Fashion and Textiles

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Exploring personalized fashion design process using an emotional data visualization method

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Abstract

In recent years, rapid economic growth and a rising personal income have increased the demand for personalized services. To address this demand, the fashion industry and academia are increasingly analyzing and developing methods to provide personalized fashion design products. This study investigated an emotional data and data visualization-based design method for personalized fashion products. By visualizing emotions and involving consumers, we generated experimental designs to encourage interpersonal and emotional communication. In addition, we proposed methods for visualizing 28 levels of emotion in design elements, as well as a generative design process based on emotional and personal text messages. In fashion products, we used color and print to match the emotion and intensity of the emotion. As a result, 40 design experiment participants rated personalized fashion design tools, outcomes, and purchase intention positively. The highest score was received by the average value for expression of personality (4.43), purchase intention (4.38), and preference and recommendation (4.42). Consequently, this study could be applied to the use of personal data in generative fashion design, as well as the systemization of the data-driven design method for personalized and participatory fashion design.

Keywords: Emotional design, Data visualization, Generated design, Personalization, Fashion design

Introduction

Online fashion consumption along with the younger generation's desire to consume personalized goods has grown rapidly in recent years. Therefore, customized services have received a lot of attention in fashion and design (Lee & Chung, 2017), with fashion companies trying to highlight product diversity through customized services (Park & Yoo, 2018). These elements have accelerated the customization trend in the fashion industry (Mackey et al., 2017).

Consequently, an increasing number of entrepreneurs and academics are emphasizing the importance of personalized products to meet each consumer's needs and provide a personalized shopping experience (Endo & Kincade, 2008; Franke et al., 2009). However, personalization is challenging to implement in design because of its low efficiency. As a

result, the connection between personalized designs and consumers is less effective than many expect, and in practical industry applications, the elements of personalization and customer experience are reduced. Personalized elements and a sense of experience in design results are reduced (Franke et al., 2009; Simonson, 2005).

In recent years, extensive data-driven recommendation system technology has received a lot of attention. Many companies have tried to create personalized product recommendation systems (Yu et al., 2019). Researchers are also working on improving recommended accuracy and matching solutions in order to meet personalized customer demands (He et al., 2016; Lee & Chung, 2017; Vasileva et al., 2018). The use of technological design methods for personalized expression is a significant development in the fashion industry (Mackey et al., 2017). Data Visualization is a new way to use technical resources related to fashion and art creation in computer vision, which involves using computers and systems to extract relevant information from photos, movies, and other visual inputs (Szeliski, 2011). Fashion and artistic design have also been recognized as novel areas employing technological methods. However, most data visualization research focuses on data efficiency, comprehension, and perception, with few studies focusing on methods that can directly realize emotional data visualization based on customer personality traits.

This transition has led some visualization experience researchers to propose an alternative method of consumption aimed at reshaping the user experience with user-friendly data (Kostelnick, 2008). However, these researchers prefer to establish and compile the value of visualization rather than the visual design itself (Wall et al., 2018). Therefore, emotions related to personality traits have been used in this study to investigate the application design method of data visualization in personalized fashion design.

This study focused on creating personalized design flows based on emotional language through the use and development of data visualization. P5.js software was used to process the data, resulting in private data of specific emotions and significance. We also used data visualization to design the fashion products that expressed personal emotions. Finally, using personal data, this study attempted to provide a novel method for individualized fashion design. By utilizing an open-network database, this study lays the groundwork for furthering personalized and participatory design in fashion.

Literature review

Data visualization

As technology and society evolve, data visualization is widely used in society and affects every aspect of our daily lives. Although data is an abstract and invisible aggregation, it is compelling and communicates with users through specific visual forms. Data visualization, according to Kirk (2012), is "data expression that promotes its understanding," claiming that it maps data attributes and appropriate visual elements to transfer data. Data visualization is the process of converting complex data information into visually and emotionally expressed understandable data (Kim & Chung, 2019). According to Cairo (2012), data visualization is a process that transforms unprocessed data to make it easier to understand, express, and transmit.

