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ANALYSIS OF USER FEELINGS DURING INTERFACE OPERATION: IMPLICTIONS FOR CREATIVE DESIGN

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Abstract: This research proposes a new approach for creative design based on comprehension of human feelings during user interface operation. The discussed method in this approach captures verbal input during interface operation through protocol analysis, and it identifies words and expressions which indicate the *comfort of mind* experienced by humans. Further, the method employs associative concept network analysis to identify the in-depth impressions, which are inexplicit indicators of *comfort of mind*, behind the verbalized words. In-depth impressions of subjects, identified during an experimental study in which they used operational devices in vehicles, indicate their level of *comfort of mind* with the product interface. Applying the proposed method, such impressions can be used further in the creative design of future products so that they will provide *comfort of mind* to users.

Keywords: *design methodology, human comfort of mind, interface operation, in-depth impressions, protocol analysis*

1. Introduction

One reason to pursue design creativity is to create better products in the future. Product interfaces must be improved in future products; the role of product interfaces in generating positive effects in users is an important factor in future product design. However, *comfort of mind* is not a well-understood concept, and the method to accurately identify it has not been developed. It is difficult to capture human feelings, particularly *comfort of mind*, because they are *inexplicit* (Taura et al., 2010). This paper discusses issues of *comfort of mind* and their relationship with creative design. Specifically, we discuss a method to identify human feelings and investigate the level of *comfort of mind* during product interface operation.

The main emotional state to be discussed in this paper is '*comfort of mind*', which is a pleasurable feeling of ease and well-being experienced while using or operating a product interface. In other words, comfort of mind indicates the ease of operation and freedom from stress and anxiety or frustration, and it reflects the degree to which this use or operation satisfies inner feelings and desires. Such desires may be for amusement, satisfaction, fun, nostalgia, etc.

Ergonomics, which is the study of human comfort, intends to maximize productivity by reducing human fatigue and discomfort and seeks to create more human-friendly equipment (Karwowski, 2012, p.13). Previous studies on user interfaces were done from the viewpoint of ergonomics: the focus was

on usability and other factors related to performance, precision, and safety. *Comfort of mind*, however, focuses on the human *inner state* (Taura & Nagai, 2012, p.157). In comparison with ergonomics, *comfort of mind* concerns human happiness and the sense of well-being, whereas ergonomics concerns physical comfort, operational comfort, and cognitive comfort. Human comfort is difficult to evaluate by traditional scaled evaluations such as those provided by the Semantic Differential (SD) Method (e.g. discrete seven-point scales ranging from 'like' to 'dislike') (Osgood et al., 1957).

In order to investigate *comfort of mind*, a proper method for the identification and in-depth analysis of *comfort of mind* experienced by humans during product operation is needed. This research develops a method to investigate the relationship between interface and feelings, focusing on *comfort of mind* experienced by humans during device operation in vehicles. Our method experimentally analyses free verbalizations during device operation using protocols**.** The results of our experiment show that *comfort of mind* can be identified by *inexplicit* indications. Future issues and implications of this method are discussed. We conclude by discussing the results in terms of design creativity for better products in the future. Our main future goal is to establish concrete methods of new product creation intended to maximize *comfort of mind*.

The *state of the art* in research on comfort focuses on determining optimal interface or environment parameters to generate a comfortable state in humans. It focuses on the reduction of physical loads and on making products and tasks comfortable and efficient (Andreoni et al., 2002; Kolich, 2008) or in accordance with the findings from the field of cognitive ergonomics (Walker et al., 2001).

