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WORKING TOWARDS BUILDING A SENSITIVITY INDEX FOR A VEHICLE CONTROL DEVICE: A METHODOLOGY USING CONCEPT NETWORK ANALYSIS

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1. Introduction

There is a constant need to harmonise design with human needs and behaviour and to ensure that the products are built as per human inner sensitivity and feelings. However, the engineering design methodologies and tools to assess human sensitivity are still incomplete. How then should an in-depth assessment of human inner sensitivity and feelings be conducted in order to improve the development of products according to these human aspects? This paper focuses on this question.

Fundamentally, this paper deals with the human aspect of design. This aspect is crucial and arguably essential for understanding the production of products and systems which relate to the users themselves. We discuss an advanced and innovative methodology to assess human sensitivity and behaviour when operating a device or using a product. In particular, we focus on the human-computer interface work—operating a device—in a vehicle. The purpose of the discussed methodology is to assess human sensitivity related to design at the phase of the design process where alternatives have to be compared and evaluated. It is essentially an evaluation and decision-oriented methodology. We explain why this particular methodology is necessary and why this approach is novel. We provide an example of the methodology in a test case study comparing the use of devices in two vehicles. The human sensitivity was identified on the basis of conscious and unconscious indicators of the human state. Furthermore, we identified particular sensitivity events. The results contribute to the user-centred design. This is a concurrent methodology in this field of study, and it validates how the presented approach contributes to the overall effectiveness of the phase of design where alternatives have to be compared and evaluated. Examples of the impact of the approach are provided.

2. Research on human sensitivity

In this paper, the term *human sensitivity* means the human capacity to respond to the operation of a product in terms of induced sensitivity and feelings. The product or device is serving as stimulation.

2.1 Human sensitivity from products

Induced senses and feelings in humans have been the focus of design research for a long time. The area branches out into fields such as Kansei engineering, design for emotion, or emotional engineering [Nagamachi 1995], [Desmet et al. 2000], [Fukuda 2011]. Kansei engineering aims to translate induced senses and feelings in humans into design requirements, later intended to create a desired impression. On the other hand, design for emotion focuses on creating emotional experiences from products or the use of devices. Further, emotional engineering associates emotion with the creation of values from products and processes. *Kansei* is sometimes referred to as ‘affective engineering’—focused particularly on integrating affective values into product design. This requires the development of appropriate methods, which can capture and translate subjective and often unconscious human sensitivity and feelings about a product into concrete parameters of design [Schütte 2005].

2.2 Assessing sensitivity in vehicles

Vehicles are common targets for research on human sensitivity and feelings, since they are a part of everyday activities. Kansei engineering research on human sensitivity in vehicles, for example, focused on an evaluation of a vehicle’s interior image, especially the factors which affect comfortableness using design elements and dimensions. However, more current research focuses on not only the general factors but also on the factors of particular elements in vehicle interiors. For example, *Kansei* in the case of visual images of head-up displays were investigated by Smith and Fu [2011]. Relationships between the design of head-up display presentation image and the drivers’ *Kansei* were quantitatively and qualitatively analysed. *Kansei* factors, together with design elements of head-up displays—for instance, soft–harsh or relaxing–anxious—were identified. Design for emotion in the case of vehicles focuses on the visual aspect [Desmet et al. 2000]. Human perception of the quality of control panels in vehicles in different modes—visual, tactile, and hearing—has been compared by Burnett and Irune [2009]. Touch is critical for perceptions of quality and design differentiation. Further steps in understanding the tactile perception of elements of the user interface in vehicles indicate their importance to human sensitivity and feelings [Wellings et al. 2010]. The feel of push-switches in context (in-car) and out of context has been assessed, and the characteristics of switch haptics have been explained using three independent factors—‘Image’ and ‘Clickness’, which are relevant, and ‘Build quality’, which was found to be important for human perception.
However, human sensitivity is difficult to capture in connection with a particular operation or element of design, because often, the changes in senses and feelings are minimal and not realised by a human. This is even more difficult during complex activities such as operating various devices in a vehicle.

3. Aims and method of research

To address the aforementioned difficulties, we formulate the purposes of the study as follows:
(1) To propose an elaborate methodology, which is focused on a particular operation or element of design, to assess human sensitivity during the operation of a control device in a vehicle;
(2) To construct a methodology to compare human sensitivity from different vehicle control devices.
First, we focus on existing gaps in the methods assessing human sensitivity.

