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Living room design using Kansei Engineering approach with toddler safety aspect

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ABSTRACT
Toddlers experience physical accidents in the house at a rate of 90 percent. Based on observations, the living room was the most dangerous part of the building compared to other parts. That condition made the parents feel that the safety of their little one was not fully supported. This study aims to design a living room that is safe and comfortable for Toddlers. The design output supports the interior designers in creating a safer Toddler environment. Kansei Engineering guides the identification of living room design for parents looking for their toddlers' safety. The Kansei words gathered from the study are comfortable, multifunction, safe, easy to clean, simple, large capacity, and harmonious. These Kansei words injected into the concept design, which is the harmonious design concept and the simple design concept, by using Principal Component Analysis. The harmonious design has a wood table (X5.1) with a sofa (X7.2) and TV (X9.1) and no flower vase (X11.2) as its decoration, while the simple design has a plastic table (X5.2) with a wood seat (X7.1) and with flower vase (X11.1) but no TV (X9.2). The insights gathered were designed with Blender 3D and integrated with virtual reality Oculus simulation through the SketchFab website.

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1. INTRODUCTION

Children aged 0 to 6 need a safe home environment during their sensorimotor, physical, cognitive, social, and emotional development [1,2]. However, child safety is an issue raised by parents. This happens because house objects or furniture cause parents' concern [3]. Parents' concerns can be supported by the fact that the physical environment of the house in terms of housing and house objects whose safety is ignored because paying attention to safety at home is a burden of responsibility [4]. In addition, the National Basic Health Research results show that the proportion of injuries in Indonesia for toddlers aged 1 to 4 years is as much as 91.2 percent in the home and environment based on research data from 2018. Therefore, the conclusion that can be drawn is that injury cases experienced by toddlers occur when the child is at home [5]. Safety risks at home and the causes and incidents that can occur include punctures, cuts, falling foreign objects, burns, falls, swallowing, drowning, fire, sprains, fractures, swelling, head injuries, and tripping [6–8].

Previous researchers have put forward guidelines on preparing a suitable home environment for toddlers, how parents assess children's play areas, and the material facilities that can be selected. The journals reviewed only discuss things that must be considered in designing a child-friendly home descriptively. However, there needs to be visualization of the overall layout of the house and the design of facilities that are safe for toddlers. In addition, research related to toddler safety is still being conducted in developed countries such as South Korea [9]. Meanwhile, previous studies have not included the overall safety aspect in their research [10]. Therefore, further research on home design that considers toddler safety is needed to complement previous findings and bridge parents' needs for home facilities, especially the family room. The family room is the most common room in the house. Based on initial interviews conducted with 28 respondents consisting of mothers and women who care for toddlers, the family room is considered risky for toddler safety even though parents or caregivers of toddlers closely guard the toddlers, as shown in Figure 1. Toddlers spend most of their time in the family room. Therefore, research is needed to create safe family room facilities for toddlers. Several approaches that can be used for products design that are oriented towards user needs such as family room facilities include Quality Function Deployment (QFD) and Kansei Engineering [11,12]. However, the Kansei Engineering approach is considered more appropriate for the design of safe family room facilities, because it can describe important objects in the environment and capture the emotions and desires of product users [12–14].

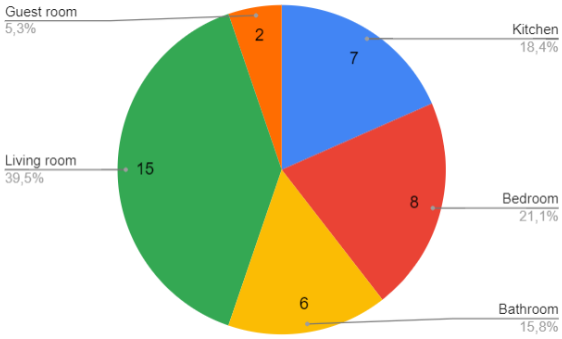


Figure 1. Recapitulation of the distribution of rooms in the house with high safety risks

Kansei Engineering is an ergonomics approach used in product development or facility design. This approach pays attention to the psychological aspects of the feelings and desires of product users [12–14]. In this approach, the family uses words representing emotions or psychological aspects received by product users [13,14]. These feelings or psychology will be considered when designing product elements [13,14].

Research related to homes and places for toddlers can be developed to provide precise visualization of the design of safe facilities for children's growth and development, hoping to bring innovation in designing homes that meet child safety criteria. The research objective is to correlate design attributes, user needs, and safety perceptions that can support architects and interior designers in creating safer environments and visualizing safe and comfortable family spaces for toddlers by collecting user perceptions using Kansei Engineering.

2. MATERIALS AND METHODS

The research was started because of the high Toddler safety risks in Indonesia, and at the same time, parents' concern about their toddlers is still there. In this study, Kansei engineering will be implemented along with home safety to design the ideal condition of a safe living room environment. The framework of this research is shown in Figure 2.