On the other hand, efforts to evaluate human feelings, including comfort provided by an interface, generally use the SD Method (Wellings et al., 2010; Smith and Fu, 2011). That method is based on ad hoc scaled evaluations of human feelings. The basic principle of the SD method is that a quantitative measurement of meaning (as a relational concept) can be achieved on the basis of representational language behaviour, and hence, representational language behaviour may serve as an index of meaning (Osgood et al., 1957). Subjects render scaled evaluations based on two connotative words in one semantic dimension (e.g. 'comfortable' – 'uncomfortable'). The disadvantage of such ad hoc evaluations is that the exact level of *comfort of mind* remains ambiguous and is generalized by the framed evaluations which are applied. *Comfort of mind* has not yet been identified. The main *issues* with identifying it are:

- Human feelings and particularly *comfort of mind* are difficult to *identify* during normal use or operation.
- Human feelings and particularly *comfort of mind* are *inexplicit*; thus, it is difficult to capture and further analyse them.

Therefore, to identify *comfort of mind*, it will be necessary to determine its identifiers and make it more direct and *explicit*. Another issue with the analysis of *comfort of mind* experienced by humans lies in finding the most appropriate ways to collect data and perform analysis. Employing the verbal protocol (Ericsson and Simon, 1996) during device operation or product use provides a viable representation of *comfort of mind*. *Comfort of mind* is difficult to capture, and we consider the verbal protocol to be an efficient method of capturing this comfort during interface operation. Through verbal protocol analysis, we can quantify indices for the value of feelings of interface operation. Thus, protocols of free verbalizations are sources of important data, as the protocols reveal implicit indicators of *comfort of mind*. In other words, we do not directly identify a comfortable state; however, we identify the indicators of *comfort of mind*.

2. Aim and methods

The aim of this study is to identify *comfort of mind* from human interface operation and propose an approach for creative design of interfaces based on *comfort of mind*.

This study does not attempt to evaluate product interfaces as a whole; rather, we focus on the identification of inner human comfort during interface operation. Particularly, we focus on how experimentally acquired verbal information represents human comfort during the use of different interfaces. When a human operates an interface, combining visual interactions with tactile interactions

probably represents his/her inner feelings at a deeper level than does measuring the visual modality only. Furthermore, comfort is one meaningful factor to analyse via the tactile modality. Comfort can be provided by future products; as a first step towards this end, we focus on the process of determination of comfort via verbal protocols.

In analysis of verbal protocols, we focus on two methods of capturing comfort:

- Identification of words and expressions as explicit indicators of *comfort of mind*
- In-depth analysis of the free verbalization words identified by the protocol

2.1. Bases of the method

In contrast with traditional approaches to comfort evaluation in disciplines such as ergonomics, we apply a method based on in-depth analysis of free verbalizations. First, we develop an analysis method using protocols of free verbalizations in user interface operation. Our strategy to address the aforementioned issues is to pay particular attention to the words identified by the verbal protocol. We identify particular words and expressions as indicators of *comfort of mind* (onomatopoetic words, negative expressions, words indicating abilities or difficulties). Second, our strategy includes the analyses of what underlies the free verbalization words provided by this protocol. We conduct further in-depth analysis of all identified words and expressions based on an underlying layer of impressions (Figure 1; see section 2.3; Nagai et al., 2011).

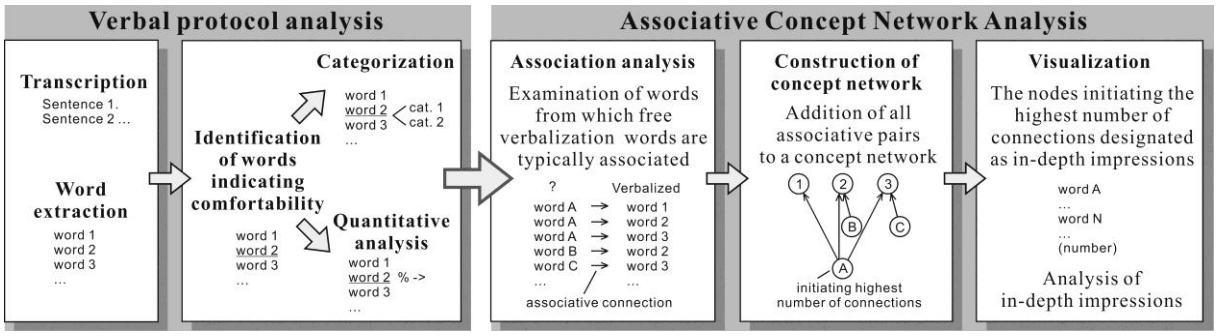

Figure 1. Method for identification of comfortability

2.2. Verbal protocol analysis method

The method of analysis of protocols of free verbalizations using video recordings relies on the following steps (Figure 1):

