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CONSIDERING EMOTIONAL IMPRESSIONS IN PRODUCT DESIGN: QUALITY OF LIFE THEORY AND ITS IMPACT ON DESIGN STRATEGY

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1. Motivation

We are in times when competition significantly increases and the pressure to attract customers raises for manufacturer of technical products. This leads to a stronger focus on user requirements all along the product development process. There, the most significant user involvement occurs at the early stages, when it is being decided what the product will be like and how it is going to create value for users [Kujala 2008]. But it is also important to ensure the presence of valuable knowledge throughout the whole process chain to meet the users' real requirements. Therefore, User Centred Design (UCD) becomes important.

UCD comprises the consideration of physical, cognitive, sensory/perceptual, emotional and communication capabilities of individuals in relation to the tasks they need to perform using processes, systems, or technologies in their environment [Stanton et al. 2005]. Therefore, it is essential to consider that the perception of products is based on user needs interwoven with the context of use [Kujala 2008]. A high relevance in these aspects is obvious, especially in Universal Design (UD). Although there are many good approaches how to consider physical inclusion, there is still a lack in fostering psychological aspects. Steinfeld and Smith [2013] describe this problem field as follows:

"[...] designing products to be usable by a broader population is not sufficient to ensure an improved quality of life. If a product makes an individual feel or look awkward when using it, a user will avoid it, even if it is free of barriers to usability. The psychosocial perspective on a product, including stigma, is very important to end users" [Steinfeld and Smith 2013].

Concluding, there is a lack of considering those aspects that are highly implicit and hard to capture. But empirical evidence shows that they are doubtlessly of high relevance. For instance, there are already very good designs in the cell phone for seniors market, which already are a challenging UD task itself. Although they might thus perfectly suit to compensate physiological disfunctions from an objective point of view, we still state a low acceptance of these products. This leads to the entitled assumptiom that users' decisions in this field are highly subjective. We need to provide a methodology to efficiently take the final step to a holistic consideration within this theme where the margin of manoeuvre can be exploited to the last. It will be thus of great value both for the success of the products themselves and for the ameliorisation of the quality of life for everybody if we unveil the potential of those design parameters that can now support both physiological and psychological acceptance.

Scientific approach and research aim

In this paper, the necessity of emotional considerations in the context of UD is treated. The difficulty lies in the fact that emotional aspects in particular are often very vague, highly subjective and intensely complex. This might be a reason for their insufficient consideration in UD so far.
Therefore, we reconsider the initial aim of UD to better understand the current work fields. Moreover, we look at quality of life models to locate the position of emotional design in UD research. In order to then overcome the lack of emotional aspects in UD decision making, we look at other research fields to provide adaptation potential. We state that before giving answer to the question how to raise the quality of life in UD, we have to investigate UCD issues as it breaks down the aggregated problem formulation to a single levelled question. Later on, the answer to this question can be subsumed to heterongeneity of observed users, leading back to UD considerations.
Referring to present methodologies, we work out an alternative approach how to integrate emotional aspects. Hence, the ACADE - an Application for Computer Aided Design of Emotional impressions - is introduced. This concept shows high value for the respective task and offers a platform for further investigation in the field of emotional UCD and therefore for UD.