Kansei Engineering is an ergonomic research method introduced in 1978 by Mitsuo Nagamachi. This method transfers the psychological aspects of the user into a design form. Kansei itself in Japanese means expressing emotions through sight, hearing, smell, and tongue taste. This psychological aspect is described as a product that can be used and viewed after the end of the research. The product design will be supported by technology and by the needs and interests of users at the end of the study [12–14]. Kansei Engineering implements the feelings of product users. This method is successful when the product being developed meets user expectations. Therefore, this method is also called human-oriented or human-oriented product development. The main goal of the Kansei engineering approach itself is to involve human Kansei, namely taste, sensitivity, sensitivity, and sensibility, in product design [14]. This research flow will be shown in Figure 3. The research flow shown how the study started until the product design evaluated.

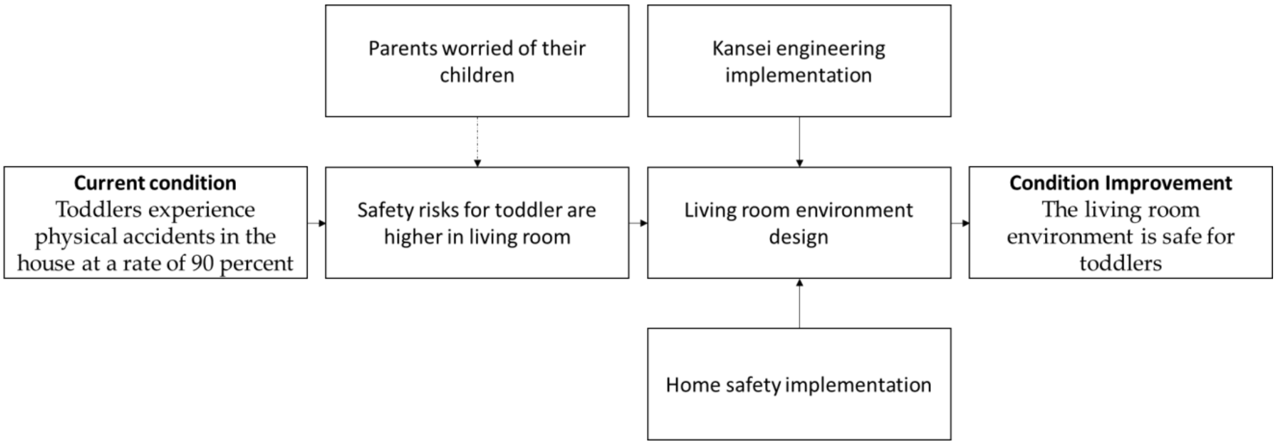


Figure 2. Living room with Kansei Engineering research framework

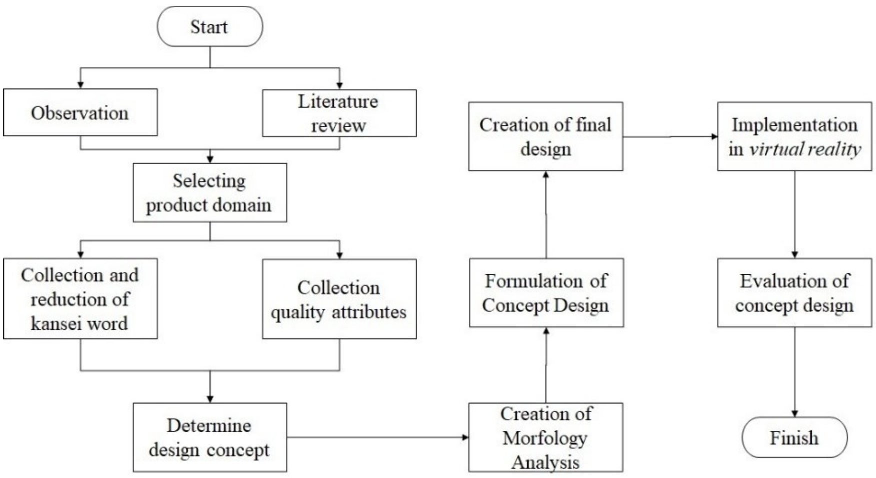


Figure 3. Research flow

Elements and quality aspects were determined by giving participants questionnaires using purposive sampling. Purposive sampling is a technique used in qualitative research that relies on the judgment of the participants with selected characteristics. Participants were chosen to interpret fit information, and identification was conducted to maximize knowledge resources. Purposive sampling was a strategy that held the stance that diverse participants were needed to conclude different perspectives and issues. Participants should be willing to deliver opinions and perspectives to interpret preferences or characteristics of the information received [15,16].

