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Integrating Usability in Automotive Navigation User Interface Design via Kansei Engineering

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Abstract

Balancing user requirements as well as usability requirements can be an exacting task for designers. Automotive navigation user interfaces are of no exception. The aim of this study was to integrate the concept of usability in the design process for automotive navigation user interfaces. A modified Kansei Engineering approach was used in order to define the concept of usability for automotive navigation user interface. Both regular and professional Malaysian drivers participated in the Kansei evaluation experiment (n=118). Results were analyzed with Principal Components Analysis (PCA) as well as Partial Least Squares (PLS) method. A finalized list of design specifications was developed and the design specifications were then used to develop a new automotive navigation interface design.

Keywords: automotive navigation user interface, GPS, Kansei Engineering, Malaysian drivers, safety. introduction

1. Introduction

Mobile connectivity has become part and parcel of today's society. The demand of today's society is such that the need for information exchange between individuals across the globe must occur in an instant. Mobile phones have transformed themselves into smart phones with various functions for leisure and business productivity. Similarly, the public demands that the vehicles are also equipped with features similar to their smart phones.

Hence, the rapid development of automotive navigation user interface has brought forth the concern for the development of safe and usable automotive user interfaces systems for the end users. Usability and aesthetics need to go hand in hand even though aesthetics and actual usability may not be related at all (M. Mohamed, 2011).

Compared to the mobile phones market, the automotive user interface systems need to cater the primary concern of the driver, which is safety (Mohamed et al, 2015). In order for users to enjoy features of their automotive navigation user interface, the design of automotive navigation user interface system needs to promote and enhance the safety of drivers. However technological advancement of automotive navigation user interface systems has become so rapid that it is a tall order for manufacturers to ensure seamless interactions between automotive navigation user interface and drivers. Car dashboard designs have changed substantially from being cluttered with buttons to a single touch screen system with multiple functions. Usability and ergonomics have started to come into the picture where the interaction between drivers and dashboard is mentioned. (M. Mohamed & Mustafa, 2014)

A popular concept which is often discussed in interface design is the concept of mental models. A mental model is a representation of a certain process or the surrounding environment in a human mind (Wickens, 1992). Mental models influence how a person reacts to their surrounding environment, and how a person perceives their environment. In the case of developing safe and usable products, the products should match a person's mental model to ensure a positive user experience. Users come with their own mental models; and the designers often have their own mental models when developing products. A mismatch often occurs with designer's mental models and the user's mental model; thereby causing problems when users interact with products (Lim, Pangam, Periyasami, & Aneja, 2006).

With the popularity of automotive navigation systems in cars, designing usability into automotive navigation systems is a real challenge for designers. Designers and users often have different conceptualizations of what usability is. This phenomenon was illustrated by Norman & Ortony (2003) by the concept of affordances between users and designers. Designers may try to influence the user's emotion through their product design (visceral and behavioral aspects), but users may perceive the design differently. Currently, there is little research bridging the gap between the users' and designers' mental models for automotive navigation interface design. Researchers such as Chang (2010), Knapp (2007), Winter et al (2009) looked at the differences that arose from different user backgrounds when interacting with a user interface. Different users tend to have different mental models; therefore there is an acute need to accommodate different mental models' of users when designing products such as automotive navigation interface design. Researchers and designers do understand that differences exist, but what can be done in order to address the issue on hand? Designers need a practical method or tool to integrate safety and usability during product design process. The design stage of a product is the most crucial; this is where the changes can be made to accommodate various user requirements.

Various ways have been proposed in order to improve the safety and usability of automotive user interfaces during the design process. Popular methods for integrating safety and usability have been primarily dominated by expert-led techniques such as rules and guidelines related to automotive user interfaces (Alliance Guidelines, 2002; Bhise, 2012; Green, Levison, Paelke, & Serafin, 1993). In expert-led techniques, user inputs during the design process are not considered at all. Expert-led techniques do not take into account how the users might actually perceive the product or system in use. A user-led technique such as Kansei Engineering (KE) for example, puts the user at the forefront where their perceptions of the product to be designed are taken into account during the design process. The word "Kansei" means total emotions, those feelings that are elicited by products or services (Schütte, 2005).