2. State of the art

Whereas many solutions for physical inclusion are provided (e.g. [Clarkson et al. 2013], [Waller et al. 2013]), we have only little knowledge how to consider psychological inclusion. Although marketing strategy is increasingly focusing on implicit factors in consumer behaviour, still it is hard to translate the softly described, implicitly derived characteristic of a marketing's customer segments into robust and measurable product requirements [Kett et al. 2014].
Indeed, the user's subjective well-being is a main issue for product design. From a user's perspective, it is not the physics of a product that contributes to happiness. Products are rather resources that address meaningful goals and what we do with products that can make us happy [Desmet and Pohlmeyer 2013]. In this regard, understanding user motivation can be even more essential. If the product idea does not involve user values and motivations, it will not be accepted at all and any redesigned task sequence is not useful either [Kujala 2008]. Recent UCD research therefore understands the interaction of users and products more as a whole micro-cosmos, also including subjective processes [Steinfeld and Smith 2013]. These processes are hard to measure but have great impact on user acceptance.
On the contrary, product design still demands for a strict requirements definition to ensure the value proposition and reliability of processes. Besides many other more or less mathematical approaches such as the Usage Coverage Model [Yannou 2013] or the Perceived Quality studies by Stylidis et al. [2015], Kansei Engineering (KE) is a good example how to quantify soft factors and especially subjective user experience in product design. By analysing varying product attributes and their impact on users' impressions, it is tried to translate and to make them usable for design consideration [Nagamachi 2002], [Guo et al. 2014]. The relationship between human beings and their immediate environment can thus be examined in a systematic way [Lévy 2013]. We also know instruments other disciplines such as marketing strategy (see chapter 4.1). But still there is no discrete integration into product development processes. The more, there is not synthesis of the findings in emotional investigations so far. Even if a correlation between the product's shape to the emotional impression e. g. "comfortable" may be assumable within a study, still it is not the answer to the question, "how comfortable the user wants the product to be". We need to link those results to special users' profiles so that robust design synthesis can be derived. In this paper, we pick up these findings to propose a new approach in emotional user centred design.

3. Universal design and quality of life

As stated in [Kett et al. 2015], UD validations often strongly differ from user's actual perception. This leads to a low acceptance of universally designed products. To unlock the potential of UD and raise its acceptance, we need to foster the initial meaning and look beyond current practice.
Universal design aims for an inclusion of as many persons as possible, however diverse they may be. It ensures the accessibility and operability of products and environments [Story et al. 1998].

But as it can be stated, many approaches include mainly physiological (dis-)abilities. Moreover, they are strongly deficit-oriented.
Indeed, the overall goal of all UD efforts is the raise of quality of life for everybody. After Felce [1995] the quality of life can be divided into five domains (see Figure 1, a). It is defined as a combination of life conditions and personal satisfaction. Starting from physical and material wellbeing, it also includes social and emotional wellbeing as much as development and activity [Felce 1995].