Participants were asked important Kansei words that they wanted in their living room. The researcher chose Kansei words using TF-IDF (Term Frequency-Inverse Document Frequency) to decide which words should be used for the next steps. Specifically, TF-IDF is utilized to gather words from documents and more. TF-IDF itself collects information on specific words raised by quantity. These quantities will be the input for this research [17]. TF-IDF combined Term Frequency and Inverse Document Frequency. Term frequency measured how often a word was raised in the written information gathered. At the same time, Inverse Document Frequency separates different words with weight [17]. The words with a weight more than counted will be chosen as the Kansei words for the concept design, and their definitions will be defined with dictionary meanings and study behind the concept of the chosen Kansei words. Eq. (1) was used on weighting TF-IDF. Wd was the weight of TF-IDF, fw is the frequency of Kansei word found in texts in document d, and D is the number of documents in the text collection [18].

$$Wd = fw\ x \log(|D|/fw, D) \quad (1)$$

The following aspects were applied to the study's next step, which involved a semantic differential scale to determine concept designs for the living room creation. Concept designs were concluded by using Principal Component Analysis (PCA). PCA was implemented to determine the relationship between elements of design that could be concluded by other elements [19]. This multivariate statistical data analysis is a way to define patterns from statistical aspects to show the similarities and differences [20,21].

Concept designs were analyzed again by implementing QTT1 after another exchange with participants. QTT1 was needed to understand the implementation aspects of the living room design. Preferences could be determined with this method as well [22]. The design visualization was completed using Blender 3D as the software design, and Oculus from Meta was used to view the final model after the QTT1 analysis was done.

The final design was created while implementing safety aspects in Blender 3D. This software was used in product design, focusing on living room visualization in this study. The software provides features during the designing process, including realistic materials, rendering, and simulation [23–25]. Materials and the design shape will reflect the safety aspects of previous research literature. The research added the safety aspect to the living room design as it adds value to the purpose of the study. Identified factors that shall be avoided for the safety of Toddlers include furniture with sharp points, the unsafe architectural plan of the house, no child-friendly plan of the house, unsafe furniture, low-quality safety equipment, and easy access to sharp objects shown on Table 1. The requirements for safe equipment/furniture for toddlers as defined by the Ministry of Women's Empowerment and Child Protection of the Republic of Indonesia, namely the Standard Guidelines for Child-Friendly Playrooms (RBRA), should also be followed. This requirement is used to implement security for toddlers. The conditions include the size and shape of the equipment or furniture being adjusted to the age of the toddler, the furniture is protected from rust, and the paint does not peel off easily; the furniture is wrapped with a sponge or rubber; the furniture is made from wood, which is resistant to termites but free of pesticides, furniture has blunt corners. It is safe; pediatricians are involved in planning and procuring play furniture to consider the child's growth and development, and there must be a distance between pieces of furniture periodically to maintain the excellent condition of the furniture [26].

Table 1. Participant's demography

Reasons and accidents happened at Toddler home	**Author**		
	Leili et al. [6]	**Fahad et al. [7]**	**Eda et al. [8]**
Stab	*	*	
Cut	*	*	
fall of foreign object	*	*	*
Burn	*	*	*
Poisoning	*	*	
Fall		*	
Fire		*	*
Strain/sprain		*	
Fracture		*	
Swelling		*	
Slip		*	
Head injury		*	
trip			*

Implementation of virtual reality is done right after the design process is completed. Virtual reality will support the initial design phase, specifically on product evaluation. This phase can detect early trouble with the help of virtual reality. This technology will be beneficial by combining CAD and Computer-Aided manufacturing technology [27]. Virtual reality will be seen in SketchFab as this website is a supporting tool to enable virtual reality functionality.

3. RESULTS AND DISCUSSION

3.1. Participants

The research was conducted to deliver a living room design that involved aesthetic and safety aspects. Before designing the living room model, surveys were given to participants, mainly parents, guardians, and caregivers who often cared for Toddlers and young children in their homes, with purposive sampling purposes. Participants included during the research were people who manage or handle toddlers two times a week. Participants were coming from age 17 to 50 and above. Participants were included in the study to discover the uniqueness of each segment. Each was segmented by gender, age, and last education. Table 2 was the recapitulation of the participant's demography.

Table 2. Participant's demography

Characteristic	Category	Number of Participants	Percentage
Gender	Male	10	23.0%
	Female	33	77.0%
Age	17-24	12	27.9%
	25-32	10	23.3%
	33-40	6	14.0%
	41-50	5	11.6%
	>50	10	23.3%
Last Education	High School	15	34.9%
	Vocational School	4	9.3%
	Bachelor's degree	22	51.2%
	Master's degree	2	4.7%

3.2. Collection and reduction of Kansei word

Kansei words were collected and chosen with TF-IDF (Term Frequency-Inverse Document Frequency). These words were obtained from participants who filled out the questionnaire. Based on the result of TF-IDF shown on Table 3 , 7 Kansei words were chosen by weight of more than 2.325. Based from the table, the kansei words that will be used are comfortable, multifunction, safe, easy to clean, simple, large capacity, and harmonious.