As programming has advanced, data visualization has been widely applied to many areas of art. Previously it was only an academic discipline, but has now entered the

domain of multidisciplinary research. Furthermore, data visualization applications encourage consumers to participate in new business models and draw public attention, making it a new trend (Kim & Chung, 2019). A review of extant literature indicates that current data visualization research has focused on different methods to represent and provide data visualizations for various types of information and examined the diversity of data visualization in artwork (Cairo, 2012; Kim & Park, 2013). Paik and Lee's research also emphasized personalized fashion design through data visualization in fashion. This study emphasized that data visualization, rather than being a single type of scientific visualization, uses colors, forms, lines, spaces, and other design elements to reasonably display data (Paik & Lee, 2017). Further research on data visualization as a participatory fashion design tool is required to meet the needs of consumers in the fashion industry.

Visualization of emotions

Emotion is the interaction of cognitive, psychological, and behavioral factors to elicit a psychological response to specific events or stimulate human instinct (Lee & Yoo, 2013). In other words, before making decisions on specific subjects, people's emotions respond to sensory stimulation such as sight, sound, smell, touch, and taste.

According to Scherer and Ekman (2014), the six basic emotions expressed through facial expressions are fear, anger, happiness, disgust, sadness, and surprise. Confucian philosophers argued that there are four origins and seven emotions that are standard forms of the philosophical concept of emotional expression (Ivanhoe, 2015). Plutchik (1980) defined basic human emotions as comprising sadness, disgust, anger, expectation, joy, trust, fear, and surprise, whereas Ortony et al. (1988) classified basic human emotions into 22 categories.

People are often unable to communicate their changing emotions effectively (Chen et al., 2017). Consequently, effective emotional communication and scientific research methods require additional attention and investigation. Furthermore, linguistic factors are rigid in daily emotional communication, whereas non-linguistic factors are more user-friendly and expressive. Therefore, more informative approaches are used in simple linguistic communication methods that use visual, aural, and other factors, as well as sensory and non-linguistic communication methods (Han & Kim, 2010). Thus, visualizing linguistic factors can be crucial in reliably conveying emotions.

Many existing studies have looked at designs that represent emotional information. For example, Urquhart and Wodehouse (2018) restored the basic line model of form, emotion, and semantics by reviewing visual perception, form theory, and emotion theories, and conducting a historical analysis of forming changes in aesthetic art. Yang (2018) redesigned ice cream boxes by analyzing and interpreting eight emotional expressions. Yoo (2018) also created dynamic graphics for emotions and expressions in smartwatches by analyzing six emotions' shapes, colors, and dynamic changes. Kim (2016) investigated emotional demands in social media and four approaches to emotional visualization. Finally, Weerdesteijn et al. (2005) developed an educational product that teaches kindergarten children how to express their emotions through body language using a static approach based on appearance and (interactive) dynamic movement. Based on prior research, we analyzed the characteristics of how emotional content is expressed in a

visual form to design personalized fashion products. This article used visual expressions related to personal emotions to implement personalized fashion design.

Personalized fashion design

The primary trends of industrial society have been mass production and consumption. However, as modern consumption trends shift toward diversity, personalized consumption is becoming more popular in a society centered on mass culture.

Personalization, according to Kumar (2007), would prefer to recognize customers or service objects as individuals rather than as a group. Personalization has recently focused on how consumers change the functions or outlooks of a product from a product-oriented standpoint.

While employing personalized services, consumers may have the option to choose the appearance or functions of the products and participate in the design process to experience co-creation (Mattelmäki & Visser, 2011). Additionally, personalized products can be created through tailoring or customization to improve the end user's experience (Sundar & Marathe, 2010).

Involving customers in the design process may increase the likelihood of products meeting customer needs while also improving end-user satisfaction and interaction (Steen et al., 2011). Thus, by intervening in the design process, consumers can obtain products that have important personality traits or meet their needs. Furthermore, personalized goods are the process of expressing oneself while implying special meaning for the consumer (Mugge et al., 2009).

The real-time visualization of consumers' own designed products is at the core of achieving individual product customization and demand satisfaction (Saibna et al., 2014). As a result, when compared to conventional fashion design methods, computer-aided design allows for more personalized and participatory design (Hu, 2021). We used computer-aided design software in this study to allow consumers to express their emotions as individual data while also providing a flexible framework for data collection.