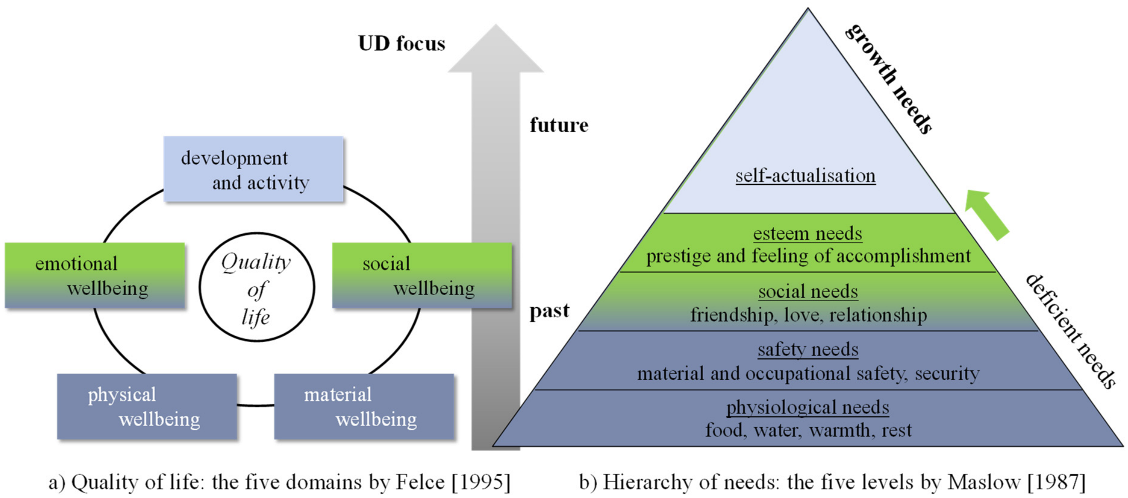

Figure 1. Different models for the quality of life

In the same row, Maslow already identified different stages of quality of life for individuals (see Figure 1, b) in 1987 [Maslow 1987]. There is no doubt that the basic needs, physiological and safety needs such as eating and drinking, security and safety, must be secured firstly. These are the so-called deficient needs or, from a product development point of view, hygienic factors (comparing to Kano's model [Prefi et al. 2014]). Having these ensured, the quality of life is mainly influenced by growth needs. These include psychological (social and esteem), and self-fulfilment needs (self-actualisation).
Concluding, the value of a product does not only comes from its material and the physical accessibility of environments and services associated to this (lower levels of the hierarchy), but also from the intended meaning in social, emotional and self actualisation aspects (higher levels).
With regard to these theories, we have to adjust the understanding of UD in this manner. Whereas past UD methods provide a very important contribution in deficient needs satisfaction, the growth needs mostly remain unattended. Therefore, we also have to follow up these systematics in product development processes to get one step further in maturity.

4. Measuring emotions

We indicated high potential for design inclusion by extending our understanding of the users' product experience. Besides physiological and material needs, we also have to consider non-physiological aspects. One main component in user's product experience is the emotional perception.
To get insight in emotional processes from a product development point of view, we need to translate these into quantifiable, comprehensible factors. Indeed, emotions are highly subjective and implicit. We do not understand so far, how the processes work that lead to certain impressions from a biomedical point of view. But we know some about human physiology and sensory perception. Moreover, we know the product properties, e.g. lengths or materials of a product. These lead to specific product characteristics (e.g. proportions) that are then again the basis for the user's perception. So we might be able to implicitly steer the product properties and implicitly follow up the changes and effects on physiological (sensory perception) and emotional impressions.

4.1 The relevance of user's emotions in buying decisions - the case of marketing strategy

It is nothing new that psychological factors mainly influence buyer's or user's decisions [Kotler et al. 2014]. In other disciplines of industrial environments, the process architecture is already adapted to user's non-physiological needs.

Besides the large field of software development, marketing research and practice already understand the relevance of emotional perception. There, methods and tools to better characterise and segment target groups have been developed. Portfolio techniques, for instance, help to better understand the target markets and the different needs of users. Especially non-physiological, mainly implicit characteristics such as motives, self-image, norms and values can thus be gathered and visualized.

To link the potential of marketing strategy and information acquisition, we focus on alternative market segmentation strategies. Traditional market segmentation is mainly based on e.g. demographic or geographical characteristics. The milieus methodology as a contrary example takes alternative resources and user specifications into account [Koppelmann 1995]. In Figure 2, a market description based on both the social situation and the basic orientation of consumers was conducted. The segmentation methodology then shows different outcomes that often lead to a more holistic and more precise acquisition of users' requirements [Sinus 2012].

