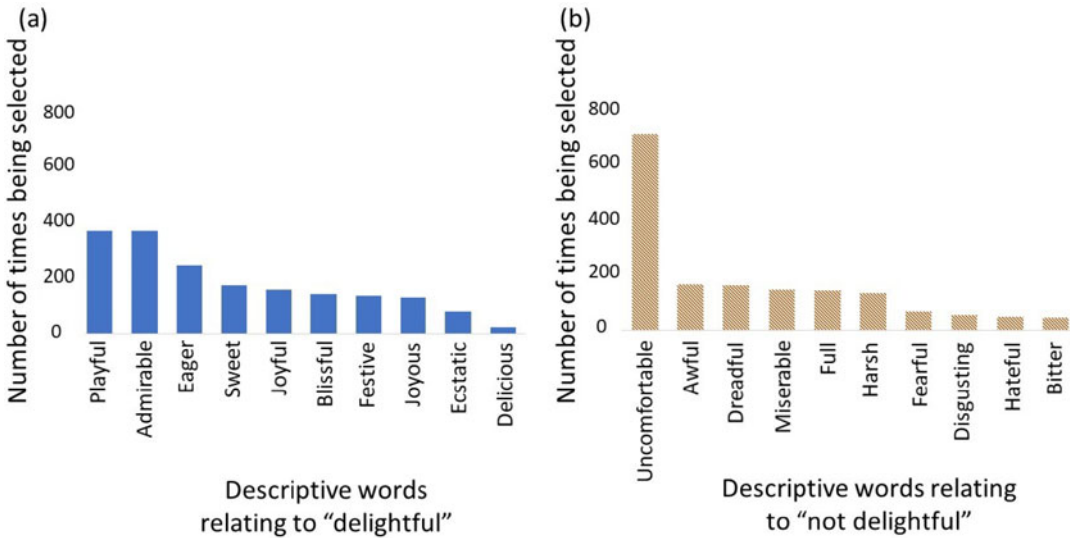
Figure 8. Number of times of the (a) delightful-related (blue) and (b) not-delightful-related (orange) words being selected on the collage with axis labels "Not delightful/Delightful".
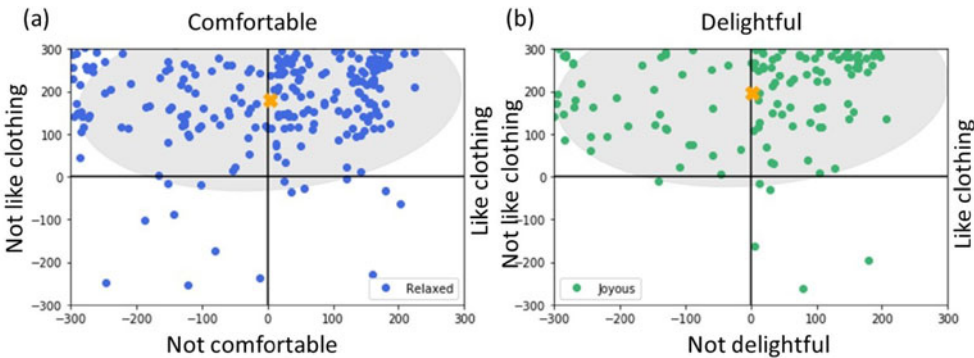
Figure 9. Positions of the descriptive word (a) "Relaxed" on the collage with axis labels "Not comfortable/Comfortable" and (b) "Joyous" with axis labels "Not delightful/Delightful".

delightful" (see Table 2). The words being most selected are "Uncomfortable", "Playful", "Admirable", and "Eager". Particularly, the word "Uncomfortable" was selected 713 times, as the most frequently used word when evaluating products' delight, indicating users associated the product comfort and delight during the product evaluation.

6.4.2. Positions of the most positive and negative words
Shown below (blue dots) in Figure 9(a) are the positions of the most positive word "Relaxed" on the collage with axis labels "Not comfortable/Comfortable". Its average position (3.24, 179) is shown as the orange "X", with the largest Euclidean distance between the average position and the origin in the first quadrant. The light grey ellipse indicates the confidence region with two SDs from the average

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Figure 10. Positions of the descriptive word (a) "Miserable" on the collage with axis label "Not delightful/Delightful" and (b) "Embarrassed" with axis label "Not useful/Useful".