1. Transcription of speech to be analysed by protocols and extraction of speech to be analysed.
2. Conversion of words to standard language (i.e. dictionary forms of words).
3. Check inter-rater reliability of results of steps 1 and 2 (Two independent transcribers).
4. Word extraction (morphological analysis): expressions broken down into separate words (identification of separate nouns, verbs, adjectives, and adverbs).

Steps 5 and 6 are applied if the language is not English:

5. Translation into English and cross-check of word extraction. Check for translation consistency.
6. Enter word into English translation database, ensuring consistent translation.
7. Words indicating comfort are identified. Roles of specific expressions indicating *comfort of mind* experienced by humans are examined, particularly:

- Onomatopoeic words (e.g. ‘whirl’ or ‘rumble’)
- Negative expressions (containing no/not, e.g. ‘not hot’)
- Expressions indicating abilities and difficulties (e.g. ‘easy to manipulate’ or ‘difficult to go’)

8. All words provided by verbal protocols are categorized after analysing whether they fall into any of three categories: (1) related to comfort; (2) related to a lack of comfort; and (3) words not falling into aforementioned two categories.

For example, onomatopoeic words are reputed to play a distinctive role in design creativity (Mougenot and Watanabe, 2011). The formation or use of onomatopoeic words goes beyond simple imitation of sounds associated with the objects or actions to which they refer (e.g. 'twirl'). They give a special impression of reflecting the senses of the human operating the interface.

The method of protocol analysis which we have developed allows the identification of words and expressions expressing *comfort of mind* experienced by humans through verbal protocols and allows further in-depth analysis of these words and expressions. Further, we institute a method to analyse in-depth these words using Associative Concept Network Analysis (CNA), further developed on the basis of previous study (Nagai et al., 2011).

2.3. Associative CNA method

In this paper, Associative CNA is discussed as a method of identifying inexplicit associative layer of the free verbalizations expressed during the operation of a device. Such associative layer is comprised of *in-depth impressions* that underpin many free verbalizations and are indicative of human *comfort of mind*. Associative CNA consists of following steps:

1. Association analysis: at this stage, all free verbalizations are examined for words from which they are typically associated. That is to say, the examined words are typically associating the free verbalizations (e.g. an examined word 'dolphin' associating verbalized word 'smart'). This is done by reference to an existing associative concept dictionary, built on experimental basis.
2. Construction of concept network: associative pairs are added to a network structure on the basis of the number of outgoing connections.
3. Visualization: Graph visualization of resultant concept network designates nodes initiating the highest number of connections as in-depth impressions. To detect the nodes that initiate only the highest number of connections, approximately the upper 50 per cent of the groups of the words initiating connections (i.e. if groups of words initiate six, five, four, three, two, and one connection, then all of the words from the groups initiating six, five and four connections) are taken as in-depth impressions. These in-depth impressions are further analysed, as they reveal the reasons underlying free verbalized words, based on their *associative nature* and *accumulative characteristics* (number of connections).

We test the method in an experimental study in which we identify human *comfort of mind.*

3. Experimental study

3.1. Experimental procedure

The initial experimental study included 6 subjects (3 males, 3 females) and 2 vehicles with different operational devices controlling the operation of the air conditioners, navigation, and audio systems. Car A was equipped with conventional operational device A (buttons, knobs, and touch screen), while car B was equipped with new operational device B (remote controller). One subject was in age group of 21-25 years, 3 in group 26-30 years, 1 in group 36-40 years, and 1 in group 41-50 years. All of the participants were familiar with the conventional device A, while 4 of the participants were familiar with device B. Both cars were stationary in designated experimental space, with running engines.