Methods

The aims of the research were to structure a personalized design process using data visualization of emotions and to create personalized fashion products. As shown in Table 1, the entire design process was divided into three stages: the construction of the algorithm framework, programming, and implementation.

We collected and analyzed the elements, classification methods, and expressions of emotions based on previous research on emotional shapes in the first stage, and we collected emotional data and visual representations via questionnaires in the second stage. In the first stage, we used a questionnaire based on previous research on the shapes of emotions to collect emotional data and visual expressions. Following that, we created a design to realize the visualization of emotions after analyzing the data. Finally, we establish a connection between the categories of emotional data, intensity and design elements (color, form and size). In the second stage, we used P5.js software to code the application interface, visualize expression elements and data, and establish a correlation to construct the algorithm. Finally, in the third stage, to assess customer experience and

Table 1 Stages in the personalized design system

Stage	Content			Method
		Input	Output	
	Data collection	Emotional words Modifiers	Emotional color theory Formal beauty principle	Preliminary research
Algorithm architecture	Data analysis	Type/Intensity setup of emotional words Adverb of degree/Negatives	Setup the scope of emotional colors Collection of forms	Preliminary research, questionnaire
	Corresponding relationship	Emotional categories Emotional intensity Adverbs of degree Negatives	⟷ Colors/Forms Brightness/Shape & Scale/Material Shapes & Scale Purity of colors	
Programming	Front end-Input window/ Output window/ Product selection area			
	Rear end-Data archive-Emotional words/ Adverbs of degree/ Negatives			P5.js software
	Run program-Visual forms/Color setup Corresponding relationship/ Front-end interface			
Implementation	Front-end input window for consumers-Data input/Selection of product sizes			
	Pattern confirmation/File generation			Use by consumers
	The producer corresponds product material and size/Pack up, printing, and producing			

final products, we surveyed 40 people aged 20 to 30 via an online questionnaire. We developed the questionnaire based on previous research by Tian (2021). It was scored on a 5-point Likert Scale and comprised 16 questions divided into four categories: personality expression, product differentiation, customer satisfaction, and purchase intention. There were 15 male respondents and 25 female respondents.

Emotional patterns based on data visualization

In the first stage, we used a literature review and a questionnaire to collect basic emotional information and designed shapes in preparation for further integrated analysis. As a result, designs in shapes corresponding to various emotions were created. This study chose language elements that convey emotional information as data. As expressive elements, the seven most frequently proposed emotions (happiness, anticipation, anger, disgust, sadness, surprise, and fear) were collected (Scherer and Ekman, 2014). The emotion words, as well as the emotion dimension and emotion intensity of each emotion word, were classified in the Korean language based on a classification study of emotion words (Sohn et al., 2012).

To visualize emotions, we divided the terms into seven categories: happiness, anger, surprise, anticipation, disgust, sadness, and fear. A total of 426 emotion-related words were chosen, along with their emotional categories. Furthermore, they were arranged by intensity as the foundation for achieving emotional visualization. The effect data now included degree adverbs like "very" and "special," as well as negative words like "not."

Table 2 The process of creating emotional patterns

Type of emotion	Association of emotion and form		Synthesis	Pattern
	Precedent research	Questionnaire		
Happiness				
Anger				
Surprise				
Anticipation				
Disgust				
Sadness				
Fear				

We conducted a questionnaire survey among 30 undergraduate and postgraduate students aged 20–30 who majored in or had a strong interest in fashion design, including nine male and 21 female students, to improve consumers' recognition of each emotional pattern. The questionnaire was available online from November 10 to November 12, 2019. The questionnaire sought to describe the visual manifestations of seven emotions. The respondents were instructed to draw images of each emotion using dots, lines, and planes. We observed the characteristics of lines and shapes that frequently appeared in previous studies and compared them to those of the questionnaire. Then, we evaluated these characteristics to incorporate these highly ranked elements into the design sketch. The final visualized sketch, as presented in Table 2, was created.

Algorithm of the personalized design program

The algorithm used in the first stage was built in three steps: data collection, analysis, and the corresponding correlations. First, data collection gathered the necessary emotional words, modifiers, and theories. Following that, the data analysis phase examined emotional terms, intensity, modifier categories, and emotional forms. Finally, the processes of input data (emotion words) and output results were correlated (output forms).

