User-Centered Design of a Smart Refrigerator Integrating Kansei Engineering Principles

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ABSTRACT

Today's world, smart devices are most common with all the people. Smart devices are electronic gadgets or machines that have the ability to interact, connect, and share information with other smart devices. They have become an integral part of our daily lives, and their use has increased significantly over the years. This paper describes the creation of a smart refrigerator that uses Kansei Engineering method to improve the user experience by considering the psychological and emotional aspects of design. Potential users' Kansei words were gathered to find out how those words made them feel. These feelings were then studied statistically to find links with technical aspects like color, size, style, and usefulness. The findings revealed that users prefer smart refrigerators with a silver color, two-door design, and 275-liter capacity. The study provides a useful way to consider how to build smart refrigerators, especially so that they consider people's feelings and tastes. By meeting emotional needs, these kinds of methods can improve daily life and help people feel closer to their devices, leading to more people accepting and using smart home technologies. This study provides important information to the field of user-centred design. It shows how Kansei Engineering can improve products and make devices easier for people to understand and use.

General Terms

IOT, Kansei Engineering

Keywords

Smart Refrigerator, Features, Smart Device, Product Design, User centered design, Smart Systems, User experience

1. INTRODUCTION

Developments in product design have led to many inventions. Consumers have more product choices and are becoming more popular. Constrained by a demanding market, manufacturers attempt to design products that stand out and attract consumers. Nowadays, smart devices are the most popular product that are chosen by the customers.

Smart devices are electronic gadgets or machines that have the ability to interact, connect, and share information with other smart devices. They have become an integral part of our daily lives, and their use has increased significantly over the years. Smart devices provide countless services to their owners and are great tools. However, like any other technology, they have benefits and disadvantages that come along with them [1].

If a traditional refrigerator can be converted into a smart refrigerator, it will be very useful for customers, making their lives easier. So the smart refrigerator is a type of electronic gadget that features a touchscreen interface and the ability to connect to the internet through Wi-Fi, providing a number of additional features. Smart refrigerators have also incorporated sensors that make opening the door with your handful without any trouble at all and also they include internal cameras, more flexible user-controlled cooling options, and the ability for you to interact with their features using your smartphone or tablet even when you're away from home.

Kansei engineering is a design methodology that aims to improve products and services by translating the customer's psychological feelings and needs into the domain of product design. It was founded by Mitsuo Nagamachi, Professor Emeritus of Hiroshima University. Kansei engineering links the customer's emotional responses to the properties and characteristics of a product or service, allowing products to be designed to bring forward the intended feeling and this method has been used in various fields such as product design, architecture, and marketing research [2].

The Kansei Engineering method is used for this project to selecting color of the product, selecting dimension and the capacity and selecting sensor types and display sizes etc. Customer emotion and feelings provide to make the best results.

This project aims to design a smart refrigerator that uses the concepts of Kansei Engineering to efficiently record and take user preferences and emotions into account throughout the design phase. The final objective is to design a refrigerator that satisfies practical demands and appeals to customers' aesthetic and emotional needs, thereby increasing user pleasure and convenience in daily life.

2. LITERATURE REVIEW

This section shows the smart refrigerators build before and currently and provides an overview of current smart refrigerators to identify their relevant theories and methods.

2.1 LG Smart InstaView Refrigerator

This smart refrigerator developed by LG electronics. This have 29inch LCD display. This refrigerator supports many features such as access to your favorite apps, browse recipes, watch videos and more. You can also see inside your fridge without opening the door. It turns the screen transparent with a simple knock. The LG Smart InstaView Refrigerator also has a voice-activated assistant that can help you with tasks like adding items to your shopping list, checking the weather and playing music. Available colors black and silver [3].

2.2 Whirlpool Smart Door-within-Door Refrigerator

This smart refrigerator developed by Whirlpool Company. The refrigerator has a capacity of 25 cubic feet which is enough to store up to 26 bags of groceries. It also features a full-width pantry drawer, adjustable gallon door bins, and a dual cooling system that helps prevent freezer burn and spoilage. The French door design allows access to the fresh food section easily, while the bottom freezer drawer slides out smoothly for convenient access to frozen items. The refrigerator also has a fingerprint-resistant stainless steel finish that resists smudges and adds a touch of elegance to the kitchen. Available colors white black and silver [4].