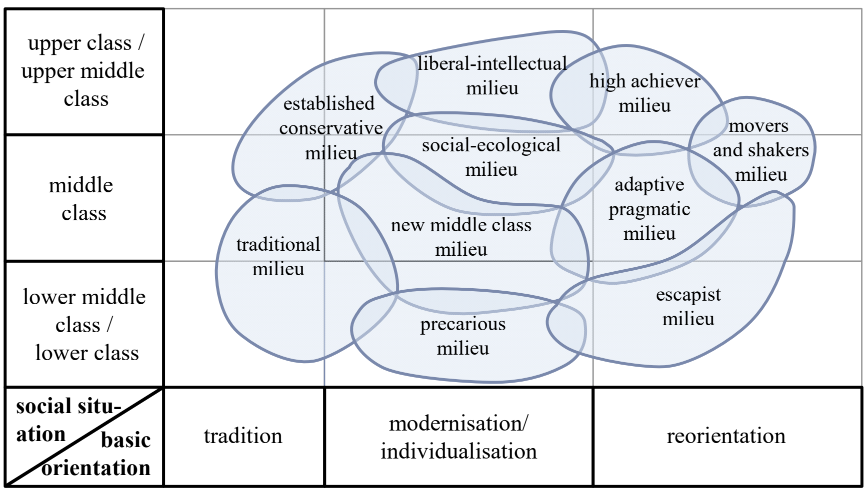

Figure 2. Target group model "Sinus Milieu" - based on socio-cultural studies [Sinus 2012]

One difficulty within these methodologies is the soft description of the segmentation groups. To get measurable and reasonable guidance for and from these methods, marketing needs a quantitative data basis. Extracted from customer surveys, specific user profiles are created to characterize certain target groups and segmentation criteria. These data sets are called impressions differentials [Frey 1993].

4.2 Linking marketing and product development

Like in marketing strategy, product development needs justifiable, quantitative data to work with. As emotional impressions are highly implicit and subjective in nature, we need ways to translate these into workable values. With the aforementioned profiles, the impressions differentials, we already have good potential to start with.

So far, there is no direct adaptation of these profiles into product development processes. Once the profiles are translated into product requirements, they are no longer used. But to keep focus on user's soft requirements, these findings can be captured and used as measuring instruments for product design decisions.

We therefore adapt basic elements of this methodological process for emotional investigation. To keep to the profile strategy, it can be either used for requirements investigation on product variations (as shown in this paper) or for a later user segmentation check vice versa. Hence, a translation scheme needs to be qualified.

In the following, we present an approach how to use these user profiles for a valuable, ongoing integration into product development processes. There, profiles consisting on opposite impression pairs are used to link emotional impressions to specific product properties.

5. ACADE - Application for Computer Aided Design of Emotional impressions

So far, a stronger focus on user's emotional affection was impressively highlighted. Based on current findings in physical UD, we look for a way how to assess and consider both physiological and even more emotional factors. The aim to raise the measurability and the understanding of emotional aspects in UD leads to the creation of ACADE - an Application for Computer Aided Design for Emotional impressions.
Using this, the product developer will be able to work without any deeper interdisciplinary knowledge as the programme gives valuable guidance how to integrate considerations of the user's emotional impressions of a product. To ensure the usability of the system itself, we use common tools such as CAD software to ensure to ease of use for the product developer himself. Moreover, we already highlighted the importance of traceability down to the specific product properties. These are mainly set in CAD environments. In the following, we present the architecture and main structures of ACADE. It refers to methodological approaches from KE and marketing and breaks down implicit, hardly assessable user impressions to quantitative, measurable product properties.

5.1 General framework of ACADE

The basic question ACADE starts from is the gap between a product's and a user's perspective, the hidden structure (see Figure 3). We further divide these two systems into two domains each: products have characteristics (characteristics set, e. g. lengths or radii) that lead to unique product properties (properties set, e. g. volumes or roundness), and users get their perception using their sensory systems (e. g. to assess volume level, light intensity) to generate emotions (e. g. comfort, aesthetics). Within this framework, two classes of parameters can be identified: On one hand, human sensory perception parameters and the product characteristics parameters can be objectively assessed and are therefore tangible and quantifiable (first class). On the other hand, human emotional parameters and product properties consist on strongly implicit or subjective values as they are both intangible and dependent from the other domains (second class). Emotional parameters can only occur based on the perception parameters of sensory systems. Simultaneously, product properties are created by the specific combination of characteristics [Weber 2005].