3.1 Existing methods and the method proposed in this study

Various methods try to address the aforementioned difficulty to capture it in detail. The existing methods to measure human sensitivity can be plotted on a relative map of methods with two axes—conscious-unconscious activities and functional-emotional assessments (Figure 1). The two scales represent consciousness of human activities and approach of the assessments. From this map, we can observe that many of the existing methods focus on conscious human activities or functional assessments (e.g. groups of methods based on formalized evaluations, behaviour analysis of humans, or psychological/physiological measurements), rendering insufficient attention to the quadrant of unconscious activities and emotional assessments. We consider this a reason for the difficulty in assessing human sensitivity during complex activities and minimal changes.

3.1.1 Method proposed in this study

To build a method capable, at least partially, of accounting for unconscious activities and emotional assessments, we develop an in-depth analysis on the basis of freely verbalized impressions. We focus on connecting free verbalized impressions using the formalized evaluations method, followed by the inner associative layer method and finally a physiological measurements method.

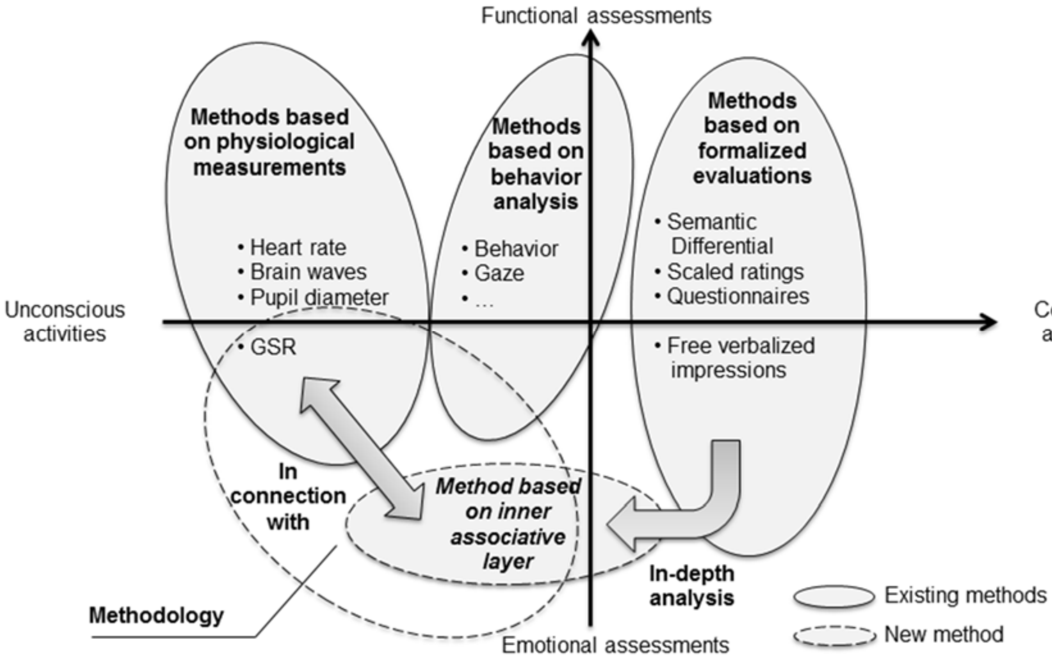


Figure 1. Positioning this research's methodology on the relative map of methods measuring human sensitivity

The structure behind the impressions has already been analysed as deep impressions—defined as those which are related to the deep feelings towards a product and lie beneath surface impressions [Fasiha et al. 2010]. To conduct an in-depth analysis of verbalized human impressions, we consider that human sensitivity can be described as having two layers: a verbalized (expressed) human impressions layer and an inner associative layer. Moreover, we consider the latter layer to consist of *in-depth impressions*, which initiate the expressed human impressions but remain primarily unconscious to the person who is actually expressing the impressions on a particular activity. In other words, the connections between the two layers are associative in nature and have accumulative characteristics; the elements of the inner associative layer, which underpin more of the verbalized human impressions, play a greater role in forming human sensitivity. This approach has the benefit of identifying the unconscious human sensitivity as *in-depth impressions* on the basis of the number of associative connections to the verbalized human impressions. Moreover, our consideration is that such in-depth impressions which underpin the verbalized impression are indicative of human sensitivity and feelings and better portray the reasons or motivation behind certain verbalized impressions.

3.2 Definitions

To clarify the above arguments, we introduce the following definitions:

(1) *In-depth impressions*

In-depth impressions comprise an inner associative layer of outwardly expressed human impressions during the operation of a device or use of a given product.