2.3 Samsung French door Refrigerator

This smart refrigerator developed by Samsung electronics. This Samsung Refrigerator offers a variety of features to suit customer needs. The refrigerator has a large capacity of 27.4 cu. ft., with flexible storage options such as adjustable shelves, gallon door bins, and a full-width drawer. The refrigerator also has a Twin cooling plus system that maintains optimal humidity levels in both the refrigerator and freezer compartments, keeping your food fresh for a long time period. The refrigerator also features a water and ice dispenser with a filter that reduces contaminants and odors. Moreover, there is a fingerprint-resistant stainless steel finish that adds elegance to the kitchen. This also have 29 inch display and Wi-Fi support. Available colors silver and black [5].

3. METHODOLOGY

The Kansei Engineering Methodology is used as the basic design approach for this proposed smart refrigerator. Kansei Engineering Methodology is a design approach that aims to create products or services that evoke positive emotional responses from the users. It is based on the concept of Kansei, which means the feelings or impressions that a person has when interacting with something. Kansei Engineering Methodology involves identifying the Kansei attributes that are relevant for a specific product or service domain, measuring the users' preferences and perceptions of these attributes, and translating them into design specifications that can be implemented by engineers or designers. Kansei Engineering Methodology can help to create products or services that are more satisfying, appealing, and competitive in the market [6].

The methodology was broken down into several steps (see Figure 1) involving data collection, analysis, and the translation of emotional inputs into practical design features for a smart refrigerator. The following steps outline the entire process.

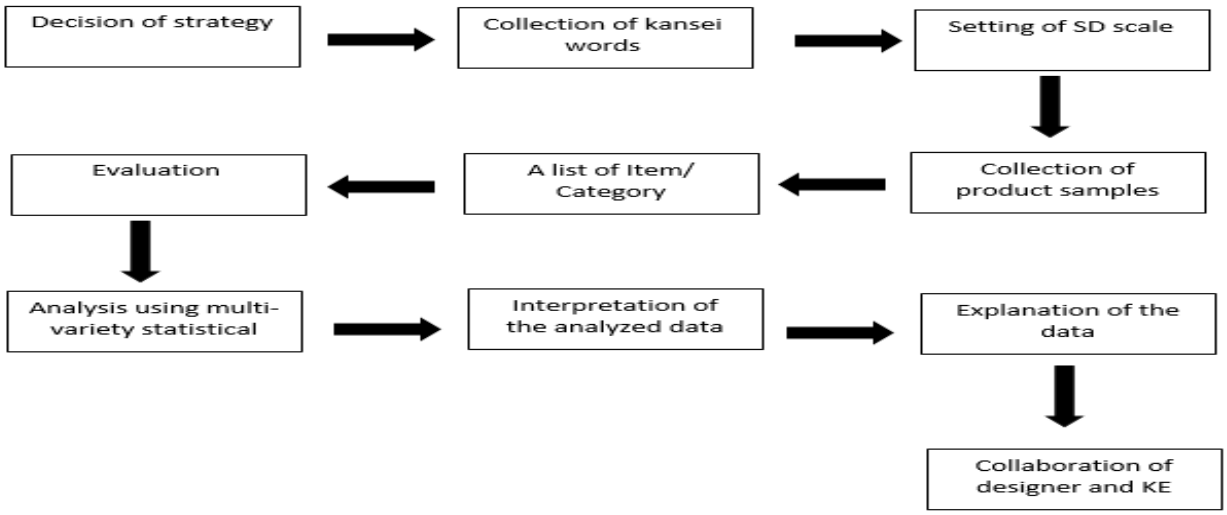

Fig 1: Flow of Kansei Engineering

3.1 Data Collection and Kansei Word Identification

A survey was conducted to capture the emotional responses of users. These participants were selected to represent a diverse range of demographics, including gender and age groups, to ensure the broad applicability of the findings. Kansei words, which show how possible users feel and what they think, are gathered in several ways, including through conversations and polls. In the first step, Participants were asked to express their emotional and psychological responses to various refrigerator designs using Kansei words such as spacious, elegant, convenient, etc.

