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KANSEI ENGINEERING APPROACH FOR DESIGNING A SELF-MONITORING BLOOD GLUCOSE APPLICATION

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ABSTRACT

The proportion of people with diabetes in Indonesia is 6.9%, of whom, 90% suffer from type 2 diabetes. To control diabetes, the International Diabetes Foundation has a self-monitoring blood glucose program (SMBG) that is designed to gather detailed information about blood glucose, which can be used to define the required dietary and physical activity. In Indonesia, SMBGs have not been applied widely due to some difficulties with the SMBG application, including difficulty with interpreting blood glucose levels and the required food consumption. The rapid development of smartphones and the internet in recent years may provide a solution for SMBG applications in Indonesia. Therefore, the aim of this research is to design an SMBG application that meets the needs of people with diabetes. In designing the application, the Kansei Engineering method was used due to its ability to capture impressions of the product that reflect hidden needs. Kansei Engineering was applied to translate the patient's perception into design elements. Statistical analysis – particularly Factor Analysis and Partial Least Squares Analysis – were used to support the Kansei Engineering method. Statistical analysis indicated that four main design components needed to be considered in the design, including 'data record persistence', 'ease of use', 'data presentation', and 'visual attractiveness'. These four components were used as the basic design concepts, which were transferred to new design specifications based on Partial Least Squares Analysis. The selected design elements (or premium Kansei) were 'color scheme – light', 'language – Bahasa', and 'input dialog – typing'. The result of this research is a design for an SMBG android-based application that is easy to use and also provides appropriate information to patients with diabetes so they can plan their diet program.

Keywords: Android application; Kansei Engineering; Product design; Type 2 diabetes

1. INTRODUCTION

The International Diabetes Federation (IDF) Diabetes Atlas ranks Indonesia (with a total of 8.5 million diabetes patients) as the country with the seventh highest diabetic population, following China, India, the United States of America, Brazil, the Russian Federation, Mexico, and Bangladesh. Indonesia is also considered to be the country with the highest diabetic population in South East Asia. Basically, there are two types of diabetes, which are type 1 and type 2 diabetes. Type 1 diabetes is caused by the body's inability to produce insulin; it can occur before the age of 40, but usualy appears in childhood. With type 2, the body can initially produce insulin, but due to several factors, such as unhealthy eating habits and lack of physical

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activity, the body becomes insulin resistant. This means that insulin can no longer transport glucose in the bloodstream into the body's cells and turn it into energy (IDF, 2015). Type 2 diabetes is the most common type, with the highest population. As many as 9 out of 10 of the diabetic population are included in this type. In Indonesia, the proportion of diabetic patients is 6.9% of the Indonesian population, of whom 90% suffer from type 2 diabetes. Considerable effort is needed to prevent the increase of diabetes in Indonesia.

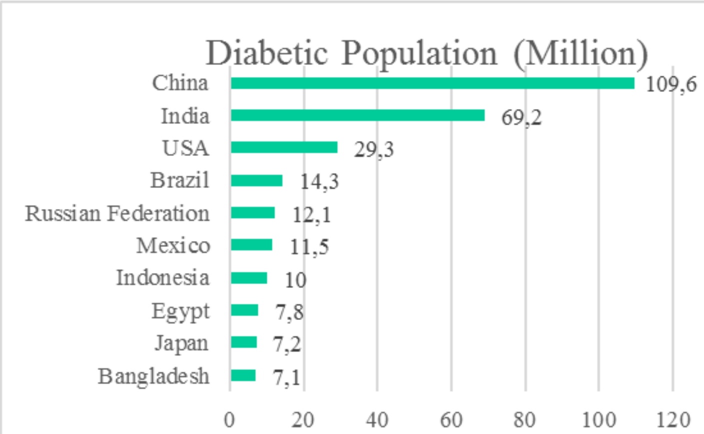

Figure 1 World rank of highest diabetic populations (IDF, 2015)

Diabetes can lead to other serious health problems such as heart disease, stroke, kidney disease, nerve damage, and so on, and it therefore needs to be controlled. To control diabetes and other non-communicable diseases (those with long duration and slow progression), the Indonesian Ministry of Health has promoted different ways of controlling the disease, such as providing counseling, risk prediction, socialization, and community health care services. While the government has provided many programs, it is apparent that the main key to controlling diabetes is health self-management. In this regard, the IDF has a program named SMBG. It is designed to gather detailed information about blood glucose at specific times, which can then be used to manage dietary habits and physical activity, based on blood glucose levels. The SMBG has proven useful for diabetic patients, as demonstrated by Bosi et al. (2013). The research by Bosi et al. (2013) was carried out with 1,024 type 2 diabetes patients over 12 months. The study proved that structured and controlled SMBG usage could increase the control of blood glucose levels and can be used as an appropriate guide for both medicine prescription and diet improvement.