During the initial stage of developing the algorithm, we matched the input data set (emotion category/emotion intensity/modifiers) with the output (visualized

expression factors). As indicated in Table 1, the correlations correspond to each side of the arrow's input and output. Shapes, colors, materials, and patterns are prevalent fashion design elements used as modeling standards (Yoo, 2018). This study focused on two factors: prints and colors, both of which could provide a visual experience. The emotional categories were based on Plutchik's (1980) wheel of emotions. These emotion categories corresponded to the colors and shapes in the output simultaneously.

Furthermore, color brightness was related to emotional intensity, which influenced the brightness of the output color in the data (stronger emotions typically had higher color intensity). The intensity of colors increased proportionally to the number of adverbs in the input data. Each intensity, however, was designed to correspond to its shape during output to distinguish it from the intensities of emotion words. The colors' purity matched the negative words in the input data.

In the second stage of the study, the programming was divided into front-end and back-end programs. The front-end program was a user interface that included input and output windows, a product selection area, and the input text.

Furthermore, the operations interface was the back-end program, which was made up of two parts: data files and a running program. Initially, we restricted the input data to include emotion, adverbs, and negative words. The running program then included the visualized forms of each emotion, color settings, correlations between input data and output results, as well as the front-end interface.

In the third stage, consumers could type the texts they wanted to express themselves and choose the products. After generating the patterns, the consumer chose their background colors. The final pattern design could be generated randomly, and consumers could select their preferred patterns for digital printing and the final fashion product.

Results

Systemization of personalized fashion design phases

Schema of the algorithm

The participants' emotional data was matched to their performance forms in the first phase. Figure 1 illustrates how participants created 2D patterns for each emotion and chose colors for each pattern to create a visualization effect diagram depicting each emotional dimension. Depending on the intensity of the emotions, the data could be graded from two to nine. For example, in the case of happiness, a number on a scale of two to nine degrees for the intensity of the emotion can be chosen and plotted with an effect diagram (see Fig. 1).

When discussing the relationship between data and design elements, the generated graphics were used to display design elements such as shapes and colors, as presented in Fig. 2. The first icon used the primary color to represent the seven emotions from Plutchik's (1980) emotion model. As illustrated in Fig. 2A, these primary forms appear only in situations involving emotional factors. The colors in the design factors did not change when there were adverbs of degree, and the original pattern displayed an expanded outline, as depicted in Fig. 2B. When negative factors were present, the generated patterns remained unchanged, and only the colors were altered by chroma reduction, as shown in Fig. 2C.

Programming

The programming phase entailed converting the algorithm architecture in the first stage into a program and writing the front- and back-end sections separately using P5.js software. Its front-end interface allowed consumers to individually select the colors and shapes of the patterns or input data information to customize their patterns. For example, after entering a paragraph into the input box, the back-end could recognize emotional information as well as other factors and then perform a series of calculations based on this information. Using the system's automatic recognition, product shapes in the front-end could be produced into corresponding patterns with random layouts; these patterns, along with repeated confirmations, were set in the coding for the back-end program. Consumers could thus choose the final generated pattern to achieve data visualization capabilities via repetitive and random pattern outputs. Following the design process, the visualized patterns were created and printed.

Implementation of personalized design program

Figure 3 depicts the three design implementation phases of the personalized design system: consumer, algorithm, and producer. The interface for the personalized design system was created using the P5.js consumer interface, comprising three modules: selecting items, selecting a background color, and typing the message. The participant selected a background color and typed the messages as part of the first phase of consumer participation. Scarves, perfume labels, packaging boxes, and greeting cards were among the items that could be adapted for emotional visualization. In the second phase, structured algorithms were used to convert the emotional words in the message into symbols. The consumer's input messages validated the emotional intensity, and whether the symbols' shapes and colors match. The symbols were randomly arranged and placed in the pattern design section by the structured algorithm. After the consumer confirmed the personalized pattern designs using emotional symbols, the final patterns were applied to the selected items. Customers were able to preview the final interface design. In the third phase, the items mapped to the pattern designs were e-mailed to the digital textile printing producer. After printing the fabric and paper, the manufacturers created the items.