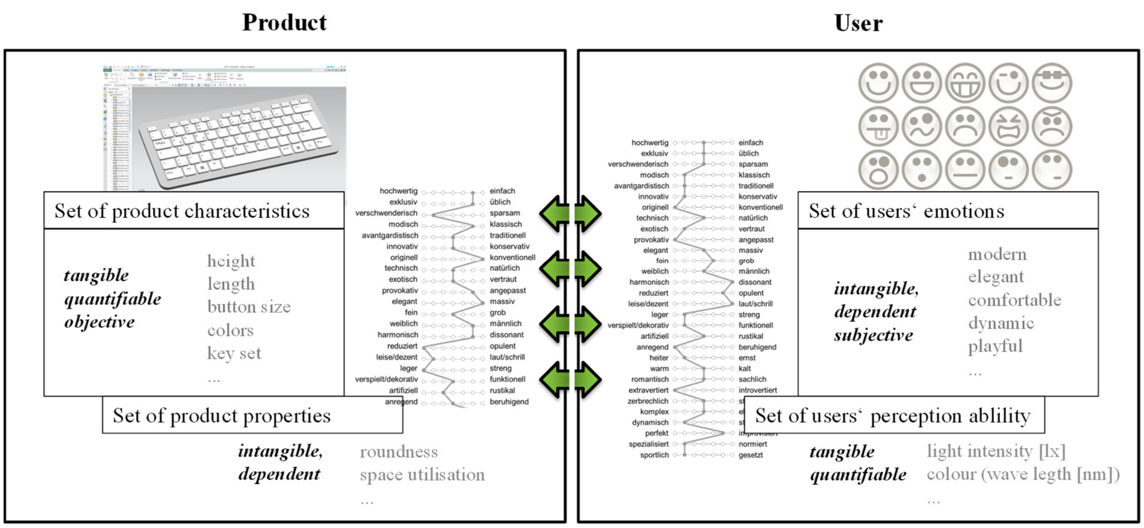

Figure 3. Schematic framework of the ACADE architecture - a systematic match-making between products' properties and users' emotional profiles

The links between the four domains enable an understanding of the hidden structure to unveil. Aiming for this, we analyse the emotional profiles referring to specific product characteristics, considering other influences. We use standardised tools and processes to ensure consistency. The following chapters offer a deeper insight into this architecture and its respective processes giving a vivid example.

5.2 Asking questions and getting answers with ACADE

User's emotional impressions may be affected in multivariate ways - it is not that easy to sort out whether it is only the surface or the geometry that makes a product look luxurious, expensive or modern. In some cases, we may already have a certain assumption, but we cannot substantiate it in a quantitative manner. One aspect - which we explicitly exclude - is the cause of impressions from a medical or psychological point of view. For instance, the impression of a product may be influenced by similarities to commonly known companies' branding or personal reminiscences. Within this work, we only focus on the actual appearance of impressions and its dependencies to product design, eliminating individual influences if possible. Moreover, to examine emotional changes in users' product perception firstly, we consciously reduce product perception to visual impressions.
In the following, we present a case study to illustrate a certain part of the ACADE procedure. The case study consists of a variation of keyboards and the measurement of its changes in their appeal to users. By reducing both the changes on visual product properties and the set of examined emotional impressions, interdependencies can be thoroughly assessed using statistical analysis.

5.2.1 Product variation

It is obligatory to ensure the availability and quantifiability of product characteristics. Based on the product developer's expert knowledge and experience, e. g. colours or relevant geometry elements may be selected out of a given ACADE database. The product characteristics parametrises need to be consciously reduced to the most significant ones. A parametric CAD file then defines the type and quantity of each characteristic change and translates the profile of each product variation into a visual representation. In Figure 4, an extraction of a product characteristics variation table is shown, which leads to the CAD visualisations. The so quantified product characteristics can subsequently be aggregated to product properties such as roundness (consisting of radii, proportions between lengths and heights, etc.).