Despite the usefulness of SMBG applications, in Indonesia, self-monitoring has not been used widely, because there are many obstacles to its application. One of the obstacles is patients' ability to interpret blood glucose levels to determine their food consumption. Considering the rapid development of smartphones and the internet in recent years, information and technology could provide a solution to help SMBG succeed in Indonesia. Some SMBG Android applications are already available on the market, but the design does not fully represent Indonesian diabetes patients' needs. Patients need an application that can be used easily and effectively in daily life in order to control their blood glucose. Initial observations identified that there are hidden needs, implicitly expressed by respondents, which require a design method that is able to capture these needs within design elements. However, there is little information available for the design purposes of this application. Therefore, this study aims to create applications that can help Indonesian patients with type 2 (non-insulin-dependent) diabetes to apply SMBG effectively, by using methods that can effectively capture patients' implicit needs.

2. METHODOLOGY

Product development was conducted using the Kansei Engineering (KE) method. KE was used to translate customer/patient perceptions of the application into design elements. There are several methods that are commonly used for product development. These include Quality Function Deployment (QFD), Conjoint Analysis (CA), and Voice of Customer (VOC). All these methods have the same goal, which is to develop products that satisfy consumers' needs and desires. KE is also a method for designing products, but with a slight difference compared to previous methods. The difference is that while VoC, QFD, and CA focus on explicit consumer needs and develop design requirements that match those needs, KE is more focused on implicit needs and associates them with product design characteristics.

There are six main steps of KE: (1) collecting Kansei words using the Feedback Capture after Task (FCAT) method; (2) setting the five-point Semantic Differential (SD) scale; (3) determining the most important customers' Kansei words, which can be done by using Factor Analysis; (4) determining the item/category of design alternatives; (5) interpreting the results from the viewpoint of KE to find relationships between Kansei words and product properties, which can be proced by using Partial Least Squares (PLS) Analysis; and (6) gathering the application components (Nagamichi et al., 2008).

In the first step, prospective users should complete five tasks as shown in Table 1. The task required users to carry out several activities using the BeatO application.

Table 1 FCAT task description

Tasks	Description
1	You are a new user to this application. Create a new account on this application
2	Input your current blood glucose
3	You will eat fried egg this afternoon. Find the fried egg indicator to determine whether it is permitted or not
4	You have gained weight recently. Edit your weight in your profile
5	Read your blood glucose report

From the interview using the FCAT method, user feedback was gathered. The user's response was used as the input for Kansei words and then used to construct the application's attributes. The FCAT results were analized and matched to the related Kansei words. Each Kansei word can represent more than one FCAT output, and vice versa. For example, from task 1, user 1 answered that 'too much information is required in the sign-up process'. While for task 2, the response was 'too much information on one page'. From these answers, it can be inferred that the user wants both a simple process and a simple screen interface. Accordingly, the word 'simple' can be included in the Kansei word list. This process is repeated until no further words can be extracted. Examples from the Kansei word checklist are presented in Table 2. Kansei words were then combined with the five-point SD scale and distributed to 60 type 2 diabetes patients in Surabaya.

Sixty respondents were analyzed based on calculations using linear time function as shown in Equation 1.

$$n = \frac{T - t_0}{t_i} \tag{1}$$

where:

n : Number of respondents

T : Time available for research (survey time is 1 month, 4 effective days per week, 4 weeks × 3 days = 12 days) = 5 hours/ day × 12 days = 60 hours

t_0 : Sampling time = 3 hours/day × 12 days = 36 hours

t_i : The amount of time for respondents to complete questionnaires = 24 minutes = 0.4 hours