3.2 Calculating grade and weight of Kansei words

After getting the Kansei words, a semantic differential (SD) scale was used to quantify participants' emotional responses to product features. Each participant rated the Kansei words on a 5-point Likert scale, where 1 represented "strongly disagree" and 5 represented "strongly agree.

$$"Weight = \frac{\text{The total grades of the word}}{5\times \text{No of participant}} \quad (1)$$

Using (1) allowed us to rank the importance of each Kansei word and identify the most emotionally significant design features.

3.3 Correlation Analysis and Creating an SD scale questionnaire using selected Kansei words.

After determining the most relevant Kansei words, we performed a correlation analysis between these emotional descriptors and the technical features of the refrigerator. The goal was to identify product attributes, such as color, door type, capacity, etc., most closely associated with the Kansei words. A questionnaire was conducted online with participants, and a Semantic Differential (SD) scale was used to calculate grading for some questionnaires.

3.4 Design Development

Based on the analysis, the final design of the smart refrigerator was proposed. The design process followed a structured workflow that incorporated emotional inputs from the users, which were translated into functional features using the Kansei Engineering approach.

The collected data is carefully described and analyzed, which gives information about what users like. When designers and Kansei Engineering experts work together, these emotional insights are turned into useful design features for the product. The design is then judged based on these results to ensure that the finished product closely matches user's emotional and practical needs. This creates a smart refrigerator that makes users happier and makes their daily lives easier [7].

4. RESULTS

4.1 Finding suitable Kansei words

Survey was given to 20 participants including male and female. Step one is to calculate suitable Kansei engineering words for the smart refrigerator. The 12 words (see Table 1) that have been collected and gathered.

Table 1. List of Kansei words

Kansei words			
Smart	Modern	Durable	Safety
Capacity	Functional	Attractive	Strong
Elegant	Cheap	Customizable	Colorful

4.2 Calculating grade and weight of Kansei words

Semantic Differential (SD) scale used to calculate grade and weight of Kansei words. Semantic differential can be known as a kind of a rating scale which is designed to measure the connotative meaning of objects, concepts, and events. For this, the n 5- grade-likert was used because it is more accurate and easy to use [8].

4.3 Weighting of Kansei words

Using weighting Kansei words, it is easy to determine the importance of the word to the product. Weighting data can help to correct for biases or imbalances in the sample. Weighting data can improve the accuracy and validity of the statistical analysis and inference.

$$Weight = \frac{\text{The total grades of the word}}{5\times \text{No of participant}} \quad (2)$$

Using (2), the weighting of each word is calculated.

The weighting, the grades (see Table 2) of the selected top 7 Kansei words out of 12 and meaning got by above calculations (see Table 2).

4.4 Creating SD scale questionnaire by using selected Kansei words

Semantic Differential (SD) scale is used to calculate grading for some questionnaires. Most of these questionnaires are made by getting the list of Kansei words (see table 2). For this, the n 5- grade-likert was used because it is more accurate and easy to use.

TABLE 2. The selected top 7 Kansei words

Kansei words	Grade	In-weight
Smart	80	0.80
Modern	78	0.78
Durable	88	0.88
Capacity	83	0.83
Functional	80	0.80
Strong	72	0.72
Colorful	76	0.76

TABLE 3. The top 7 Kansei words with meanings.

Kansei Words	Meaning	Positively Correlated to KW	Negatively Correlated to KW
Smart	Advanced in technology and features	Intelligent, Connected, Automated	Basic, Manual, Outdated
Modern	Contemporary in style and design	Stylish, Trendy, Sleek	Old-fashioned, Vintage, Dated
Durable	Able to withstand wear, pressure, or damage	Everlasting, Strong, Permanent	Synthetic, Breakable, Fragile
Capacity	The amount of space available for storage	Spacious, Large, Roomy	Limited, Small, Constrained
Functional	Designed to be practical and useful	Efficient, Practical, Versatile	Inefficient, Impractical, Useless
Strong	Able to perform under pressure without breaking	Sturdy, Robust, Resilient	Weak, Fragile, Delicate
Colorful	Having a bright and varied range of colors	Vibrant, Lively, Multicolored	Dull, Monochrome, Drab

4.5 Survey results

Results were taken from 20 participants (see Table 4). Some of the important survey results are shown below.