Based on the TF-IDF output, the rest of the Kansei words need not be used or implemented in the design. The meaning of Kansei Words is referred to the Indonesian dictionary and Cambridge Dictionary. Table 4 was the definition of chosen Kansei words, and the meanings were implemented to make the product designs, as how the prototype grasps the user's desire .

Table 3. Summary of term frequency-inverse document frequency

Number	Kansei Word	TFIDF	Number	Kansei Word	TFIDF
1	**Comfortable**	**4,405**	12	Full of furniture	1,633
2	**Multifunction**	**5,843**	13	Soft	1,633
3	**Safe**	**3,469**	14	Flexible	1,633
4	**Easy to clean**	**4,126**	15	Warm	1,633
5	**Simple**	**3,469**	16	Relax	1,633
6	**Large Capacity**	**2,665**	17	Room for all	1,633
7	**Harmonious**	**2,665**	18	Pillowy	1,633
8	Practical	1,633	19	Place to communicate	1,633
9	Durable	1,633	20	Open	1,633
10	Strong	1,633	21	equal design	1,633
11	Economic	1,633	22	lively	1,633

Table 4. Meaning of Kansei word

Kansei Word	Meaning
Comfortable	Condition of feeling good, calm, and peaceful
Multifunction	Able to function differently
Safe	Free from danger and disturbance
Easy to clean	Require low energy and work on dirt.
Simple	Low reflection on luxury
Large capacity	Ability to hold a significant amount
Harmonious	Balance of different elements

3.3. Design concept decision with Principal Component Analysis

The design concept must be defined using PCA (Principal Component Analysis) after choosing Kansei words with TF-IDF. PCA needed information such as participants' preferences by using Kansei words so this research could gather essential aspects that people want in their living rooms. Specifically, these Kansei words are crucial to generating a design concept by merging different Kansei words into one word that could represent the participants' preferences. That is why Fifteen pictures were portrayed as participants filling out the survey using a semantic differential of five scales to obtain accurate output. Figure 4 was the semantic differential for the research, and this was used to define which samples are the closest to the Kansei word definition.

	Strongly Disagree	Disagree	Neutral	Agree	Strongly Agree	
uncomfortable	☐	☐	☐	☐	☐	Comfortable
Single-function	☐	☐	☐	☐	☐	Multifunction
Unsafe	☐	☐	☐	☐	☐	Safe
Difficult to clean	☐	☐	☐	☐	☐	Easy to clean
Complex	☐	☐	☐	☐	☐	Simple
Small Capacity	☐	☐	☐	☐	☐	Large capacity
Disharmonious	☐	☐	☐	☐	☐	Harmonious

Figure 4. Semantic differential

Figure 5 used samples of living room images for the Figure 4survey. This step is essential for the researcher to determine critical elements to consider during the designing process. The sample family room used in the photo is a room with a house where there are toddlers. Participants rated all fifteen living rooms with the same questions: how would you rate the living room samples from comfort, functionality, safety, access to hygiene, simplicity, capacity, and harmonious aspects?

The semantic differential questionnaire was used to decide the concept of the living room design. The output of the analysis was supported by the software R. Principal Component Analysis (PCA) was the research method used to identify variables that represent the variance of the dataset. Components were counted from the correlation matrix or covariance matrix. The output of PCA consists of the eigenvalues, variability, and cumulative proportion of the total variance of each principal component and the coefficient of each principal component shown in Table 5. Eigenvalues show styles with the most influence, and variance percent show the height of PC1 and PC2 that is significantly bigger with enough distance from the rest of the PCs. PC1 and PC2 were kept as the design concept as the developed concepts because the first concept (PC1) has a cumulative proportion of more than 70%, and the second concept (PC2) fulfilled the minimum proportion by adding 19,69% to the Principal Component [28].