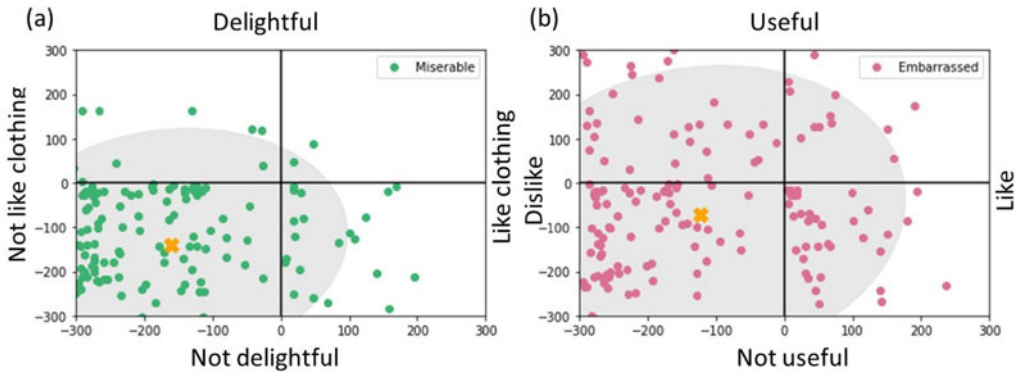position along both axes. The region almost equally expands the first and second quadrants on the plot. This plot indicates that instead of the sensory characteristic such as being soft, mentally feeling relaxed may cause a comfortable feeling. This result supports the argument that building emotional connection can enhance products' wearability.

Figure 9(b) shows the positions of word "Joyous" in the collage, as the most positive word. The average position (2.11, 196) locates closely to the y-axis, which indicates that being joyous is not related to whether the device looks like clothing or not.

In addition to desired qualities, the word "Miserable" has the minimum scores on both axes on the collage with axis labels "Not delightful/Delightful" and "Not like clothing/Like clothing", and the points clearly cluster in the lower left quadrant in Figure 10(a). This suggests that while being alike clothes may not cause a more delightful experience, being unlike clothes or obtrusive can be associated with the undesirable feeling.

Figure 10(b) shows the positions of the word "Embarrassed" in the collage with axis labels "Not useful/Useful" and "Dislike/Like". This word has the minimum average score on the scale of product usefulness. Most words locate to the left of the axis "Dislike/Like" but are spread out along the axis "Not useful/Useful". This indicates that the perceived usefulness of a product is not relevant to users' feeling of embarrassment.

7. Discussion and conclusion

In this paper, we demonstrated the design and development of a new approach that allows users to interactively evaluate multiple products, under various targeted criteria and to self-reflect on their emotions when perceiving the products. The approach with the collage tool aims to capture the relationship between users' visual perception and emotional responses. As mentioned in Section 2.1, Desmet *et al.* (2007) instructed participants to reveal their emotions and then visualized the results in a two-dimensional space; this tool produces a similar type of results in a more intuitive manner.

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Figure 11. Illustration of the design for a wearable for infants using "Easy" and "Play" as guidelines.

As for the exploratory question 1 and 2, the user responses suggest that the wearable products more closely resembling clothing are perceived as both more comfortable and more delightful. In addition, the outputs indicate that products users liked more were considered as more useful. Product No. 1, smart shoe insole (see Table 1 for more details), was rated as the most comfortable and delightful item, potentially because participants perceived it as soft based on their personal experience, even though the shoe insole was not described as being made of soft material. This observation validates our assumption that users transfer the feeling from wearing clothes to wearing electronic devices. However, six out of eight products received negative average scores on the scale of liking. These results answer exploratory question 3 and demonstrate a gap between fulfilling the functional requirements and providing user satisfaction. This finding is in line with the previous literature, which suggests a marginal effect of meeting fundamental functions on increasing user satisfaction beyond a certain extent (Kano *et al.* 1984; Berger 1993; MacDonald *et al.* 2006). On the collage of "Like/Dislike", product No. 2 (a ring) was rated as the most favourable product, potentially because the ring is closely associated with pleasant experience across cultures.

The results indicate that users obtain a more pleasant experience if they perceive the wearable products that are more like clothing. This finding highlights a potential avenue to design wearables to be softer and more breathable with soft fabrics or be incorporated into clothing, such as product No. 1. In addition, users are not opposed to products that are worn directly on the body, like product No. 2; however, products that needed to be mounted in a novel way, such as product No. 4 and No. 6 can be perceived as intrusive.