$$n = \frac{T - t_0}{t_i} = \frac{60 - 36}{0.4} = \frac{24}{0.4} = 60\ samples$$

Table 2 Kansei word checklist

No	Kansei Words	SD					Kansei Words
		5	4	3	2	1	
1	Interesting						Uninteresting
2	Simple						Not simple
3	Easy						Not easy
4	Clear						Unclear
5	New						Not new
6	Unique						Not unique
7	Intuitive						Not intuitive
8	Professional						Not professional
9	Consistent						Inconsistent
10	Accurate						Not accurate
11	Detailed						Not detailed
12	Systematic						Not systematic
13	Cheap						Not cheap
14	Innovative						Not innovative
15	Flexible						Inflexible
16	Formal						Informal
17	Neat						Not neat
18	Specific						Unspecific
19	Modern						Not modern
20	Good Design						Not good design
21	Plain						Not plain
22	Practical						Impractical

There were 28 male respondents and 32 female respondents in this research. Regarding respondent age, respondents were mainly aged from 40 to 49 years old. Respondents aged between 30 and 39 and below are fewer in number because this age range more usually have type 1 diabetes.

In addition to KE analysis, statistical analysis – particularly Factor Analysis and PLS Analysis – were also applied. The Factor Analysis method is a statistical data reduction technique employed to explain variability among observed random variables, in terms of fewer unobserved random variables, which are called factors. This reduction is possible because some attributes are related. By applying factor analysis to the collected responses on a given questionnaire, it is possible to group responses with common meanings, thereby reducing the number of required indicators to explain all responses (Mamaghani et al., 2014). In KE, PLS Analysis was used to identify the influential design elements. PLS was conducted using the data from the Kansei words survey and influential design elements. It is a list of the physical trait alternatives that can be generated from design elements. The relationship between Kansei words and the design elements described in the influential design elements was then defined (Nagamichi et al., 2008).

3. RESULTS AND DISCUSSION

3.1. Statistical Analysis

Factor Analysis was conducted to find the most important Kansei words to use as design specifications in the final designing stage. Some results were obtained after conducting Factor Analysis using SPSS 17.0. In all, 9 components were extracted from 22 Kansei words. Components with total sums of squared loadings less than the mean of 1.860 were ignored. This is because the correlation of those components with other components is low, and if they were selected and put through to the next process, they would not make a big impact on customer satisfaction. Thus, it can be inferred that components 1, 2, 3, and 4 were suitable for use in the next process. The summary of Factor Analysis results are shown in Table 3.

Table 3 Factor analysis output

Component	Total	% of Variance	Variable	Correlation
1	2.447	11.122	Professional	0.856
			Consistent	0.654
			Accurate	0.627
			Neat	-0.536
2	2.199	9.994	Clear	0.800
			Flexible	-0.513
			New	-0.747
3	2.155	9.797	Detailed	0.879
			Systematic	0.579
			Formal	-0.772
			Good design	0.511
4	2.008	9.126	Interesting	0.779
			Specific	0.739
			Practical	0.718

Kansei words associated with component 1, such as ‘professional’, ‘consistent’, ‘accurate’, and ‘neat’ can be grouped together as ‘data record persistence’. This is because the words ‘consistent’ and ‘accurate’ are related to countable data, while ‘neat’ and ‘professional’ are related to well organized data presentation. Thus, the first component can be categorized as ‘data record persistence’. For component 2, the words ‘clear’ and ‘flexible’ are related to application flow and application usage. ‘Clear’ means the application is able to present its contents clearly so that it will be easy to operate. Therefore, component 2 was named ‘ease of use’. The word ‘new’ was ignored because it has no relation to application elements. For component 3, the words ‘detailed’, ‘systematic’, ‘formal’, and ‘good design’ were grouped together as ‘data presentation’. ‘Detailed’ means the data are recorded in a specific and regular frequency. ‘Systematic’ implies that the data are arranged in a systematic way. ‘Good design and formal’ refers to good visual presentation. For the last component (component 4), the words ‘interesting’, ‘specific’, and ‘practical’ are associated with the display and interface arrangement. Accordingly, component 2 was defined under ‘visual attractiveness’.

Next, the relationship between chosen Kansei words ‘data record persistence’, ‘ease of use’, ‘data presentation’, and ‘visual attractiveness’ and the design elements were described. In this way, design items or technical respond that are related to the selected Kansei should be identified.

For example, for the first attribute, ‘data record persistence’, to maintain persistence, a reminder or notification may need to be applied. In this regard, two types of notification can be considered. The first is an alarm type, and the second is a drop-down notification, which can be shown in the smartphone’s system bar (PC SOFT Online help, 2016).