4.5.1 Total participants

TABLE 4. Total participants.

Gender	Total count
Male	12
Female	8

4.5.2 Ice requirement

A majority of respondents, 11 in total, reported needing ice once a week, suggesting a moderate level of ice consumption for regular activities or social gatherings. Six respondents mentioned they require ice only once a month, indicating minimal usage, possibly for occasional events. On the other hand, a smaller group of three respondents stated that they need

ice every day, reflecting a high demand for ice, likely due to daily consumption or specific lifestyle needs (see Table 5).

TABLE 5. Ice requirement.

Ice Requirement	Total count
Once a week	11
Once a month	6
Everyday	3

4.5.3 Color

Semantic Differential (SD) scale was used to select color. With 72 points, silver was the most popular color. With 59 counts, dark blue came in second (see Table 6).

TABLE 6. Color

Color	Semantic Differential (SD) count
Silver	72
Dark blue	59
White	52
Black	51
Maroon	34

4.5.4 Door type preferences.

The Semantic Differential (SD) scale survey findings on door type preferences show that users' preferences for various refrigerator designs vary (see Table 7).

TABLE 7. Door types

Door Type	Semantic Differential (SD) count
Double door(regular)	64
Double door(side by side)	56
French door(3 door or 4 door)	53
Single door	25

4.5.5 Capacity type

Semantic Differential (SD) scale was used to select capacity type (see Table 8).

TABLE 8. Capacity type

Capacity	Semantic Differential (SD) count
vegetable compartment	82
fridge storage without freezer and vegetable com.	68
freezer storage	56

4.5.6 Usage time

Semantic Differential (SD) scale was used to select the usage time (see table 9).

TABLE 9. Usage time

Time	Semantic Differential (SD) scale count
Morning	58
Night	53
Evening	51
Afternoon	46

4.5.7 Features

Survey results, detailing user preferences for smart refrigerator features, including the count and corresponding percentage of respondents who favored each feature(see Table 10).

TABLE 10. Features.

Feature	Count	Percentage
Wi-Fi connectivity	9	45%
LED display to get inside temperature	14	70%
Entertainment	12	60%
Fingerprint protector	5	25%
Fingerprint resistance material	5	25%
Auto open and close door	9	45%
Screen transparent with small screen	8	40%
Voice assistance	7	35%
Automatic ice dispenser	11	55%
Sensors to control temperature	12	60%
Mobile phone connectivity	10	50%
Different cooling methods in compartments	14	70%
AI and machine learning algorithms	13	65%

4.5.8 Final design

Final design has been designed (see figure 2 and figure 3) by using the AI tools and Adobe Photoshop [9].

Fig. 2 Front View of the Proposed Refrigerator

Fig. 3 Inside View of the Proposed Refrigerator

5. DISCUSSION

According to the survey of the smart refrigerator, gathered data from 20 participants 40% female responses and 60% male responses. Most of the participants selected the color as silver, suggesting that users liked its sleek and contemporary look. Secondary option is dark blue color, indicating a preference for a daring but fashionable appearance. Therefore, the refrigerator is designed with the silver color (see figure 2). These findings emphasize how crucial it is to provide a variety of color choices in order to accommodate a wide range of user preferences and improve the smart refrigerator's overall attractiveness.

Going to outside details of this smart refrigerator, most of the participants like two door regular refrigerator, indicating a strong preference for its practicality and familiar design and most of them dislike single door, suggesting limited appeal due to its traditional and less spacious design. French door is the secondary option. So the refrigerator is designed with two doors. These insights emphasize the importance of offering various door types to meet diverse user preferences and enhance the smart refrigerator's overall functionality and attractiveness. The survey shows that most of the people need ice once a week. So always keeping ice inside the refrigerator is very important, suggesting a moderate level of ice consumption for regular activities or social gatherings. These findings show how important it is for the smart refrigerator to have a flexible ice-making feature that can meet the needs of a wide range of users. Therefore, added an automatic ice maker to the refrigerator. Now anyone can get ice without opening the door anytime.