(2) *Sensitivity event*

A sensitivity event is a human response (or change) during the operation of a device or use of a given product which can be identified on the basis of conscious and unconscious indicators of the human state with regard to comfortable or uncomfortable feelings.

We make the following assumptions for this definition:

(2a) In-depth impressions and other indicators of human sensitivity occur simultaneously.

(2b) In-depth impressions can indicate the comfortable or uncomfortable state of the human.

(3) *Sensitivity index*

The sensitivity index is a set of in-depth impressions characterizing the type of product or device and can provide scales or maps on the basis of which the degree of sensitivity from different devices or products can be compared or evaluated.

Further, in the following section we discuss how to capture the in-depth impressions during the operation of a control device in a vehicle.

4. Approach using concept network analysis complemented by physiological measurements

4.1 Concept network analysis method

To capture the in-depth impressions during the operation of a control device, we build upon previous methods to identify in-depth impressions in the case of tactile interactions with materials [Georgiev and Nagai 2011], [Georgiev et al. 2012]. This method described the structure behind the explicit impressions that humans derive from materials as affected by personally held associations, providing deeper understanding users' emotions and product experience.

In particular, the concept network analysis method here consists of the following main steps:

- Association analysis of verbalized user impressions: At this stage, all verbalized user impressions are examined for words with which they are typically associated. A list of all such common associative pairs is created on the basis of an existing associative concept dictionary, build on experimental basis.
- Construction of concept network: The associative pairs are added to a network structure, which is associative in nature, having two types of nodes—verbalized human impressions (receiving connections) and associative nodes (initiating connections).
- Visualization of the graph of the resultant concept network to detect in-depth impressions as the nodes initiating the highest number of connections

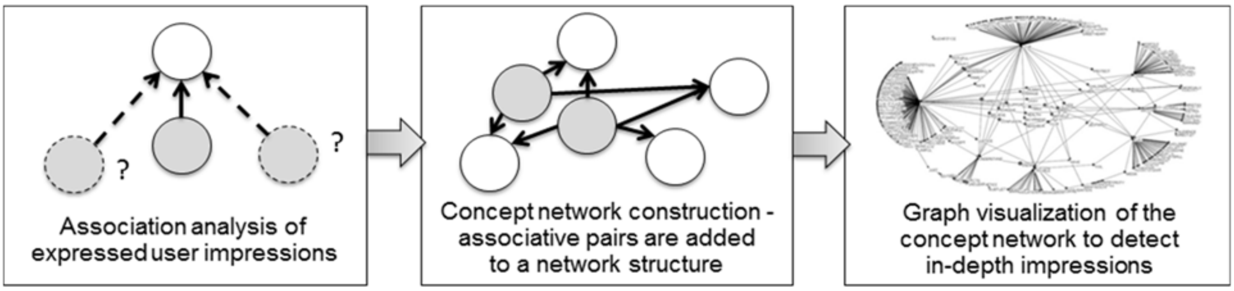


Figure 2. Steps of a concept network analysis

This method allows us identify in-depth impressions from verbalized impressions in general. However, we need additional methods to match in-depth impressions to a particular activity or device operation in a vehicle. We consider supplementary indicators of human sensitivity which can be measured at a particular moment.

4.2 Supplementary indicator of human sensitivity and combined analysis

For other indicators of human sensitivity, we focused on a common and easy-to-capture indicator (a physiological measurement): the biofeedback of a Galvanic Skin Response (GSR). However, one of the shortcomings of the GSR is that the valence of the arousal is difficult to judge. In a general case, the valence of the arousal is not always possible to observe from the speech of the subject. By combining a concept network analysis with GSR, we are also addressing the shortcomings of the biofeedback of GSR—an indication of the valence of the arousal (positive or negative); this valence can be judged on the basis of the type of in-depth impressions.

In Figure 3, we present a method to match the physiological measurement (a GSR peak at a specific moment) with in-depth impressions. The verbalized impressions just prior to and just after the GSR peak are taken into account to apply the concept network analysis method. By matching these two indicators in a particular way, we can identify the sensitivity event. Furthermore, a sensitivity event (or a group of them) can be used to determine the feelings of comfortableness or discomfort in humans.