The second attribute, which is ‘ease of use’, relates to the home screen interface, blood glucose input, and language. Home screen interfaces are divided into two types, which are list fragments and detail fragments. List fragments show the menu option in a list style, while detail fragments highlight the most important menu option in a larger size. Detail fragments often use graphics as representations (Vogel, 2009). For the blood glucose input dialog, there are also two options available, which are typing and scrolling. The user can complete the blood glucose input by directly pressing the specific time on the regimen table or by clicking the icon until a typing window appears. With regard to language, Bahasa is one of the choices because the application users are mainly Indonesian diabetes patients. However, it does not limit the possibility that the application can be modified by using English, which is a common language used in most applications.

The third attribute, ‘data presentation attribute’, relates to blood glucose reporting and how the blood glucose report will be presented. Dynamic reports on the application are best presented as bar charts or line charts (Laurinavicius, 2014).

The ‘visual attractiveness’ attribute relates to all the aforementioned components because each component combination plays a role in how the user sees the application in general. In addition, ‘visual attractiveness’ is also related to the application’s color scheme. There are two basic application color scheme themes, which are light and dark. Light color schemes are useful in text and data-based applications, whereas dark color schemes are good for image-based applications, and they consume less energy (Li et al., 2014).

After defining the relationship between Kansei words and design elements, the weight of the selected Kansei word compared with the item/category classification needs to be calculated. The weight of four selected Kansei words compared with the item/category classification is calculated using a Likert scale from 1 to 5. In this scale, 1 means Kansei and design elements are highly unrelated, 2 means not related, 3 means not too related, 4 means related and 5 means highly related. The weights of selected Kansei words compared with influential design elements are shown in Table 4.

Table 4 Selected Kansei words and category weighting

	Color Scheme – Light	Color Scheme – Dark	Language – English	Language – Bahasa	Main Activity – List Fragment	Main Activity – Detail Fragment	Notification – Alarm	Notification – Drop Down	Input Dialog – Scroll Bar	Input Dialog – Typing	Input Method – Click the Icon	Input Method – Click the Regimen	Report Shape – Line Chart	Report Shape – Bar Chart
Data Record Persistence	4	2	2	4	2	4	4	2	1	5	4	2	4	2
Ease of Use	4	2	1	5	1	5	2	4	1	5	4	2	4	2
Data Presentation	4	2	3	3	2	4	4	2	2	4	2	4	5	1
Visual Attractiveness	2	4	4	2	1	5	2	4	5	1	4	2	4	2

After the weighting process, the data were processed using PLS Analysis with software Excel XLSTAT 2016. The weights, along with the Kansei questionnaire results, become the input of the calculation. Then, the list of relationships between Kansei candidates and each item/category concerning four selected Kansei words was obtained. Table 5 shows the PLS calculation results.

Table 5 PLS results

	Data Record Persistence	Ease of Use	Data Presentation	Visual Attractiveness	Means
Color Scheme – Light	0.924	0.377	0.957	0.511	0.692
Color Scheme – Dark	-0.924	-0.377	-0.957	-0.511	-0.692
Language – English	-0.474	-0.875	-0.567	-0.933	-0.712
Language – Bahasa	0.474	0.875	0.567	0.933	0.712
Main Activity – List Fragment	0.818	-0.399	0.712	-0.360	0.193
Main Activity – Detail Fragment	-0.818	0.399	-0.712	0.360	-0.193
Notification – Drop Down	0.818	-0.399	0.712	-0.360	0.193
Notification – Alarm	-0.818	0.399	-0.712	0.360	-0.193
Input Dialog – Scroll Bar	-0.817	-0.575	-0.857	-0.662	-0.728
Input Dialog – Typing	0.817	0.575	0.857	0.662	0.728
Input Method – Click the Regimen	-0.602	0.668	-0.585	0.460	-0.015
Input Method – Click the Icon	0.602	-0.668	0.585	-0.460	0.015
Report Shape – Line Chart	0.602	-0.668	0.585	-0.460	0.015
Report Shape – Bar Chart	-0.602	0.668	-0.585	0.460	-0.015

Table 5 shows the highest positive value in each column, which means the design item should be selected, and the lowest negative value, which means bad design that should be avoided. Based on Table 5, 'color scheme – light', 'language – Bahasa', and 'input dialog – typing', should be then selected for premium Kansei, because these three elements have the highest relation to the Kansei words. Conversely, 'color scheme dark', 'language – English', and 'input dialog – scroll bar' should be avoided. In addition, other design elements that have means lower than 0.60 can be ignored since their relation to Kansei words are so low.