KE is among the earliest technique of customer oriented design method developed in Japan by Mitsuo Nagamachi. One of the successful examples of KE was the birth of Mazda Miata, which fully utilized KE technique. The Mazda Miata became one of the best selling cars in history due to the implementation of KE in its design process, as all the relevant aspects for customer's emotional needs such as structural, functional and aesthetics were considered (Nagamachi & Lokman, 2010). As a precursor to this study, the concept of usability related to automotive navigation user interface research was carefully defined by Mohamed et al (2015a), where it was narrowed down to eleven variables as shown in Figure 3.

2. Method

A modified Kansei Engineering approach was utilized in this study. Instead of focusing on the emotional and aesthetics, safety and usability were the primary focus, as proven by an earlier research on car center stack designs by Mohamed et al (2015b). Figure 1 below describes the general overview of the methods used in this study, as proposed by Mohd Lokman (2009) is shown below in Figure 1:

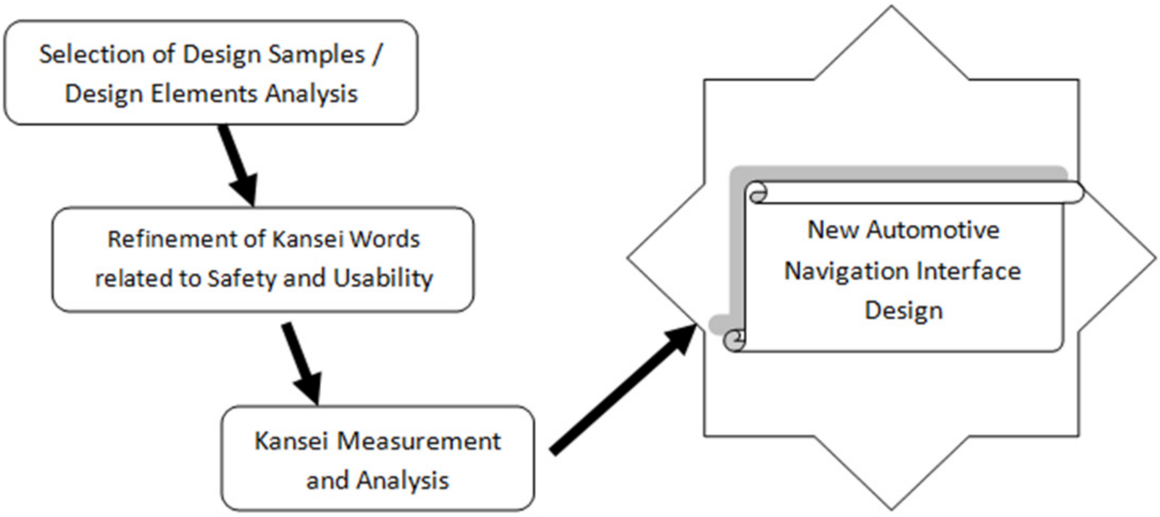


Figure 1. Simplified Kansei Engineering implementation framework

2.1 Design Elements Analysis

In order to develop Kansei equations, each of the design samples needs to be categorized according to their specific design elements. The more specific the design element the more accurate the Kansei equations will be. A detailed list of the classification is shown in Table 1. According to Mohd Lokman (2009) the selection of Kansei design samples needs to fulfill these criteria:

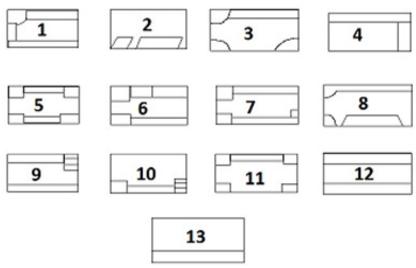
1) For each design sample, only ONE element from each design group can be selected, for example "Road Name Location" for a design sample must only have one value checked, such as "Bottom Center".