4.3 Methods of data collection and analysis

As for the methods of data collection and analysis in this study, we follow the following steps:

1. The verbalized (freely expressed) impressions during the operation of a device in a vehicle captured using video recordings,
2. The physiological measurement (GSR) simultaneously with the verbalized impressions,

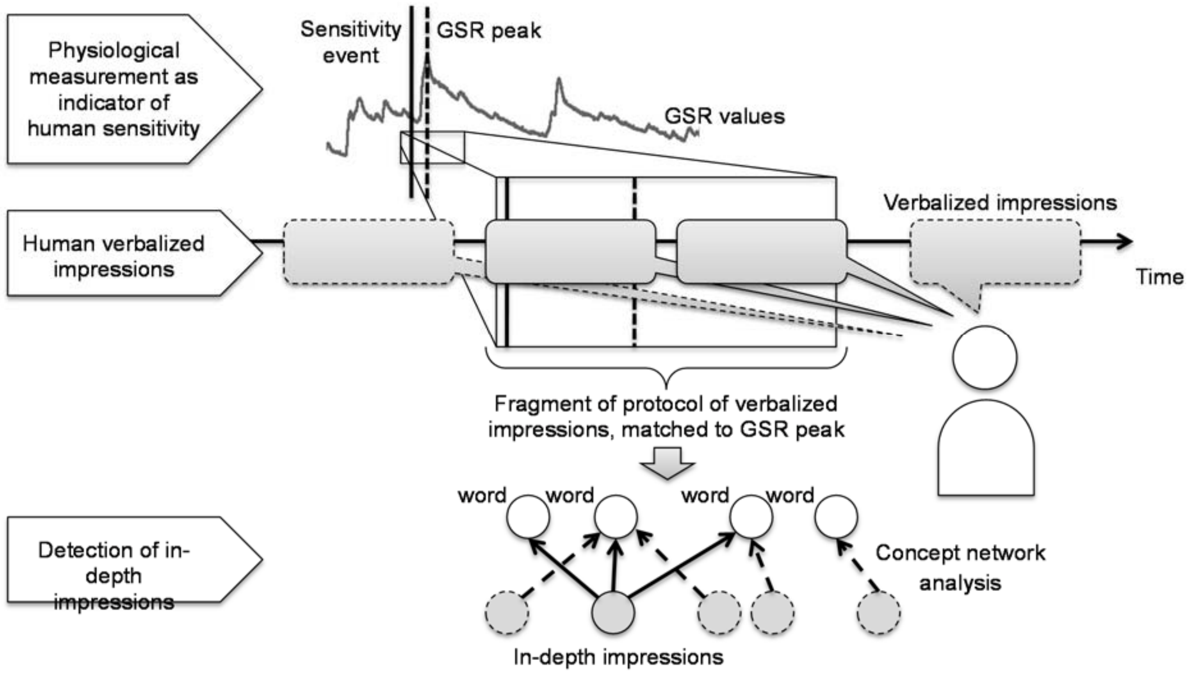


Figure 3. In-depth impressions and physiological measurement (biofeedback of GSR) of human sensitivity that occur simultaneously

3. Protocol analysis of verbalized impressions,
4. Concept network analysis of the verbalized impressions,
5. Extraction of in-depth impressions,
6. Qualitative analysis of the extracted in-depth impressions, and
7. Combined analysis of in-depth impressions with physiological measurement.

We applied the approach described above in a test case using vehicles.

For detection of the in-depth impressions, we used the most common applicable associative analysis tool—associative concept dictionary. The 'University of South Florida free association, rhyme, and word fragment norms' database created by Nelson, McEvoy and Schreiber contains very large number of English-language associative words (word-pair associations) [Nelson et al. 2004, 2011]. Furthermore, for creation of the conceptual networks we used Pajek graph drawing software [Batagelj and Mrvar 2003], [Pajek 1.25 2009].

5. Test case

We applied the methodology in a test case and used two different existing control devices with similar functionality. We focused on the conventional operation of vehicle control devices in existing vehicle interiors, such as the air conditioner and audio or navigation systems (controlled by knobs and touch screen). We compared this case with the new interface where these devices/functions are controlled by a haptic remote controller (Figure 4). They represent two different approaches to controlling devices in vehicles. Moreover, the remote controller presents greater operational change in a vehicle. This issue is particularly relevant to right-side driving countries (e.g. Japan), where such in-vehicle systems have to be mostly controlled with the driver's left hand.

5.1 Control devices and tasks to test

The two test vehicles in this case were the Vehicle 1 and Vehicle 2 (Figure 4). In the selected case of a control device, we divided the tasks into three groups which were respectively related to the: (Task group 1) air conditioner; (Task group 2) navigation system, and (Task group 3) audio system.