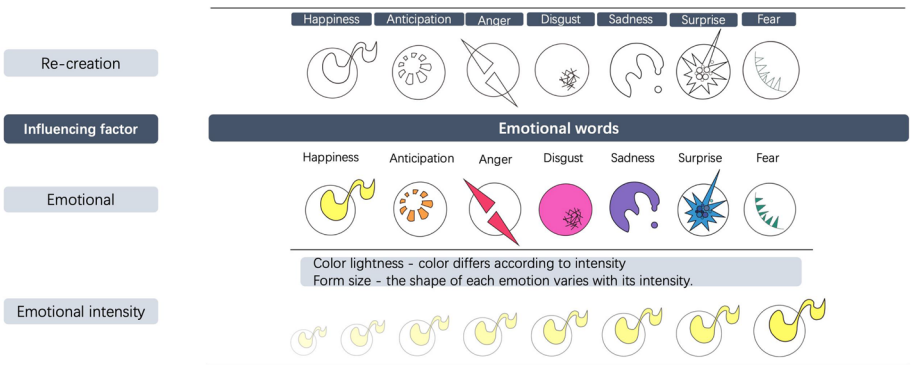

Fig. 1 Seven visualized emotions with their intensity

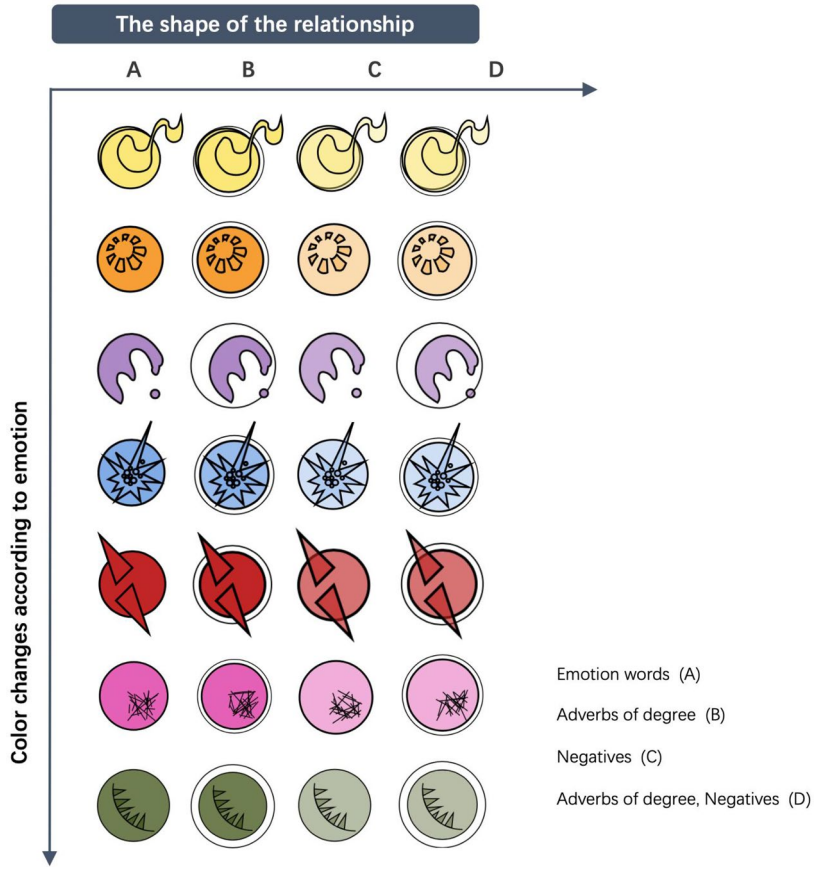

Fig. 2 Correspondence between data and visual presentation

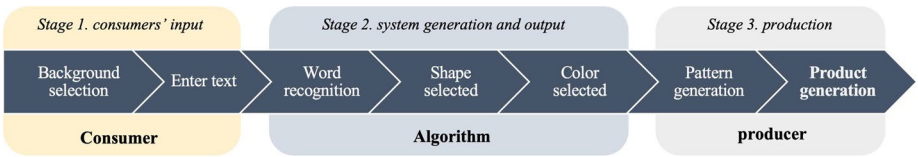

Fig. 3 Process of the personalized design program

Developing personalized designs using emotional data visualization method

Scarf design sets

According to the usage procedures of the aforementioned applications, the first participant's personalized fashion products included a scarf and its packaging. As depicted in the first graph, the participant selected her preferred fashionable scarf and color (purple) in the option on the first page. The participant (office lady) then entered the messages containing the emotions into the input box. Following the message confirmation, the system extracted five intensities of emotional words from the textual expressions and matched the emotional patterns such as happiness, surprise, sadness, disgust, and anger. Following that, we set the arrangement density coefficient to "3" based on the participant's demand for sample arrangement density. The scarf's effect diagram and relevant manufacturing data were generated automatically. Because the pattern on the scarf was

randomly arranged, the participant could choose her favorite design through repeated outputs, expanding the variety of personalized products. The output and generation processes are depicted in Fig. 4. Following that, the participant designed the packaging by first selecting her favorite packaging box. The participant used the same density coefficient for the typed data and the color of the package design. Finally, as shown in Fig. 5, the participant chose her favorite package. The information was then saved and transferred to the following steps: digital printing and sewing. Figure 6 depicts the final effect diagram. The participant also embellished the scarf with fur to convey heartwarming emotions.

Perfume package design sets