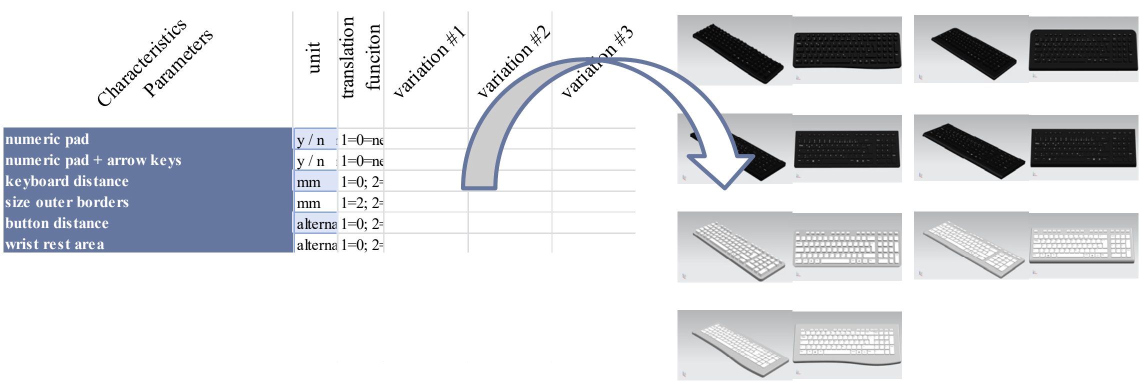

Figure 4. Parameters set for design variation on keyboards and their translation into specific representatives in CAD

5.2.2 Capturing emotional impressions

As aforementioned, marketing methodology already offers great potential for the consideration of soft and subjective factors in user's product perception and to then use them for user segmentation (see section 4). So we now take up the profiling method to capture and link the products' attributes to general users' impressions. These impressions have already proven to be relevant for the marketing strategy and influence product use. Moreover, they have to be generally understandable.

ACADE provides standardized questionnaires using impressions profiles. These profiles consist of a bundle of opposite impression pairs, e. g. functional/playful, natural/synthetic, modern/classical (see Figure 5). To manage the amount and complexity of data, a reduction of the questioned profiles to relevant impression pairs is suggested. This can be done by the product developer or the marketing expert who is able to evaluate the relevance of each impression for the project.
To gather data through the questionnaire, selected test persons are asked to fill in their profiles referring to each of the product variation generated in 5.2.1. These persons have to be either out of the focused target group or of high heterogeneity (in case of UD).

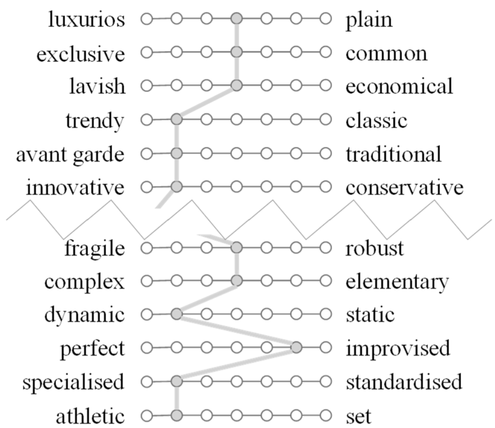

Figure 5. Set of a filled user impressions' profile based on impressions differentials (cf. [Frey 1993])

5.2.3 Knowledge production

The main challenge in emotional design is the multi-objectivity optimisation problem. A certain impression does not only depend on one single characteristic, but it is influenced by the whole shape of a product (properties set). Moreover, the profile of a user who experiences the product is multifaceted. Within ACADE, mathematical analysis unveils the inner structure between certain product characteristics and their effect on user impression, managing its high complexity. Therefore, the aforesaid systematically aggregated data of both product and user variations is linked to each other considering empirical observation. Using the keyboard example, we now link the parametric characteristics profiles of the CAD files to their respective user impressions profiles (Figure 3).
From the product properties variation, we get a set of (n) different keyboards. Each of it is assigned to its specific profile, the properties vector (P). Depending on the amount of properties to be examined, the vector has (a) dimensions. So the variations matrix for the product (MP) can be noted as in the following:

$$MP = \begin{pmatrix} P_1 \\ P_2 \\ \dots \\ P_n \end{pmatrix} = \begin{pmatrix} p_{11} & \dots & p_{n1} \\ p_{12} & & p_{n2} \\ \vdots & \ddots & \vdots \\ p_{1a} & \cdots & p_{na} \end{pmatrix} \tag{1}$$