The results of KE analysis were then used to design the SMBG application.

3.2 Application of KE to SMBG Design

After several statistical analysis processes, the SMBG Android-based application was ready to be developed.

3.2.1. Data flow diagram

To create a design for an SMBG Android-based application, the first step was to establish a Data Flow Diagram (DFD). DFD is a common visual tool used by engineers to describe the flow of data between all entities in order to design an information system. The design process starts with a description of diagram level 0 (usually called the context diagram), which shows the general system process. The context diagram of the SMBG application is shown in Figure 2. This diagram helps designers to understand the relationship between entities and how data flow between those entities. Diagram level 0 can be broken down into diagram level 1, 2, and so on, to define detailed information about the system.

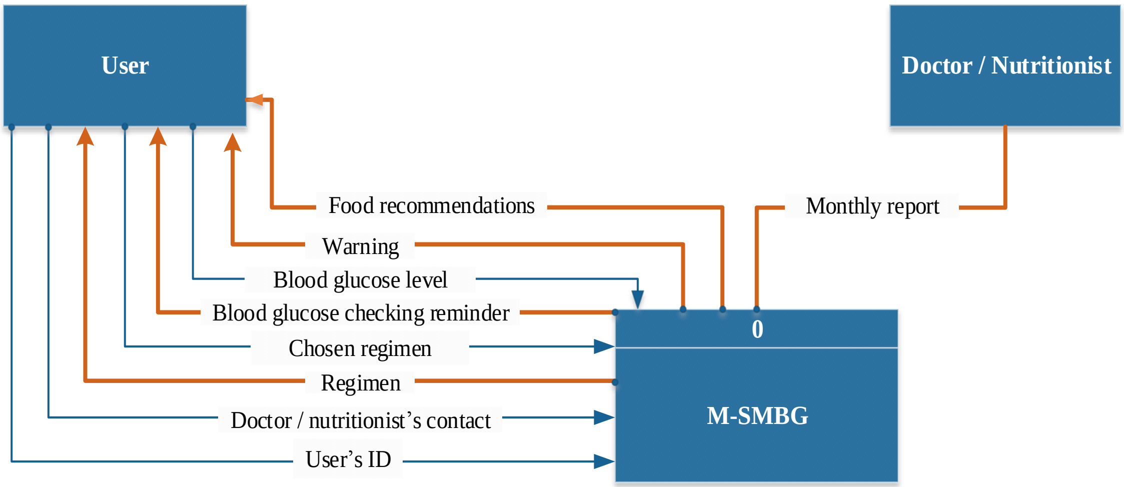

Figure 2 Diagram level 0 of SMBG application

3.2.2. Interface design

After describing the application system in DFD, the next step was designing the application interface. The application interface acts as an interaction medium between systems and users. The visual appeal or user interface of the mobile application is an important aspect of design that affects the user's satisfaction. Thus, the concept generation for this mobile application focused on physical traits. The program used to build the application prototype is the Justinmind prototyper. The application was named mControl, with the tag 'Control your blood glucose'. The mControl logo is visualized in Figure 3.

Figure 3 Application logo

Color may have an effect on emotion (Gilbert et al., 2016). Some research has been conducted to gain more insight into how color could affect emotions. In designing an application interface, color may also have an effect; therefore, for the SMBG interface design, a specific color was used. Turquoise (RGB: 55, 188, 155) was chosen as the main color because turquoise is a combination of blue and green. Blue is often perceived as being trustworthy, dependable and peaceful (Izzo, 2012). The use of blue shades may reflect on the user's feeling. The green element in the turquoise color is linked with calm, safety, and peace, which is why this color is widely used in the health sector. Furthermore, this color has good readability when combined with white. Thus, the selection of turquoise as the main color for this application aims to apply the strategic Kansei elements related to legibility, color emotion, and visual attractiveness.

In addition to color, the screen design also needs to be defined. The main screens in mControl are the blood glucose checking reminder, blood glucose input screen, food recommendation screen, warning screen and the report screen. As well as these five screens, there are additional screens such as the splash screen, sign-up screen, and regimen choice.