The other participant (a male college student) selected a perfume and designed its label, greeting cards, and packaging box for his personalized products. The participant began by selecting his favorite green color for the label and then typed the emotional messages he wanted to express through the designs. "Dear brother, how are you doing?" He wrote. "We had not seen each other in 5 years. I really miss you. I was sad, surprised, and annoyed the first time I had to say goodbye to you. I was irritated because you made me feel afraid and lonely, and my life became difficult without you." The system matched the emotional intensity output after confirming the arrangement density coefficient; two patterns for happiness, two each for anger and surprise, and one each for disgust and sadness. The perfume label's final effect diagram was composed of five emotions and eight patterns. The same method has been used to personalize the greeting cards and packaging boxes. Figure 7 depicts the effect diagrams for these two items as well as the generation process. As with the previous design, the data were saved and transferred to the next procedure, namely, digital printing, tailoring, and manufacturing, to achieve the final product, as depicted in Fig. 8. Finally, emotional information matched the perfume's fragrance.

To achieve the goal of visualizing emotions and commercializing personalized fashion design more effectively, we created a card interpreting the emotional message, as displayed in Fig. 8. Without a text message, this card could assist recipients in interpreting the symbolic meaning of the emotional patterns and design.

Assessment of the customer's experience of a personalized design program

As illustrated in Fig. 9, the average value for expression of personality was 4.43, while the average values for product differentiation, customer satisfaction, and purchase intention were 4.25, 4.23, and 4.38.

Among the questions, "I think these personalized clothes can be one of my highlights that stands out the personal expression" received the highest score of 4.50. In comparison, "these clothes are easily recognized as their own-made products" received the lowest score of 4.25. The statement "People would prefer personalized products and would purchase and recommend them to others" received a score of 4.42. Customers' satisfaction with personalized designs and matching designs had the same score of 4.23.

Thus, personalized, participatory design clothing capable of effectively expressing personality could be created. However, for a personalized design service, the distinction between items and design elements should be improved. Furthermore, we discovered