2) Only one design sample is selected if two or more samples have exactly the same design elements value.

3) Two or more design samples will be selected if they have some common design elements.

Table 1. Design elements classification

Design Groups	**Elements**
Road Color	Dark Grey Lt Grey White Lt Yellow Khaki
Routing Arrow Color on Road	White Yellow Red Blue Green Lt Blue
Distance To Turn Icon Background Color	Green Black Grey + Dark Grey Black + Reflection Gray Transparent Ocean Blue Green + Reflection Green + Dark Green Black + Dark Grey
Time to Destination Button Color	Black Gray White + Lt Gray Missing Coffee Lt Gray Transparent Gray Transparent Bluish Gray
City Background Color	Lt Grey Lt Green Beige Lt Khaki
Road Name Color on Layout	White Black Missing
Road Name Location	Bottom Center Top Center Left Top Center Missing
Highlighted Route	Pink Blue Green Purple Red Orange Missing
3D vs none buildings	3D None
Number of POIs	Zero Six Seven Eight
Road Size	Small Large
Zoom Level	Close Far
Junction View Screen	None ½ screen size

Location of Distance to Turn Icon	Top Left Bottom Left Top Right Bottom Middle None
Location of Timing Info	Bottom Left Bottom Right None
Distance Road Name Location (Together?)	Yes No
Icon Size VS Screen Size	10%-20% (Small) 30% - 40% (Medium) 50-60% (Large)
Layout Design	

2.2 Selection of Design Samples

A proper selection of automotive navigation interface design samples needs to be accomplished before the Kansei measurement. Images of the interface design specimens followed the typical automotive navigation screen dimensions of 4 to 5 inches with a minimum resolution of 800 x 600 pixels for clarity.

Briefly, all the automotive navigation interface design samples selected needs to feature a complex road geometry system, urban roads, and only designs featuring English and Malay language were selected. The complex road geometry and the urban roads were chosen as most drivers have difficulty in navigating using automotive navigation if the road design features multiple junctions and curves, as stated by Nowakowski et al (2003). Automotive navigation interface design samples were restricted to the ones featuring Malay and English language as the participants in the study were all Malaysians. A pilot study done by the authors Mohamed et al. (2015) narrowed down the design samples selection to fourteen (14) design samples to be chosen for the Kansei survey.

2.3 Refinement of Kansei Words related to Safety and Usability

In this study, since the primary focus is on Kansei words related to safety and usability, Kansei words selected are related to safety, ergonomics and usability. The Federal Motor Vehicle Safety Standards, as well as a checklist developed by Bhise (2012) were used as the main reference for obtaining Kansei words related to safety, ergonomics and usability. Eleven Kansei words are selected as shown in Figure 2. The Kansei words are as follows:

Findability	Operability	Usefulness	Recognizable
Noticeable	Legibility	Interpretability	
Understandability	Distinguishable	Guessability	Readability

Figure 2. List of Kansei Words

Each one of these Kansei words was accompanied with a Malay/English description so the words would not be misconstrued by the participants.

2.4 Kansei Measurement and Analysis

In the Kansei evaluation experiment, two types of Malaysian drivers participated, regular and professional. A total of 20 professional drivers, 53 male drivers and 45 female drivers participated during the evaluation experiment, while 69% of the participants were between 18-25 years old, 20% were between 26-35 years old, 10%

were from 36-45 years old and 1% was between 46 -50 years old. Each of the participants had to evaluate 14 automotive navigation interface design samples using the list of Kansei words (listed in Figure 3). A 7 point semantic differential scale was used during the evaluation experiment. Each Kansei word was described as such in Figure 4 below for better clarity and understanding for the participants. The results were then analyzed using Factor Analysis and Principal Component Analysis. Lastly, several Kansei equations, linking design elements and Kansei words were developed for the final outcome of this research.