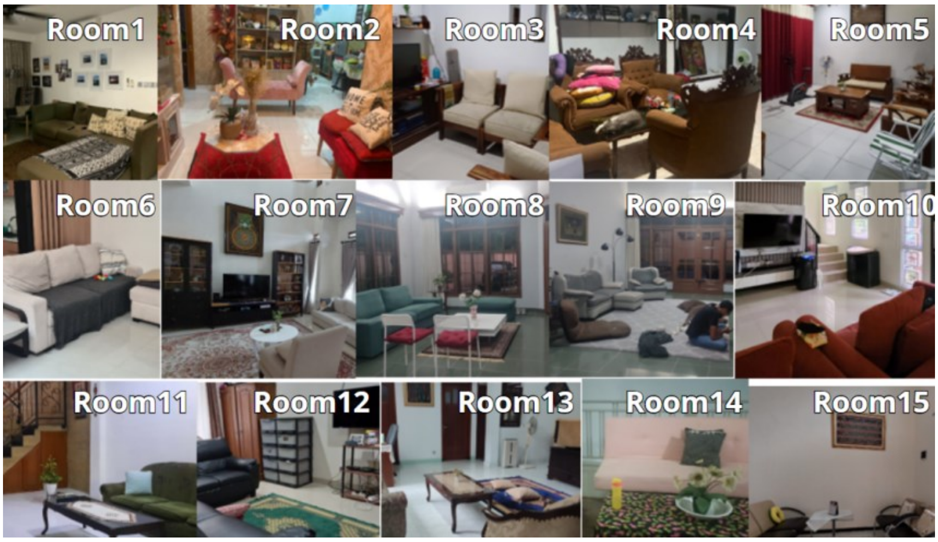


Figure 5. Used samples for the survey

Table 5. Output of PCA

Design Options	Eigenvalue	Variance percent	Cumulative variance percent
PC 1	**5.163**	**73.75**	**73.75**
PC 2	**1.379**	**19.69**	**93.45**
PC 3	0.199	2.84	96.29
PC 4	0.128	1.83	98.12
PC 5	0.736	1.05	99.17
PC 6	0.406	0.57	99.75
PC 7	0.0174	0.24	100.00

Figure 6 shows the data visualization of PCA output. Kansei words could be categorized using this statistical output. Remember, this output also showed that 7 Kansei words could be implemented as two conditions or two design concepts. Comfortable, safe, multifunction, harmonious, and large capacity were seen in the same area. While simple and easy to clean, they were on different placements. These Kansei word placements in the data visualization were marked with clips to see where the Kansei word distribution went.

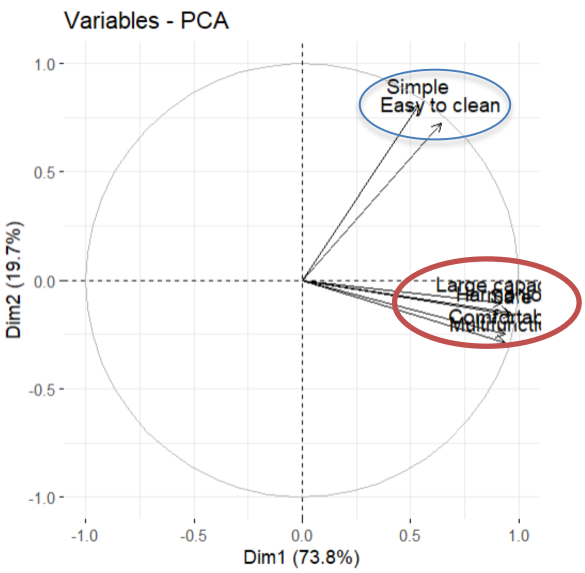


Figure 6. Output of PCA

Figure 7 gives a deeper visualization of what Kansei words belong to concept design. The PCA shows that the first design concept (PC1) consisted of comfortable, safe, multifunction, harmonious, and large capacity by seeing the color thickness and the value of the circles in the figure. The second design concept (PC2) was simple and easy to clean, as seen by the dominant color of this design concept. PC1 is called the harmonious design, as this Kansei word could represent others. At the same time, PC2 was decided to be a simple design.

Figure 7. Output of PCA

3.4. Creation of Morphology Analysis

Morphology analysis was conducted to identify the design components of the living room by analyzing the objects and aspects from the samples used. After determining what participants wanted from the previous questionnaire, 22 factors of element designs could be defined. Can the result of the morphology analysis be seen in Table 6.

Table 6. Morphology Analysis

Element Label	Living Room Element	Type 1	Type 2
X1	Wall color	Plain color	Pattern
X2	Floor color	Plain color	Pattern
X3	Table shape	Without corner	With corner
X4	Table color	Plain color	Pattern
X5	Table material	Wood	Plastic
X6	Seat color	Plain color	Pattern
X7	Seat material	Wood	foam/sofa material
X8	Lightening	Lamp	Sunlight and lamp
X9	TV	With TV	Without TV
X10	Photo frame	With photo frame	Without photo frame
X11	Flower Vase	With flower vase	Without flower vase
X12	Wall clock	With wall clock	Without wall clock
X13	Flower Vase Material	Plastic	-
X14	Anti-slip floor	Existing	-
X15	Sharp object	Not Exist	-
X16	Anti-slip Carpet	Existing	-
X17	Object utilizing fire	Not Exist	-

Element Label	Living Room Element	Type 1	Type 2
X18	Easy-to-swallow object	Not Exist	-
X19	Electric plug	Hard to reach toddler	-
X20	Cabel	Not easy to reach toddler	-
X21	Seat location	Far from window	-
X22	Window safety	Window grille	-
X23	Fire detector	Existing	-

3.5. Correlation of concept design analysis with the living room design

PC1 (harmonious design) and PC2 (simple design) are evaluated using the same 15 pictures and a Semantic Differential Scale questionnaire with values from 1 to 7. The questionnaire will give an average of each design component on the table. To get analyzed with software R. The outcome was a conjoint analysis and multiple linear regression of each concept design that helped determine the type of component to design the final design model, which is known as QTT1.