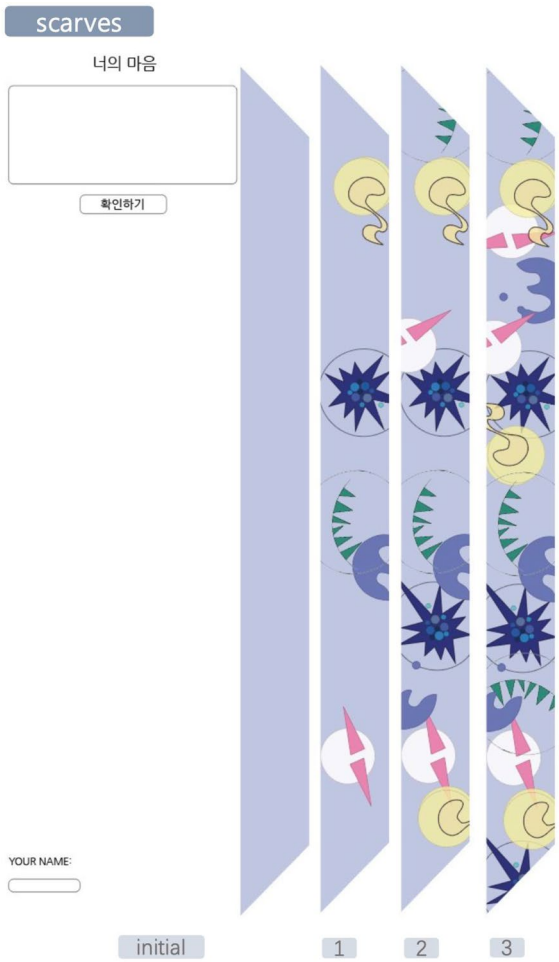

Fig. 4 Scarf pattern generation process

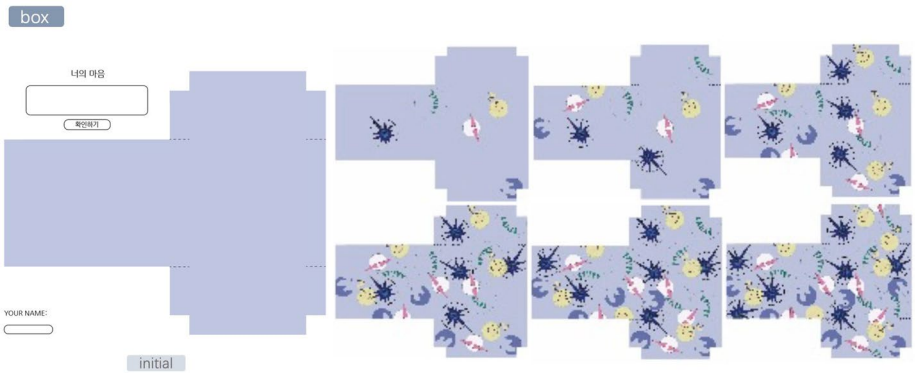

Fig. 5 Packaging pattern generation process

that personalized, participatory design was the primary concern of female respondents, with 92 percent interested in this service. Female respondents thought it could be a great way to express themselves and were more likely to pay for this service to do so.