Are all the information and icons :
1) Findability :
Easily found and located at the expected region?
2) Interpretability :
Cannot be confused
3) Guessability :
Operation easy to guess
4) Operability :
Can be operated quickly, without reading or looking at labels?
5) Legibility :
Easily seen and clear?
6) Understandability :
Easy to understand?
7) Readability :
Easy to read?
8) Usefulness :
Useful for the driver?
9) Distinguishable :
Easily differentiated?
10) Recognizable :
Easily recognized?
11) Noticeable :
Can be noticed easily

Figure 3. Kansei words with accompanying descriptions

3. Results and Discussions

A Principal Components Analysis (PCA) was conducted on the data, and only one component was revealed by the analysis, which is consistent with what the researchers are trying to focus in this study (i.e usability). The initial eigenvalues showed that one factor explained 96.892% of the variance. All of the variables contained in that component showed high loadings (minimum of 0.977 and above). The Cronbach's Alpha value is 0.980, indicating very high data reliability.

Kaiser Meyer Olkin values for sampling adequacy was 0.756, and the Bartlett's Test for Sphericity was significant at ($\chi2$ (55) = 344.866 $p < .05$) (Table 1). The diagonals of the anti-image correlation matrix were between 0.698 to 0.839, supporting the inclusion of each item in the PCA analysis. Details of the PCA analysis can be seen in Table 2.

Table 2. PCA Analysis Results

Total Variance Explained		
Component	Initial Eigenvalues	Extraction Sums of Squared Loadings

	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	10.658	96.892	96.892	10.658	96.892	96.892
2	.111	1.005	97.897			
3	.075	.680	98.577			
4	.052	.473	99.050			
5	.041	.373	99.423			
6	.032	.287	99.710			
7	.018	.163	99.874			
8	.009	.081	99.955			
9	.003	.027	99.981			
10	.001	.013	99.995			
11	.001	.005	100.000			

Extraction Method: Principal Component Analysis.

Component Matrix

	Component
	1
Operability	.995
Noticeable	.994
Understandability	.991
Recognizable	.989
Guessability	.983
Distinguishable	.982
Legibility	.981
Interpretability	.981
Findability	.979
Readability	.978
Usefulness	.977

Extraction Method: Principal Component Analysis.

3.1 Relationship between Usability and Automotive Navigation Interface Design Elements

A partial least squares (PLS) analysis was performed in order to establish the connection between the automotive navigation interface design elements and usability. The evaluation ratings for each Kansei word listed in Figure 2 were treated as dependent variables, and the design elements classification as independent variables. The results from the PLS analysis would show the relative weightings for each design elements with respect to a particular Kansei word. A high positive weighting indicates high degree of correlation with the Kansei word, and a negative weighting indicates otherwise. Figure 4 shows a sample of the PLS analysis results.

OPERABILITY (Icons in the display can be operated quickly without reading or looking at labels)

	Design Elements	Coefficient	Standardized Coefficient
Map Background Color	Lt Grey_1	0.00823	0.013089
	Lt Green	0.03911	0.051605
	Beige	-0.01789	-0.025985
	Lt Khaki	-0.07461	-0.061791
Road Name Color	White_2	-0.01418	-0.015952
	Black_2	0.00561	0.004649
	Missing_3	0.02056	0.017025
Road Name Location	Bottom Center	-0.00364	-0.005288
	Top Center Left	-0.00101	-0.001467
	Top Center	-0.00181	-0.002782
	Missing_4	0.02056	0.017025
Highlighted Route	Pink	-0.07614	-0.085679
	Blue_1	-0.03636	-0.052827
	Green_2	-0.02395	-0.026948
	Purple	0.14236	0.160196
	Red_1	0.02056	0.017025
	Orange	0.01552	0.017459
	Missing_5	-0.01536	-0.012717