Words indicating *comfort of mind* conferred by operating the two car interfaces were obtained via the outlined method using protocols of free verbalizations. The procedure to determine *comfort of mind* followed the outlined method of protocol analysis and Associative CNA, as described in section 2.

3.2. Results

Words and expressions indicating comfort and lack of comfort obtained through verbal protocol analysis were analysed quantitatively (Table 1). We classified all words into three categories according to the following scheme: (1) indicates comfort, particularly expressions indicating abilities; (2) indicates a lack of comfort, particularly expressions indicating difficulties; (3) words not falling into aforementioned two categories. A high rate of analysis of words and expressions as indicators of *comfort of mind* experienced by humans was achieved via verbal protocol analysis (see percentages in Table 1). Associative CNA was then performed on the results of the analysis summarized in Table 1. For association analysis (step 1 of Associative CNA), we used the University of South Florida free association, rhyme, and word fragment norms (Nelson et al., 2004; Nelson et al., 2011), as it is the most extensive associative concept dictionary available in the English language.

Table 1. Summary of quantitative analysis of verbal protocols.

Subject (Device)	Verbal protocol words (*percentage of verbal protocol words being able to be included in analysis*)				
	Onomatopoeias (Category (1) or (2))	Negative expressions (Cat. (2))	Expressions indicating abilities (Cat. (1))	Expressions indicating difficulties (Cat. (2))	Total words
1 (A)	11 (*91%*)	2 (*100%*)	1 (*100%*)	5 (*100%*)	147 (*92%*)
1 (B)	14 (*93%*)	12 (*100%*)	3 (*100%*)	1 (*100%*)	173 (*91%*)
2 (A)	13 (*92%*)	17 (*100%*)	1 (*100%*)	2 (*100%*)	231 (*96%*)
2 (B)	21 (*95%*)	22 (*100%*)	1 (*100%*)	-	232 (*93%*)
3 (A)	5 (*100%*)	23 (*100%*)	3 (*100%*)	1 (*100%*)	286 (*95%*)
3 (B)	16 (*94%*)	20 (*100%*)	4 (*100%*)	7 (*100%*)	329 (*97%*)
4 (A)	1 (*100%*)	15 (*100%*)	1 (*100%*)	5 (*100%*)	143 (*97%*)
4 (B)	-	21 (*100%*)	2 (*100%*)	3 (*100%*)	243 (*95%*)
5 (A)	20 (*100%*)	9 (*100%*)	24 (*100%*)	15 (*100%*)	542 (*97%*)
5 (B)	8 (*100%*)	9 (*100%*)	20 (*100%*)	6 (*100%*)	408 (*96%*)
6 (A)	19 (*100%*)	12 (*100%*)	7 (*100%*)	1 (*100%*)	380 (*98%*)
6 (B)	4 (*75%*)	12 (*100%*)	7 (*100%*)	1 (*100%*)	401 (*95%*)

In step 2 of the Associative CNA method all detected associative pairs are added to a concept network structure on the basis of the number of outgoing connections (Batagelj and Mrvar, 2003)) – out-degree centrality. Concept networks were constructed based on all words identified by the verbal protocols, and we used graph visualizations of the networks (Batagelj and Mrvar, 2003; Pajek 2.04, 2012) to identify and interpret in-depth impressions for each device and subject (Figure 2). As, clarified in section 2.3, the network nodes initiating the highest number of connections were designated as in-depth impressions (approximately the upper 50 per cent of the groups of the words initiating connections) (Table 2).

Table 2. Example outcomes of Associative CNA in terms of in-depth impressions.