This approach also facilitates identifying descriptive words regarding perception, emotions and aesthetics of each product comparatively under various criteria. The word "Easy" was the most frequently chosen when users evaluated products' comfort. The word "Playful" being the most frequently selected positive word to reflect user delight uncovers the design opportunity to make products fun to play with. Using "Easy" and "Playful" as design criteria, we created a use case of the wearable devices for monitoring infants, as illustrated in Figure 11. The prototype incorporates a playful appearance with printed cartoon patterns

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and flexible sensors to evoke an easy and playful experience. We will validate this approach by testing if the prototype can result in user perception of a more useful, delightful, and useful product. In addition, as shown in Section 6.4.2, the most positive and negative words, such as "Relaxed" on the collage of "Comfortable/Not comfortable" and "Embarrassed" on the collage of "Useful/Not useful", reflect a social experience rather than perception of physical characteristics. These underscore the need to design comfortable and useful wearable devices by focusing on emotional needs in addition to specific physical features.

The example study demonstrates this two-axis interactive collage as a tool to investigate relationships between products and emotional needs, as well as to identify meaningful design words. It focuses on revealing insights from users' visual perception, with a context of product evaluation, instead of from a text-based emotion assessment. This approach simulates a specific situation, where potential customers evaluate available options visually before they interact with physical units. Furthermore, the product images, axes and word banks can be manipulated to explore different design dimensions, as well as the online feature makes it accessible to a larger and more diverse population.

8. Limitations and future application

There are many other characteristics that relate to user comfort and delight. As this study only focuses on visual perception of the product images, other attributes that relate to material functionality were not included. Some design attributes, such as surface finish and colour, that were found to have a significant impact on the purchase intention can be included in the future experiment to provide an enriched design guideline. This study aims to mimic the early-stage exploration in online shopping, and an in-person experiment can be conducted to understand user interactions with the tactile features.

The selection of product images can potentially influence the outcome. The focal products in this study varied in terms of functions and outlooks and expanded the design space as much as possible. This variety can potentially make it difficult for users to compare. The number of wearable products being presented was relatively small, probably unable to capture many sectors in wearable design; however, presenting more focal products might increase task difficulty or cause mental burden for participants. This study focuses on wearable products, where building emotional connection can be beneficial to differentiating a product. We acknowledge that the results can be different for a different product category.

Participants were prompted to evaluate products and to express their preference under this specific construct. Their self-reported preference may change under different scenarios. As there exists no similar way to evaluate products in two-dimensional space, it is challenging to compare or validate this tool with the existing methods.

This study only included an online (as opposed to in-person) collage activity so that it could be more accessible to the general population. We do not anticipate any difference in the results caused by the modes of the experiment, but any technical difficulty with internet or computer can distort the results. In addition, the axes corresponding to the three exploratory questions were presented in the same order to all participants, which could have potentially created fixation.

Regarding the exploratory questions, we only tested linear relationships within individual pairs of axes. Furthermore, participants were surveyed about

their experience using wearable devices and future purchase intention. These factors can potentially influence participants' expectations and evaluations of the products, yet they are not taken into analysis for this study. We also plan to further analyse the data to associate emotional needs with more specific product features and uncover relationships between specific emotions and design directions.

This approach enables identifying design words that are associated with user-perceived comfort, delight and usefulness. More testing and/or industrial designers with related training are needed to embody the words in new product designs, such as the prototype shown in Figure 11. The words were generated using a computational method, and the output may be less interpretable semantically, such as "eager" for the "delightful" and "full" for the "not delightful" category.

In this article, we proposed a new approach with an interactive collage tool that captures the relationship between users' visual perception and emotional responses. The approach enables designers in understanding user emotional reactions in a more intuitive and holistic manner without using an analysis-heavy method. With the insights into users' emotional responses to product characteristics, designers can better build emotional connections between products and users so that users would obtain a more delightful experience and receive more satisfaction. It also benefits designers by allowing them to identify potentially fruitful design directions by extracting emotional requirements suggested by users. Therefore, this approach can particularly benefit exploring different design dimensions and products in the early phrase of product development and benchmarking potential market sectors with multiple alternatives. The proposed approach can enrich design exploration before more engineering effort is invested in building and testing prototypes.

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