Highest standardized coefficient values are selected

Figure 4. Sample of PLS Analysis Results

For each of the Kansei words listed, all the highest standardized coefficient values were selected as the relevant design elements specific for that particular Kansei word. A sample of the analysis is shown in Figure 4. For example, as illustrated in Figure 4, in order for an automotive navigation interface to be "Operable", the road name color and location are not required. The highlighted route should be purple in color, and the map background color should be green. When all of the relevant design elements for each Kansei word were obtained, a finalized list of design specifications for a new automotive navigation interface was made, as shown in Figure 5. The finalized list contains the common design elements across all the 11 Kansei words related to usability. From the finalized list of the design specifications, an automotive navigation interface concept which is centered on usability was developed by a graphics designer.

Design Elements	Design Specifications
Road Color	Gray
Routing Arrow Color on Road	Light Blue
Distance Icon Background Color	Green
Time to Destination Button Color	White + Light Gray
City Background Color	Lt Green
Road Name Color	None
Road Name Location	None
Highlighted Route	Purple
3D vs none buildings	3D
Number of POIs	7
Road Size	Large
Zoom Level	Close
Junction View Screen	1/2 screen
Location of Distance to Turn Icon	Top Right
Location of Timing Info	Bottom Left
Distance Road Name Location (Together?)	No
Icon Size VS Screen Size	Medium
Layout Design	9

Figure 5. Finalized list of design specifications for usable automotive navigation interface

3.2 Development of a New Automotive Navigation Interface Prototype

With the list of design specifications in Figure 5, a prototype of automotive navigation interface was developed by a graphics designer (refer to Figure 6).

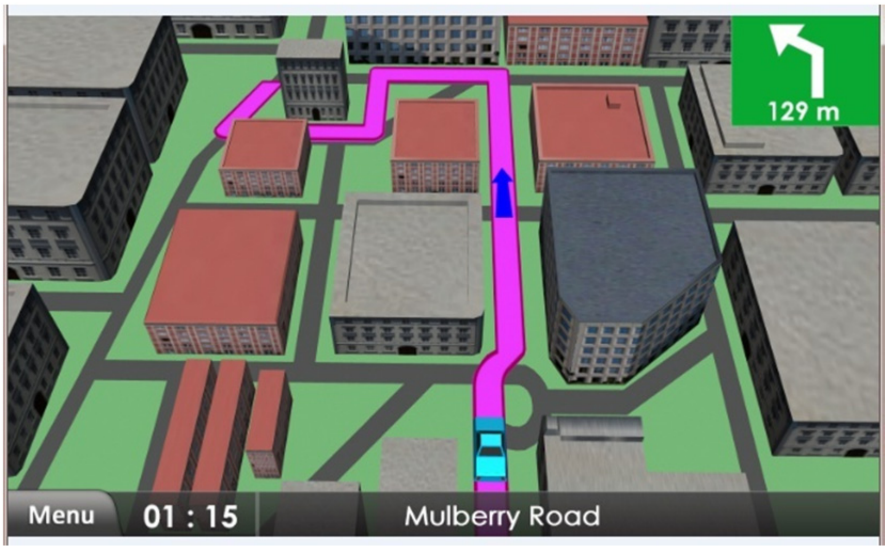


Figure 6. Prototype of automotive navigation interface design

4. Conclusions

Kansei Engineering has proven to be useful when it comes to integrating usability requirements in automotive navigation user interface design, during the early design stage. A modified Kansei Engineering procedure was carried out involving regular and professional Malaysian drivers. Results were then translated into actual design specifications. All of the design elements proposed by the Kansei analysis, centered on the concept of usability were translated into the actual design by the graphics designer. Future studies will be focused on testing and validation of the newly developed automotive navigation user interface. The modified Kansei approach outlined in this paper may be used by interface designers as a tool to implement usability right during the design stage itself, thereby minimizing usability issues in an interface.

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