Subject (Device)	Sample of the in-depth impressions **(Total number)**
1 (A)	chili, climate, cool, heat, heater, hotter, mitten, sweater, wool, defrost, Florida, fur, gentle, glove, shorts, temperature, *uncomfortable*, uneasy, etc. **(85)**
1 (B)	touch, knuckle, grown, turn, big, ease, *uncomfortable*, uneasy, extremity, great, lift, press, pump, soft, tiny, depletion, lever, minimum, minor, pedal, resistance, rough, rub, subtle, wart, etc. **(25)**
2 (A)	leave, stay, click, pedal, quit, urge, wait, away, great, party, start, touch, bully, cart, dismiss, press, enough, less, resistance, shun, some, travel, begin, demand, do, flow, grown, lever, etc. **(102)**
2 (B)	place, location, turn, advance, local, replace, stay, disperse, presence, set, action, away, flow, know, put, travel, where, direction, get, haven, healthy, oil, reliable, remove, etc. **(35)**
3 (A)	accept, healthy, feeling, great, medicine, be, alive, enough, health, most, parents, some, able, abundance, *comfortable*, exceptional, fine, get, lots, much, attitude, carrots, condition, etc. **(135)**
3 (B)	press, lever, touch, be, decision, able, fasten, beer, oil, urge, waste, click, shun, zipper, accept, fair,

	how, might, allow, cute, dismiss, fingernail, pedal, possible, pressure, pump, etc. **(47)**
4 (A)	decision, fair, extreme, lawful, basic, harsh, listen, strive, uneasy, accept, complex, complicated, demand, ease, feel, function, impossible, perceive, rough, simple, trouble, unjust, etc. **(32)**
4 (B)	fair, decision, lawful, touch, waste, able, how, be, cause, condition, oil, snap, beer, ease, get, healthy, lever, listen, pleasant, preference, taste, unjust, ability, accept, another, etc. **(52)**
5 (A)	fair, uneasy, complicated, basic, *comfortable*, complex, dangerous, ease, example, grasp, impossible, rough, simple, trouble, able, accept, breeze, breezeway, confuse, obvious, etc. **(76)**
5 (B)	fair, trouble, lawful, uneasy, *comfortable*, ease, decision, impossible, accept, basic, complex, complicated, dangerous, obvious, perception, rough, simple **(17)**
6 (A)	click, fair, pleasant, urge, music, touch, lever, lawful, theater, tone, volume, cart, *comfortable*, condition, dismiss, felt, pedal, press, resistance, accept, curve, etc. **(62)**
6 (B)	fair, lawful, be, action, flow, function, experience, felt, exceptional, excel, intent, obey, accept, aright, awesome, *comfortable*, condition, tend, able, bravado, grace, healthy, etc. **(51)**