From the specific user impressions, we get a set of (k)=(n)×(t) different profiles referring to each of the keyboard variations. (t) is the number of participants of the survey. Each of it is again assigned to its specific profile, the emotions vector (E). Depending on the amount of emotions to be examined, the vector has (m) dimensions. For each keyboard variation, we get a set of (t) emotional profiles, so the variations matrix for the emotions (ME) can be noted as in the following:

$$ME_k = \begin{pmatrix} E_{k1} \\ E_{k2} \\ \dots \\ E_{km} \end{pmatrix} = \begin{pmatrix} e_{k11} & \dots & e_{k1t} \\ e_{k12} & & e_{k2t} \\ \vdots & \ddots & \vdots \\ e_{k1t} & \cdots & e_{kmt} \end{pmatrix} \qquad with\ k \in [1; n] \tag{2}$$

The characteristics-emotional profiles matrix for each keyboard (MK_r) can hence be written as:

$$MK_r = \begin{pmatrix} \mathrm{P_{r1}\ E_{k1}} \\ \mathrm{P_{r2}\ E_{k1}} \\ \dots \\ \mathrm{P_{ra}\ E_{km}} \end{pmatrix} \quad with\ r \in [1; \mathrm{n}] \tag{3}$$

Within this matrix, we look for significance in the stability or, in other words, low standard variation of the rows' entries. This stability indicates an emotional user impression that is widely independent from the test persons. In the next step, structural dependencies between emotional impressions and the variation of every single property is examined. This leads to functional specifications. Figure 6 shows data of a pilot study where the users' impressions "comfort" and "aesthetic" are depending on the product characteristic "roundness (amount/proportion of curves)". The comparison and examination of product properties changes and its effects on emotional impressions lead to fuzzy data sets that can also be examined multidimensionally.

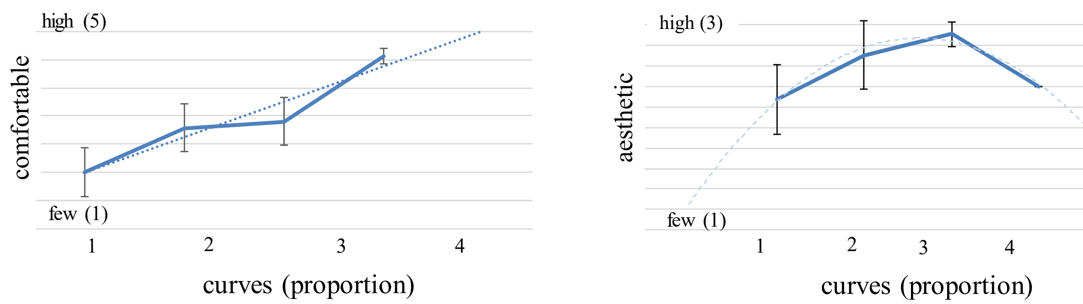

Figure 6. Extracted functional relationship between certain parameters in a pilot study with n=20, t=20

If we have a certain target user segment profile ($\mathrm{E_{target}}$) as given from marketing (see section 4.2), and we ask for the referring optimal product properties set ($\mathrm{P_{target}}$), the mathematical optimisation problem can now be defined as in the following:

$$\mathrm{P_{target}} = \begin{pmatrix} \mathrm{P_{target\,1}} \\ \mathrm{P_{target\,2}} \\ \dots \\ \mathrm{P_{target\,a}} \end{pmatrix} = \left\{ \mathrm{f(MK_r)} \,\middle|\, \mathrm{E_t} \rightarrow \mathrm{E_{target}} \right\} \quad with\ \mathrm{E_{target}} = \begin{pmatrix} \mathrm{E_{1,target}} \\ \mathrm{E_{2,target}} \\ \dots \\ \mathrm{E_{t,\,target}} \end{pmatrix}; \quad \mathrm{r} \in (1; \mathrm{n}) \tag{4}$$