Based on all these considerations, a prototype for the SMBG interface was developed. Figure 4 presents the registration and notification application interface, and Figure 5 shows several mControl application interfaces.

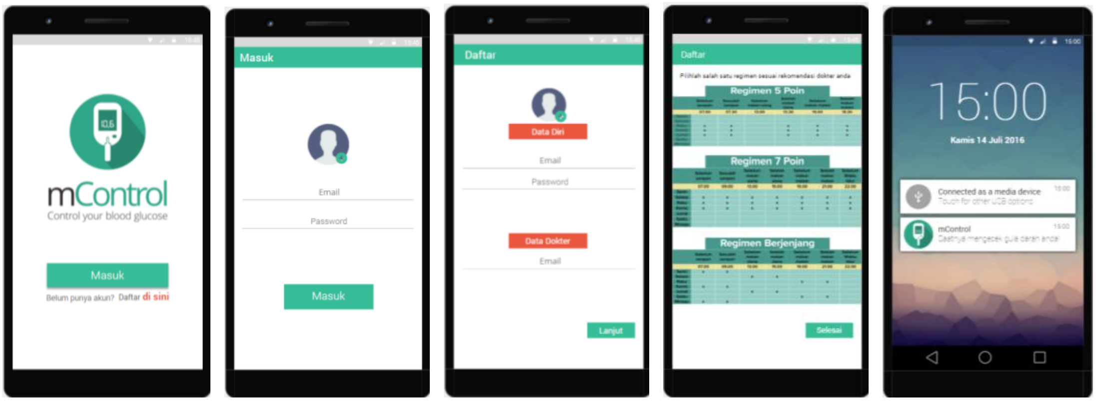

Figure 4 Registration and notification application interfaces

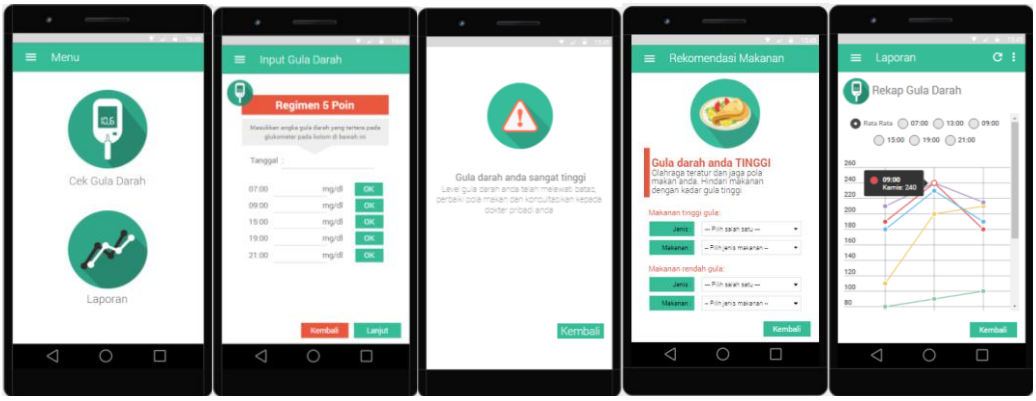

Figure 5 Several mControl application interfaces

After the application prototype was developed, the next step was to test the prototype with users. The testing process was carried out using Nielsen's Ten Heuristic method. This involved giving users questionnaire that consist of four strategic Kansei words, along with an SD scale. Users were asked to use the application to complete the questionnaire, following instructions on how to use the application. The level of user satisfaction when using the application prototype was then measured. Table 6 summarizes satisfaction levels.

The satisfaction level was then compared to initial Kansei levels to find any gaps. If satisfaction levels fall below initial Kansei levels, the design should be revised. If satisfaction levels are above the initial level, it means that the prototype already fulfills user requirements. The comparison between user satisfaction and initial Kansei levels is shown in Table 7.