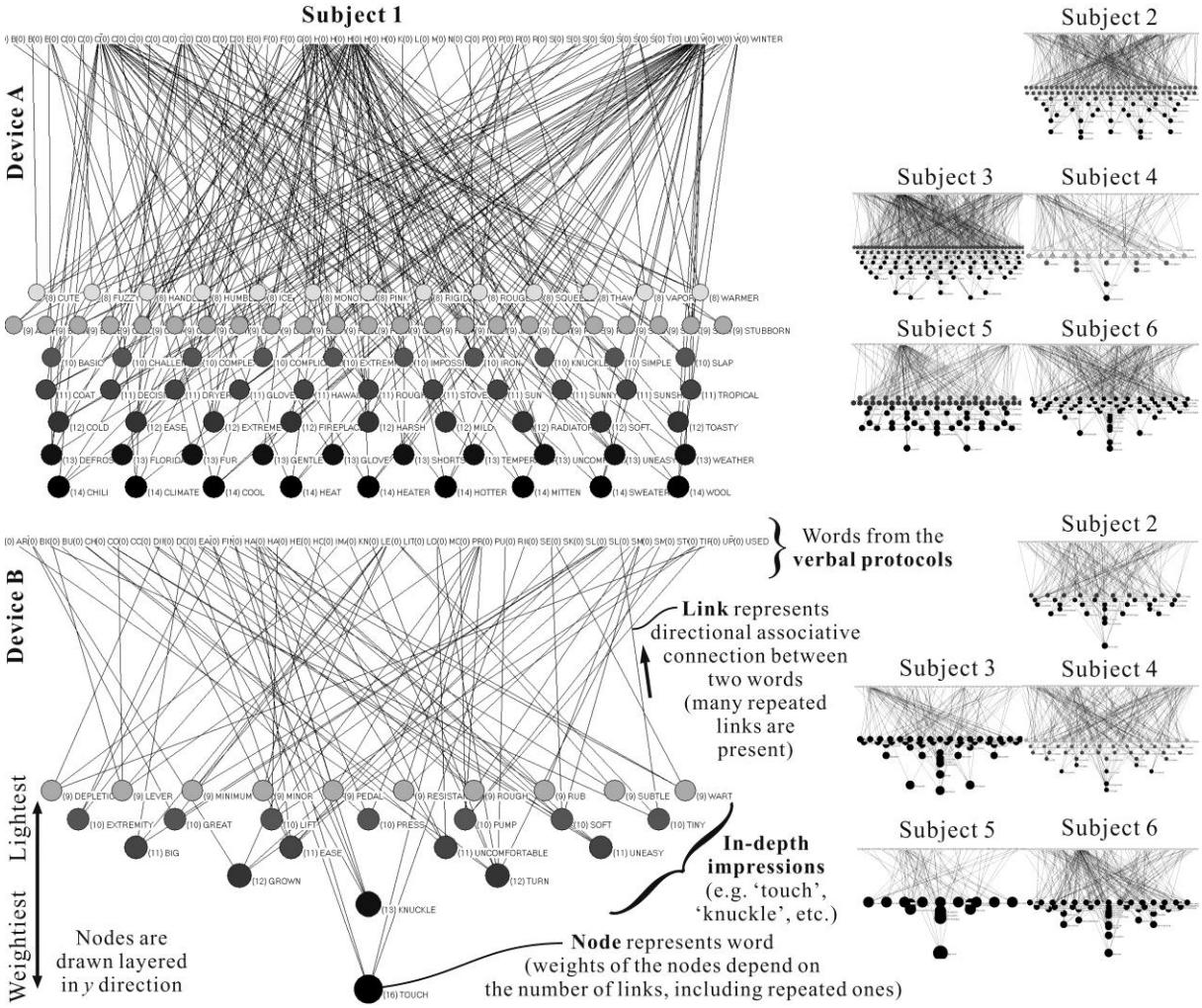

Figure 2. Graphs visualizations illustrating the outcomes of associative CNA.

Examples of concept networks from all subjects are shown on Figure 2. The nodes on the upper part of the graph visualization for each device and subject are obtained from the verbal protocol (words from verbal protocols are not visible due to their large number), while the lower nodes are the results of Associative CNA (see section 2.3). In-depth impressions are drawn layered in *y* direction according the number of connections they initiate to the verbal protocol words (the in-depth impressions initiating high numbers of connections are depicted lower in the graphs and in darker colours). These visualizations show the relative strengths of the in-depth impressions. The results of the Associative

CNA were used to explicitly highlight concepts related to *comfort of mind* (e.g. for Subject 1, Device A, the impression ‘ease’ beside numerous impressions indicating ‘cold’, ‘defrost’ or ‘extreme’).

4. Discussion

4.1. Capturing comfort of mind experienced by humans

The experiment using the proposed method to identify human comfort showed that the *inexplicit* indicators of *comfort of mind* can be captured and that the problem of inexplicitness of comfort within the frame of operation can be overcome. According to the findings, we were able to quantify the inherently qualitative feeling of comfort. This was accomplished via verbal protocol analysis developed specifically to analyse a high proportion of free verbalizations (Table 1); we further analysed these words with a thorough method based on inexplicit associative layer of in-depth impressions (Table 2 and Figure 2). We identified a proportion of the words from free verbalization as being related to the categories of comfort or discomfort. Furthermore, particular in-depth impressions *instantiate* the concept of *comfort of mind*. From the Associative CNA, we observe that certain in-depth impressions can potentially turn comfort into an *explicit* quantity and quality. For example, for Subject 1, Device A (conventional operation), impressions like ‘climate’, ‘hotter’, ‘sweater’, ‘glove’, ‘uncomfortable’, or ‘uneasy’ indicate a lack of tactile *comfort of mind*. For Subject 1, Device B (new remote controller operation), impressions like ‘knuckle’, ‘uncomfortable’, ‘uneasy’, ‘extremity’, ‘great’, ‘lift’, ‘resistance’, or ‘rough’ again indicate *discomfort of mind* related to the operational characteristics of the device.