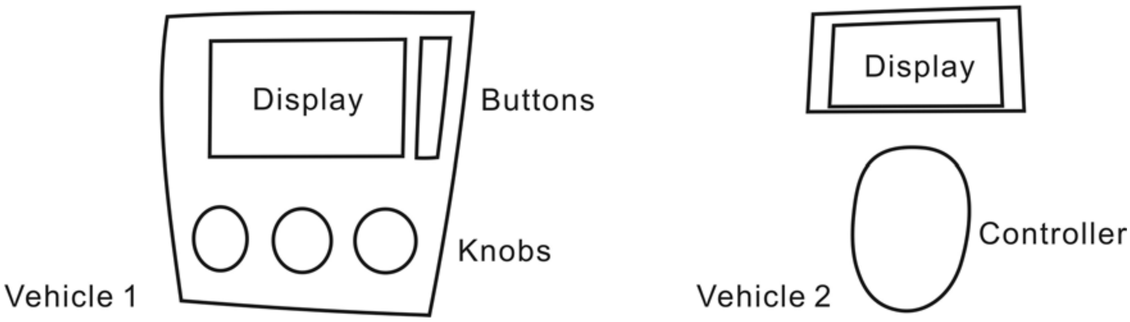


Figure 4. Evaluation of control devices in vehicle 1 and vehicle 2

5.2 Capturing sensitivity events

In the test case, we collected free verbalizations from three subjects for both vehicles. The experiments took 25–35 minutes on an average, allowing the subjects to express and freely verbalize their impressions while operating devices such as the (Task group 1) air conditioner, (Task group 2) navigation system, and (Task group 3) audio system. In this preliminary test case, on the basis of the described protocols of verbalized impressions, we were able to detect and extract in-depth impressions regarding different task groups. The in-depth impressions of one subject from Task Group 2 are shown in Table 1 (one representative case); an example of the corresponding concept network is provided.

We can observe particular differences in the in-depth impressions while operating the navigation system in Vehicle 1 (conventional operation) and Vehicle 2 (remote controller). Operating the navigation system in Vehicle 1 induced in-depth impressions like ‘must, try, absence, reliable, and responsible’, which can be classified as neutral feelings.

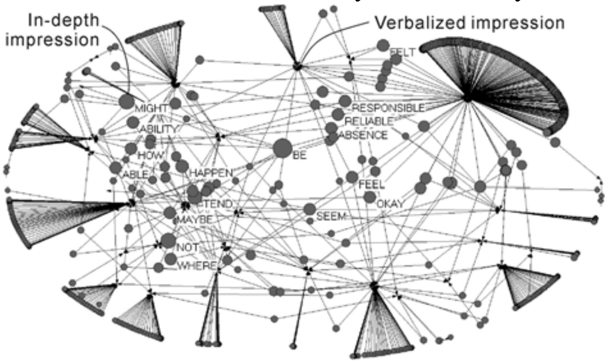
On the other hand, the navigation system in Vehicle 2 induced in-depth impressions like ‘party, challenge, ascend, cheer, event, and fun’, which can be classified as related to positive feelings. However, further reliable method for emotional rating/classification of these in-depth impressions should be considered; and qualitative analysis based on typology of in-depth impressions is needed.

5.3 The two matching methods for a sensitivity event

5.3.1 Matching based on in-depth impressions

Hereafter, we consider two methods for the identification of a sensitivity event and match it to a particular operation or element of the control device used by the subject. In-depth impressions can serve as the basis for a particular operation which corresponds with particular sensitivity and evokes particular feelings. That is, in-depth impressions associated with a particular feeling (such as ‘absence’ or ‘fun’ in Table 1) can be matched through the verbalized impressions they associate with a particular operation.

Table 1. Examples of extracted words from verbalized impressions and in-depth impressions

Vehicle 1 (Task group 2: Navigation system)	Vehicle 2 (Task group 2)
Extracted words: also, apply, associate, association, bothersome, called, can, do (2), extend, far, feel (2), feeling, go, good (2), good, how (2), I, input, investigate, is (2), it, like, more, new, newlywed, no, normal, normal, not, not (2), passable, search, so (2), somewhat (5), there, think, thinking, to (3), travel, turn, usually (2), want, widen, would (3), wrong *In-depth impressions:* be, intent, might, again, must, try, absence, reliable, responsible, experience, obey, how, felt, extra, mastery, selection, tend, think, ready, excuse, maybe  	*Extracted words:* bad, can, cancel, difficult, direction, down, every, feeling, game (3), go (2), good, hold, leave, love, move, not, powerfully (2), response, scroll, so, time, to, until, when, wonder *In-depth impressions:* action, advance, party, stay, wait, wicked, be, challenge, ascend, ascent, descend, cheer, delay, event, fun, guess, hobby, rummy, scramble, wrestling, disperse, release, retreat, travel