Table 6 Summary of satisfaction levels

No	Data Record Persistence	Ease of Use	Data Presentation	Visual Attractiveness
1	4	4	4	5
2	3	4	3	4
3	3	5	3	4
4	5	4	4	4
5	4	4	4	5
6	3	5	4	3
7	4	3	5	4
8	3	4	4	4
9	3	3	4	5
10	4	3	4	4
11	4	4	5	5
12	3	3	3	4
13	4	4	3	4
14	4	4	4	5
15	4	4	3	4
Median	4	4	4	4
Modus	4	4	4	4
Level	4	4	4	4

Table 7 Comparison of initial Kansei levels and satisfaction levels

	Initial Kansei Level	Satisfaction Level	GAP
Data Record Persistence	4	4	0
Ease of Use	3	4	+1
Data Presentation	3	4	+1
Visual Attractiveness	4	4	0

Based on Table 7, it can be inferred that most of the satisfaction levels are above the initial Kansei levels. This means that the mControl prototype meets customer needs and reflects user requirements. However, several features – including reminders and sending reports – cannot be performed by the current prototype due to software limitations. Thus, further application development could enhance the SMBG application's design.

4. CONCLUSION

The result of this research is an SMBG Android-based application. This application is made simple and concise to reduce user confusion when interacting with it. According to the statistical analysis, four main components were identified, which were 'data record persistence', 'ease of use', 'data presentation', and 'visual attractiveness'. From PLS Analysis, these main components were transferred to new design specifications that became the basic design concepts. The selected design elements (or premium Kansei) were 'color scheme – light', 'language – bahasa', and 'input dialog – typing'. A prototype of SMBG was also developed and tested.

There are some suggestions for future action. First, some features cannot be included in this application, due to software limitations. Therefore, for future research, better software or programs need to be applied so that more comprehensive features can be installed. These might include recommendations about food portions to provide further information to users. In addition, research on the Glycaemic Index (GI) of Indonesian food could be developed and added to the database of foods that are good or bad for consumption by diabetes patients.

Finally, an SMBG program needs to be socialized to increase diabetes patients' awareness about the need to monitor their blood glucose levels.

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6. REFERENCES

Bosi, E., Scavini, M., Ceriello, A., Cucinotta, D., Tiengo, A., Marino, R., Bonizzoni, E., Giorgino, F., 2013. Intensive Structured Self-Monitoring of Blood Glucose and Glycemic Control in Noninsulin-treated Type 2 Diabetes: The PRISMA randomized trial. *Diabetes Care*. Volume 36(10), pp. 2887–2894

Chuan, N.K., Sivaji, A., Shahimin, M.M., Saad, N., 2013. Kansei Engineering for E-commerce Sunglasses Selection in Malaysia. *Procedia – Social and Behavioral Sciences*, Volume 97, pp. 707–714

Gilbert, A.N., Fridlund, A.J., Lucchina, L.A., 2016. The Color of Emotion: A Metric for Implicit Color Associations. *Food Quality and Preference*. Volume 52, pp. 203–210

IDF, 2015. *IDF Diabetes Atlas*. 7th ed. [ebook] Brussels: International Diabetes Federation

Izzo, J.K., 2012. Colour: User Experience and Psychology. Available online at http://usabilitygeek.com/colour-user-experience-psychology/

Laurinavicius, T., 2014. 20 Stunning Mobile App Designs Featuring Graphs & Charts. Available online at http://theultralinx.com/2014/08/20-stunning-mobile-app-designs-featuring-graphs-charts/

Li, D., Tran, A.H., Halfon, W.G.J., 2014. Making Web Applications More Energy Efficient for OLED Smartphones. *In*: ICSE 2014 Proceedings of the 36th International Conference on Software Engineering, pp. 527–538

Mamaghani, N.K., Rahimian, E., Mortazaei, S.-R., 2014. Kansei Engineering Approach for Consumer's Perception of the Ketchup Sauce Bottle. *In*: KEER2014 Proceedings of the 5th Kansei Engineering and Emotion Research. International Conference; Linköping; Sweden; June 11-13. pp. 1–9

Nagamichi, M., Tachikawa, M., Imanishi, N., Ishizawa, T., Yano, S., 2008. A Successful Statistical Procedure on Kansei Engineering Products. *In*: The 11th QMOD Conference. Quality Management and Organizational Development Attaining Sustainability from Organizational Excellence to Sustainable Excellence. pp. 987–995

PC Soft Online Help., 2016. Android: The Different Types of Notifications. Available online at http://doc.pcsoft.fr/en-US/?1000019480#NOTE3_1

Vogel, L., 2009. Multi-pane Development in Android with Fragments – Tutorial. Available online at http://www.vogella.com/tutorials/AndroidFragments/article.html#what-are-single-pane-or-multi-pane-layouts