This leads to a pareto optimum of emotional impressions, set by specific product characteristics. Figure 7 shows an extract, examining the aforementioned examples, the user impressions "comfortable" and "aesthetic" depending from the product characteristic "roundness". There the optimisation problem is illustrated as a distance minimization task based on empirical data.

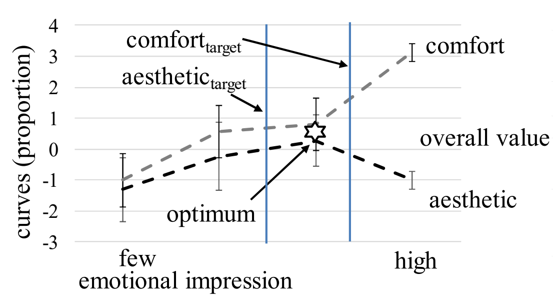

Figure 7. Graphical illustration of the pareto optimisation problem in ACADE (pilot study)

6. Conclusion and outlook

Technology companies facing high competitive markets need to strengthen their focus on users. It is no more sufficient to just take physical variation in target user groups into consideration. The integration of emotional aspects is getting more and more important for future product design as emotional perception is rather decisive in user's acceptance.

UD in its elementary sense intents to raise the quality of life for as many people as possible. So we illustrated that UD methodology needs an extension to emotional aspects. This domain has shown to be highly subjective and hard to assess. To reduce the complexity, and to manage the interdependencies of the addressed topic, ACADE was introduced. This system offers a systematic treatment to examine highly complex and implicit processes in user's product perception. It helps to unveil hidden structures and gives useful guidance to derive concrete design advice.

ACADE is not yet matured. For instance, we have to enhance mathematical analysis for problem and results visualisation (like e.g. in [Bauer 2009]). Furthermore, we need to extend our approach to other perceptions than just visual aspects, although vision is proven to be the main human sense [Dörner 2013]. Moreover, the treated impressions are not weighted to each other. So they are all in the same importance whereas in reality they might differ in their significance in perception. Another point comes along in the same direction. We do not assess so far whether and how much the variations of the individual particularities in the user's sensory systems influence the product perception. Therefore, a return system needs to be established to fully link both the knowledge about physical inclusion and emotional affection (stigmatisation). Finally, a robust validation and verification is still outstanding. It has to be assessed in what way the insights into one particular product variation study can be adapted to related product types.

Although the development of ACADE is just at the beginning, it already shows high potential. From a procedural point of view, it offers great value due to the usability of the tool itself. It is shown that many tools in UD fail due to their lack of usability for product developers themselves [Goodman 2006]. In addition, mathematical methods are used to further assess the significance and comprehensibility of the extracted knowledge. Apart from this, the (interim) results and the inner structure can be visualised to manage the complexity and the objectification process..

From a scientifical point of view, the extraction, quantification and treatment of subjective data is possible using ACADE. The emotional impression of a product depends on a whole bundle of sensory perception. Sensory systems can only identify the properties of a product, so the linkage between the actual product characteristics and the users' impressions is highly implicit and otherwise hard to gather. Moreover, many UD approaches only imply a retroperspective product evaluation [Kett and Wartzack 2015]. With the knowledge of structure derived by ACADE, the decision making process in the product development can be supported much earlier and eventually adapted to other projects.

Concluding, integrating emotional aspects into product design considerations will become quite important during the whole development process and methodologies like ACADE will be of high value for future decision making within.

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