Fig. 6 Scarf design sets

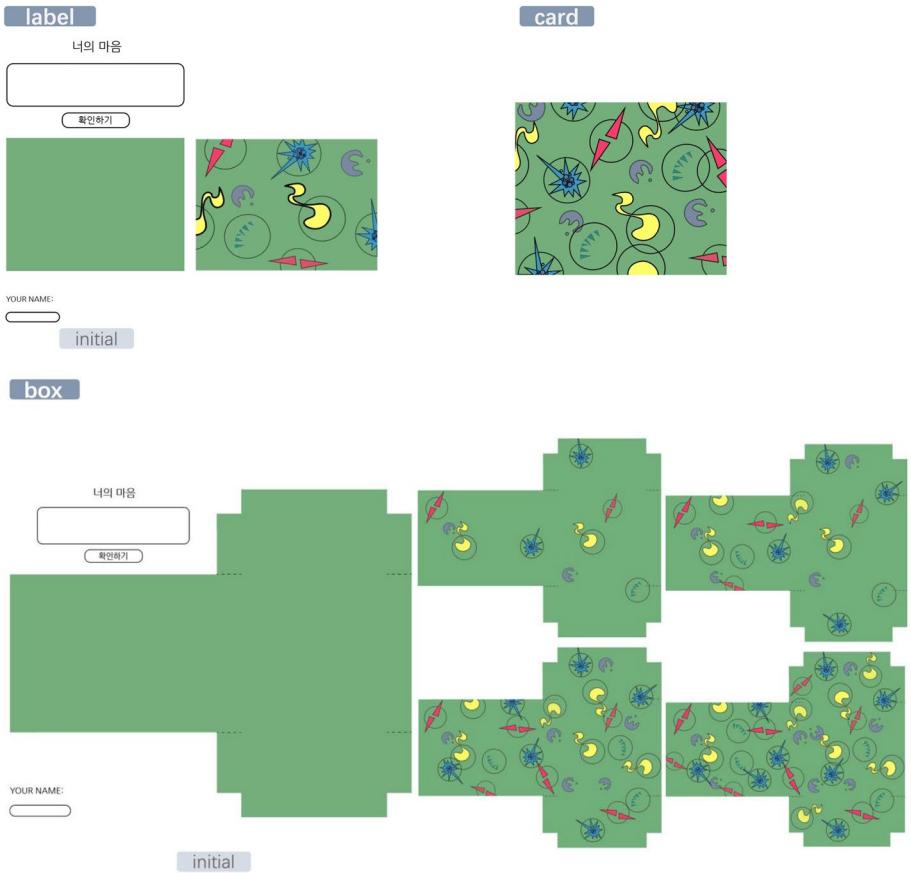

Fig. 7 Generation process of the label, greeting card, and packaging box for perfume

Conclusions

This study presented a new personalized and participatory fashion design method based on data visualization technology. We discussed a design process that uses new techniques such as data visualization and generative design after determining the issues in

Fig. 8 Perfume series effect diagram and the card illustration for reading the emotional message

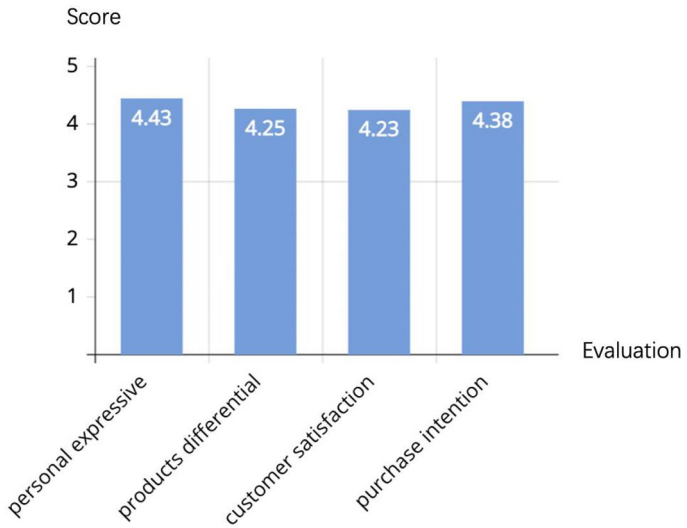

Fig. 9 The evaluation of personalized fashion products

the personalized design market and the demands of Millennial and Generation Z consumers. This research also resulted in the development of a personalized design system for transferring emotional words to design elements.

In summary, the visualization of personal information could more precisely meet consumers' needs because it could depict consumers' attributes such as emotions, personalities, preferences, and other personal data in greater detail. Personal information visualization can add variety to fashion design. The design system's algorithm effectively reflected consumers' emotional expressions on personal design outputs. Furthermore, the two-way mapping change of data and visualized emotional elements could generate more possibilities for fashion design.

Personal data visualization could enable fashion customization by using form, color, pattern, texture, and other elements. It is possible to customize an individual fashion design that comprehensively displays each consumer's innate differences by defining the colors, designs, styles, and dimensions of a personalized design system. Thus, the data visualization process can help consumers connect with the fashion company, and the participatory design system can encourage consumers to express themselves.

This study has limitations in the range of emotional words used for study, the number of participants, and the limited number of fashion items. Further practical research is required to investigate the applicability of fashion business models and consumer experiential design. However, the findings of this study could contribute to the diversity of fashion design methods that use data science in a multidisciplinary approach.

Acknowledgements
The authors are grateful to Peixing Wang for programming test.

Author contributions
NM conceived the ideas experimental design, collected the data and performed the experiments, interpreted the results, and drafted the analysis manuscript. JHL and JK supervised and gave continuous support to the study structure, performed the experiment successfully, and revised the manuscript. All authors read and approved the final manuscript.

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Funding
Not applicable.

Availability of data and materials
The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request.

Declarations

Competing interests
The authors have no conflicts of interest regarding this research, authorship, and/or publication of this article.

Received: 18 February 2022 Accepted: 18 October 2022
Published online: 15 December 2022

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