Moreover, *comfort of mind* is represented in the results by certain nodes (such as the node ‘ease’ or nodes ‘cold’, ‘defrost’ and ‘extreme’). We can determine that ‘ease’ connected to ‘cold’ and ‘defrost’ represents particular *comfort of mind* (or the lack thereof). However, additional measurement of the level of comfort may be needed to further verify these results.

We now investigate this method’s implications for design creativity, particularly its implications for the design of future products.

4.2. Implications for creative design and ideal products

The products we make are increasingly technically excellent, constantly becoming easier and safer to use. However, many people still prefer to drive old cars, use old pens, or play old games. Why does this happen, despite the fact that newer products are more usable, more reliable, or perform better? The reason is probably that these older products confer inner *comfort of mind*, providing a more pleasurable interface to users. Human senses and emotions tend to be more important than other aspects in design. To design creatively means to engage the user’s senses and emotions (Taura & Nagai, 2011). As *comfort of mind* experienced by humans during interface operation depends on the *inner senses*, it relates to the motivation and human ability to *design creatively* (Taura & Nagai, 2012, p.4).

Creative design is not routine design, and comprehension of *comfort of mind* will shed light on how to provide new, creative products with interfaces that provide comfort to users. For example, if the driver of a vehicle wants an interface which is amusing and fun to operate, identification of what provides *comfort of mind* during such operation will enable the design of such interfaces for future vehicles.

Creativity in design leads to the promise of better future products, and the methods presented here can aid future interface design. An important topic in interface design is the inclusion of analogue components: analogue interfaces are still comfortable to users. Our method can contribute by providing insight into such issues. For example, if we need to identify what is missing in a new, high-tech car system, the analysis of the output of verbal protocols examining *comfort of mind* experienced by humans is a way to identify these missing features.

The output of Associative CNA uncovers in-depth impressions related to inner human *comfort of mind*. To investigate the implications of this *method for creative design*, we examine the use of these

in-depth impressions in design. Such impressions – actual words – can be used for the main application:

- Word stimuli in early stages of design, where such stimuli have the special role of delving into the designer's inner sense, thus relating to designer's creativity

This application has particular implication for ideas for future products in that they are highly reflective of users' *inner sense*.

Future products should provide better effect and *comfort of mind*. Understanding comfort of mind based on human *inner senses* will help achieve this goal. According to the results of this research, ideal future products will have designs that respond to users' *inner senses* and provide *comfort of mind*. Future research on creative design will benefit from comprehension of *comfort of mind*.

4.3. Unsolved issues

However, certain issues still remain unsolved, particularly the need for further qualitative analysis of these initial results about *comfort of mind*, and the need to analyse the remaining indicators of comfort in word form. The latter issue includes the analysis of onomatopoeic words. Importantly, although onomatopoeic words are indisputably important reflections of comfort, and are therefore important for creative design (Mougenot & Watanabe, 2011), it was difficult to analyse the degree to which they indicate comfortable versus uncomfortable feelings.

5. Conclusions

This research developed a new *approach for creative design*. The proposed method focused on human feelings and *comfort of mind*. We conducted an experimental study in which we identified *comfort of mind* experienced by humans during the operation of two types of user interfaces. Verbalizations during operation were captured and analysed as representations of *comfort of mind*. Words and expressions indicating *comfort of mind* were identified using verbal protocols. An analysis of these words and expressions performed via Associative Concept Network Analysis identified the in-depth impressions behind the verbalized words. According to the results, particular extracted in-depth impressions indicate *comfort of mind*. These indicators of comfort can be used to creatively design new products in order to maximize *comfort of mind* engaging human senses and emotions, and to identify issues with existing product interfaces.

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