The result of harmonious design can be seen in Figure 8. With this QTT1, the researcher could define the participants ' preferences for each element. The figure should be read as the continuation of the previous morphology analysis. X12.1 and X12.2 meant the same wall clock element with different options, with a wall clock (option 1) and without a wall clock (option 2), and this should be read as the same as the other elements and options after X12. Even though each component has two options, these options help researchers firm the final design that should be implemented in the design. Options with positive values that are more significant than the other ones are chosen for the implementation. This value could be seen from the chart; the more it goes to the right, the closer the option gets to the most significant positive value. The chosen options are marked with red rectangles. This flow also goes to Figure 9, where the figure should be seen as continuation of the previous morphology analysis, but specifically for simple design.

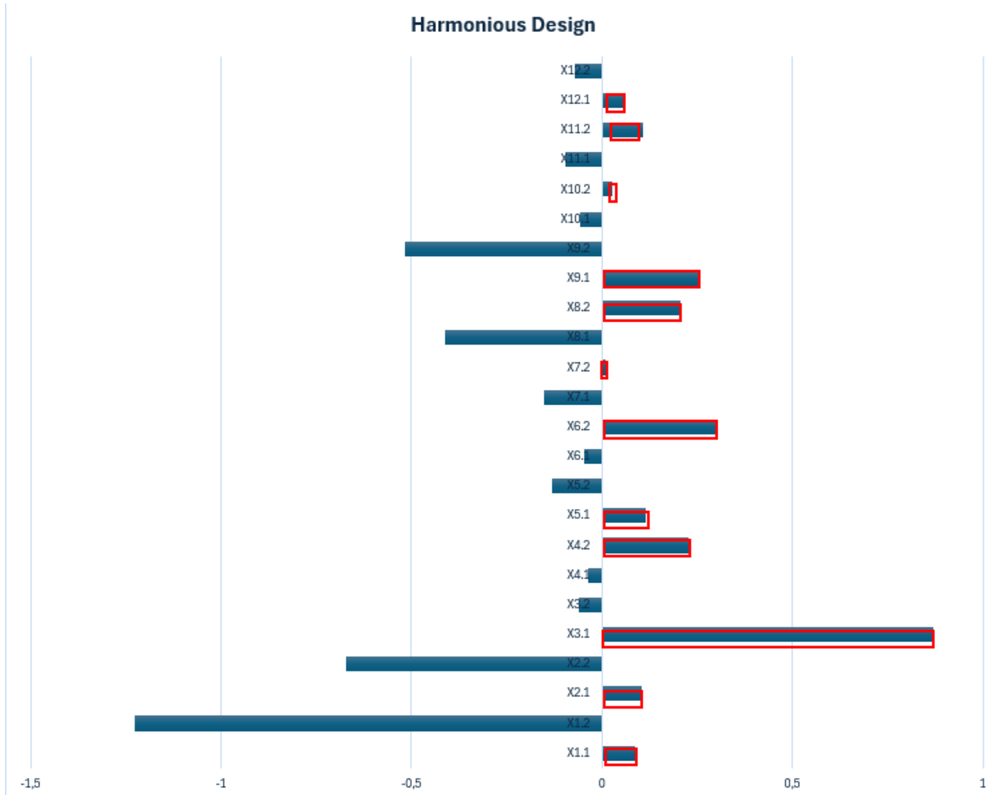


Figure 8. Output of QTT1 for Harmonious Design

The output delivered from the QTT1 charts received a positive value. Based on Multipled R-Squared, the values are 0.7087 for harmonious design and 0.987 for simple design. These multiple R-squared values are above 0.6 and could be considered proper.