5.3.2 Matching based on physiological indicators

In Table 2, on the basis of a physiological measurement indicator (GSR baseline value was at its peak value at this moment), we were able to identify particular sensitivity events (1 and 2). Sensitivity event 1 can be judged as related to an uncomfortable feeling on the basis of the in-depth impressions of ‘less’, ‘scarcity’, and verbalized impressions of ‘confused’ and ‘worry’. Sensitivity event 2 can be judged as related to a comfortable feeling on the basis of the in-depth impressions of ‘ability’, ‘be’, ‘can’, ‘possible’, and ‘experience’—evident from the verbalized impressions. However, further qualitative analysis is needed.

Table 2. Example of sensitivity events identified by the corresponding in-depth impressions

Vehicle 2 (Sensitivity event 1 during Task group 1)	Vehicle 2 (Sensitivity event 2 during Task group 3)
Extracted words: absolutely, disconcerted, smoothly, nothing, enter, position, little, accustomed, nothing, worry, perhaps, mouse, together, enter, index, finger, middle, finger, vicinity, come, want *In-depth impressions:* return, welcome, joint less, scarcity, neutral, all, assume	*Extracted words:* therefore, other, operation, method, some, oneself, hand, close, place, do, CD, enter, normal, old, audio, completion, able *In-depth impressions:* ability, be, can, cane, possible, condemn, hold, local, open, opposite, premises, recent, experience, function, how, participate, put, use, plan, procedure, routine, common, downtown, replace, none

6. Discussion

6.1 Capturing in-depth impressions

The proposed methodology to identify in-depth impressions in the case of device operation in vehicles focuses on the identification and analysis of an inner associative layer from the verbalized impressions. We were able to propose an elaborate methodology to assess human sensitivity during the operation of a control device in a vehicle. Further, we focused on a particular operation or element of design—for example, a particular operation of a navigation system in the case of vehicle 2 was associated with in-depth impressions such as ‘fun’, although ‘fun’ was not a verbalized impression. We captured human sensitivity in connection with a particular operation in which sensitivity was not realised by the subjects (which was based on in-depth impressions such as ‘ability’ and ‘possible’). We were able to compare human sensitivity from different vehicle control devices—operation of navigation system by conventional touch screen and remote controller.

This approach is novel because this is the first application of in-depth impressions in an interactive case—operation of devices—beyond passive visual or touch impressions from products. We introduced the supportive role of the physiological measurements; they aid in the identification of particular changes in human feelings in connection with device operation, which can later be matched to in-depth impressions.

6.2 Implications of the analysis methodology and limitations of the approach

A major implication of the presented methodology is that it can complement usability analysis by analysing and mapping human sensitivity from the operation of control devices. It can be expected that such evaluations will improve the design process phase where alternatives have to be compared and evaluated. This approach could be used to compare several products based on the type of feelings indicated by the in-depth impressions and thereby to help designers performing relevant technical choices. As an evaluation and decision-oriented methodology, it adds to user-centred design. This is a concurrent methodology in this field of study, and it validates how the presented approach has contributed to the overall effectiveness of building a human sensitivity index.

It should be noted that the approach has several limitations. The main limitation is that the approach is difficult to apply in cases of insufficient free verbalized impressions. Another limitation is that the approach cannot account for domain-specific terminology if they appear in verbalized impressions.

6.3 Future work

In the future, we plan to conduct a full-scale experiment investigating human sensitivity during device operation in vehicles. Post-hoc assessments with semantic differential scales and free opinions will additionally improve the identification of sensitivity events and help build sensitivity indexes on control devices in vehicles.

7. Conclusions

We proposed an elaborate methodology to assess human sensitivity during the operation of control devices in vehicles on the basis of the underlying layer of in-depth impressions. As such, we can also assess human sensitivity from particular operations. In the test case, we extracted in-depth impressions in the cases of device operation and identified them on the basis of conscious and unconscious indicators of the human state. Furthermore, we identified particular sensitivity events—comfortable or uncomfortable feelings—during the operation of vehicle control devices, which were based solely on the proposed methodology and in-depth impressions. In the future, we will focus on building a sensitivity index which will provide scales on which the degree of sensitivity from devices can be compared or evaluated.

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