Comparing the time duration, according to the survey, it shows that most of the people use refrigerator in the morning and at night. So some power saving method needs to be included for morning and night time. The survey says that mostly 2 members or 4 members use the refrigerator. Accordingly, the needed capacity must be added. Most of the participants preferred that they like 200l to 300l refrigerator capacity. So the refrigerator is designed with 275l capacity.

Going to inside of the refrigerator, 50% of people has mentioned that they want 4 racks. So adding more racks to the refrigerator is very important to customers to keep their goods efficiently inside. Therefore, the refrigerator is designed with more racks. Considering the capacity of inside compartments, more people are interested in the vegetable compartment because in Sri Lanka, many people store vegetables than meat. So designing more capacity for vegetable compartment is a must. Freezer capacity needs to be reduced and refrigerator capacity needs to be average sized. These findings highlight how important it is to balance the storage space in smart refrigerator designs, paying special attention to the vegetable and general refrigeration sections to satisfy customer demands and improve functioning.

Going to features of the refrigerator, 70% of participants need a display in the refrigerator. So a 20 inch Smart LED display is added. This display is included to show the inside temperature and the power consumption of the refrigerator. Also, this refrigerator can connect to Wi-Fi and using Wi-Fi people can watch videos such as cooking recipes. Another important fact that people like to have are different cooling system methods in different racks. Figure 12 shows that bottom of the refrigerator included separate,

Cooling racks. Using these racks, people can adjust the temperature that they want. For example, if they need to convert that rack into a freezer, this refrigerator allows to do it. Another fact is that this refrigerator has developed machine

learning and AI algorithms to reduce power. In the first month when power is up, the refrigerator automatically calculates how many times the door opens, at what time door opens mostly and save power consumption accordingly. For an example, if we don't use the refrigerator 10pm to 6am, refrigerator calculates it in the first month and automatically power off during that time period. Using smart inverter features reduce power consumption. Other functions that people have choose are auto opening and closing door, mobile phone connectivity sensors to control inside temperature and automatic ice deepener. This smart refrigerator has been designed by using these features. So people can easily manage their household works.

6. CONCLUSION

Developing a smart refrigerator using Kansei Engineering shows how integrating emotional and psychological aspects into product design can enhance user satisfaction. This study identified vital design elements that appeal to functional and visual preferences by gathering and analyzing user's emotional responses. The final user-preferred design was a smart silver two-door design with a 275-litre capacity and modern features like Wi-Fi connectivity and an LED display. Using the Semantic Differential (SD) Scale and correlation analysis allowed for a deeper understanding of how emotional responses can be translated into practical design features. This smart refrigerator not only meets the practical needs of users but also creates a more personalized and enjoyable experience, fostering greater acceptance of smart home technology. The study highlights the potential of Kansei Engineering as a powerful tool for creating user-centred designs that resonate emotionally with consumers.

The study suggests several potential areas for future research and development in smart refrigerators. These include enhanced personalization through AI and machine learning, integration with wider smart home ecosystems, and expanding emotional design to other household appliances. Future models could prioritize eco-friendly materials and energy efficiency, using advanced sensors and AI to monitor energy consumption and suggest sustainable practices. Additionally, models could integrate renewable energy sources or work with intelligent grids to minimize environmental impact. Continuous emotional feedback loops could be incorporated into smart devices, collecting real-time emotional data from users through facial recognition or voice sentiment analysis. This allows the appliance to adjust settings dynamically to enhance user satisfaction and comfort.

In conclusion, the effective implementation of Kansei Engineering in designing a smart refrigerator provides a significant understanding of the increasing significance of emotional and psychological factors in product development, ultimately enhancing user-friendliness and emotional gratification in the technological environment.

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