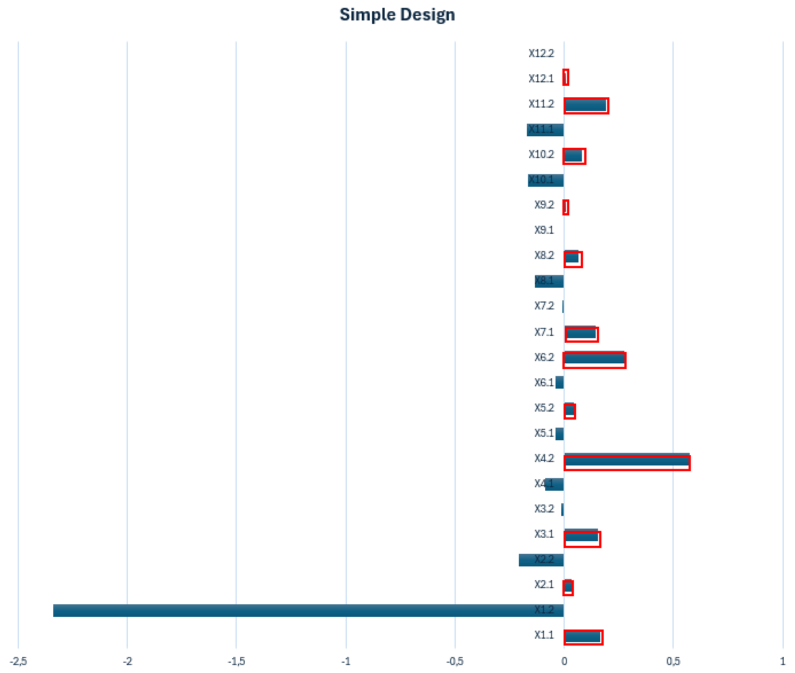


Figure 9. Output of QTT1 for Simple Design

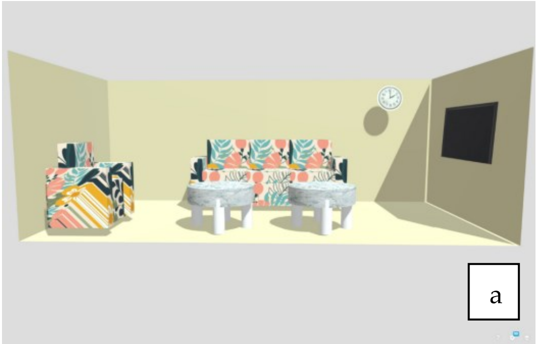
Table 8 is the concluded outcome of QTT1 in this research. These defined chosen elements will be implemented in the defined concept designs. Only elements X1 to X12 utilize QTT1 to determine the aesthetic aspects of the designed living room. The remaining elements that do not use the QTT1 formulation, namely X12 to X23, are safety aspects highlighted in the living room design.

Table 8. Conclusion of output of QTT1

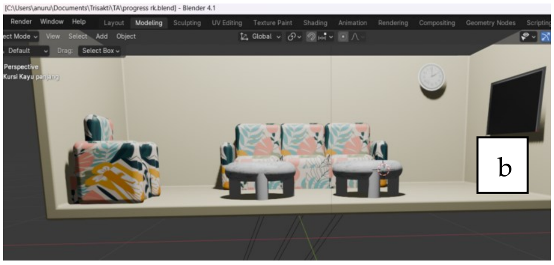
Element Label	Living Room Element	Harmonious Design	Simple Design
X1	Wall color	Plain color	
X2	Floor color	Plain color	
X3	Table shape	Without corner	
X4	Table color	Pattern	
X5	Table material	Wood	Plastic
X6	Seat color	Pattern	
X7	Seat material	foam/sofa material	Wood
X8	Lighting	Sunlight and lamp	
X9	TV	With TV	Without TV
X10	Photo frame	Without photo frame	
X11	Flower Vase	Without flower vase	With flower vase
X12	Wall clock	With wall clock	
X13	Flower Vase Material	Plastic	
X14	Anti-slip floor	Existing	
X15	Sharp object	Not Exist	
X16	Anti-slip Carpet	Existing	
X17	Object utilizing fire	Not Exist	
X18	Easy-to-swallow object	Not Exist	
X19	Electric plug	Hard to reach toddler	
X20	Cable	Not easy to reach toddler	
X21	Seat location	Far from window	
X22	Window safety	Window grille	
X23	Fire detector	Existing	

3.6. Creation of final design

The implementation of concept designs was created by using Blender 3D software. References of objects and types of furniture to be put in the final design were concluded through the conjoint analysis method. The figures used during the research showed the ideas of the objects and designs to choose from. The results shown in Figure 10 are the output of harmoniousdesign in both Sketchfab and Blender 3D.



(a)

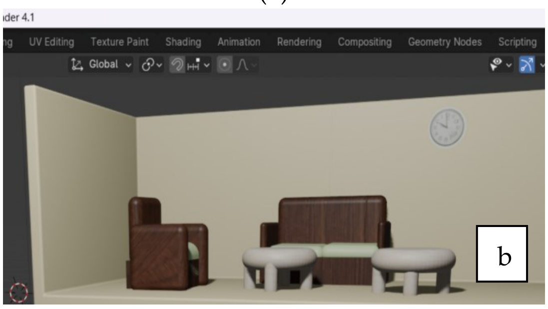


(b)

Figure 10. Harmonious design: (a.) Design in SketchFab; (b.) Design in Blender 3D

The results shown in Figure 11 are the output of the simple design concept in both Sketchfab and Blender 3D. The chosen colors and objects in the designed living room differed from the harmonious design because the QTT1 output for each concept differed.

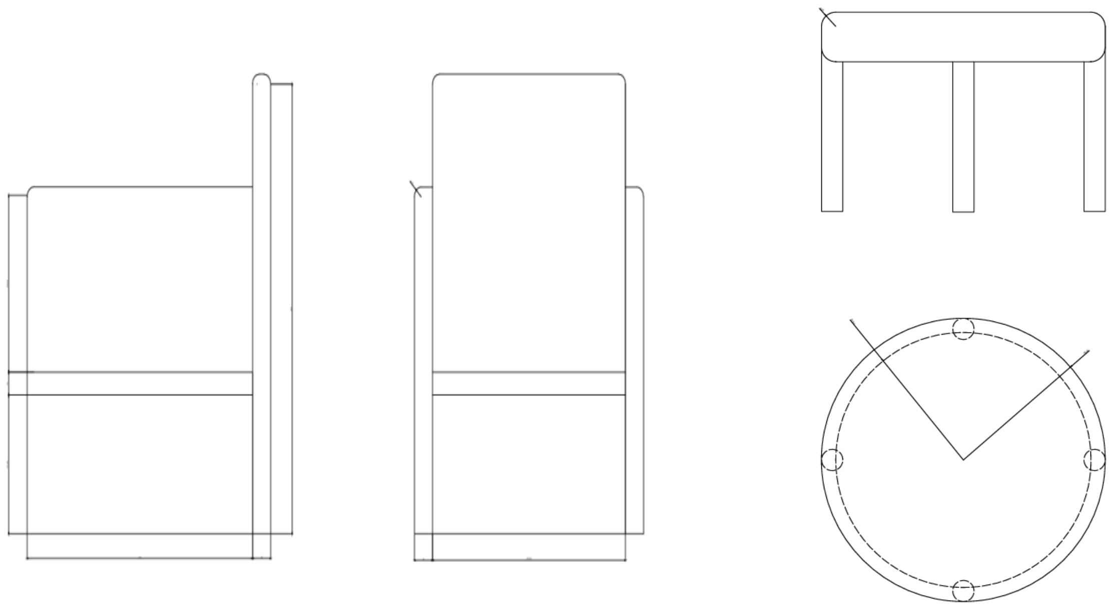
(a)



(b)

Figure 11. Simple design: (a.) Design in SketchFab;(b.) Design in Blender 3D

Figure 12 shows the dimensions of the seating and table design. The dimension was obtained through previous research that determined the furniture dimension. After the dimension was found, it was implemented in the design to make it easier if the journal reader wants to implement it right after seeing this research literature output.



(a) (b)

Figure 12. Design: (a.) seating dimension;(b.) table dimension

The dimension of the furniture, which is the sofa or the seating, will use the anthropometric of the man's shoulders' width, which is 424 mm for one person for his seat, the man's knee height, which is 403 mm, and the distance from the knee joint to a man's buttocks which is 495 mm. The table uses the anthropometric of a man's elbow height in a sitting position, which is 282 mm [29]. More implementations can be seen in Table 9.

Table 9. Conclusion of Kansei words implementation

Design Concept	**Kansei Word**	**Implementation**
Harmonious Design	Comfortable	Implementing natural light, providing safety (physiologically), and visual comfort (matching visually) [30]
	Multifunction	Capable to reuse [31]
	Safe	Use safe floors, wall paint, blunt objects, anti-slip carpets, non-flame objects, large objects that are difficult to swallow, and anthropometrically sized furniture with adult dimensions.
	Large capacity	Huge room
	Harmonious	The allocation of objects is aligned, and the colors match.
Simple Design	Easy to clean	Woods are easy to clean
	Simple	Implementing little decoration and neutral color [32]

3.7. Implementation of the final design into the virtual reality

The final step of the research is to input the final design into the virtual reality (oculus). Sketchfab was used to support the process of visualizing the design concept. The same participants were allowed to experience the virtual environment, as shown in Figure 13 participants freely view the final design of the product and gave feedback as they used the oculus.

Figure 13. Product design applied in VR

After participants viewed the final design using oculus, the previous 10 participants were asked for their rates on the living room designs. Table 10 concludes the participants' ratings on the design.

Table 10. Conclusion of concept design ratings

Questions	1	2	3	4	5
How would you rate the harmonious design concept?	-	-	-	-	10(100%)
How would you rate the simple design concept?	-	-	-	-	10(100%)

4. CONCLUSION

The research implemented two design concepts that had already been implemented during the study. The Kansei Engineering method defined These two design concepts using Principal Component Analysis. One is a harmonious concept that can include large capacity, safety, comfort, and multifunction, and the other is a simple concept that consists of a simple design and is easy to clean. QTT1 was used to define 12 design elements for the living room aesthetic visualization, which are (X1) Wall color, (X2) floor color, (X3) Table shape, (X4) table color, (X5) table material, (X6) Seat color, (X7) seat material, (X8) lighting, (X9) TV, (X10) Photo frame, (X11) flower vase, and (X12) wall clock. Elements for safety aspects in the living room are including Flower vase material (X13), anti-slip floor (X14), no sharp object (X15), Anti-slip Carpet (X16), no object utilizing fire (X17), no easy-to-swallow object (X18), hard to reach electric plug (X19), hard to reach cabel (X20), far from window seat location (X21), grille as window safety (X22), and fire detector (X23). The final design was viewed inside virtual reality via sketchFab. The limitations of this study include the background of the participants who are not very diverse, and not all participants are parents of toddlers so that the Kansei words data obtained may not fully represent the safety aspects of toddlers in general.

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