Jens Krzywinski · Mario Linke · Christian Wölfel (Hrsg.)

ENTWERFEN ENTWICKELN **ERLEBEN** 2016

Beiträge zum Industrial Design

TUD*press* | TECHNISCHES DESIGN | 10

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Considering emotional impressions in product design: Taking on the challenges ahead

Susan Gretchen Kett · Sandro Wartzack

1. Motivation

We state a growing importance in of implicit factors in user's decision making. The products they choose to use are no longer sufficient only addressing the basic functional requirements. Due to higher living standards, the users now ask for more than just the consideration of accessibility terms.

> *"[…] People have gradually enhanced their survival mentality from the materialistic fulfilment into the emotional one. This phenomenon has transcended producers' role in the market. They do not only manufacture products and provide goods, but they should also create a kind of product that can create atmosphere and stories, so that consumers can experience deeper satisfaction and emotions in their purchase behaviour." (Huang & Guan 2014)*

There is a stronger focus on emotional aspects affecting users' product selection as ever before. Physiological UCD, however, already is a challenging task itself, regarding all parties and factors influencing its decision making process, so the concentration on other, more subjective factors still remain widely unconsidered. Recent User Centred Design (UCD) approaches already take up this fact, but still this is at the very beginning regarding UCD implementation (Law et al. 2010).

As on addressing emotional aspects in particular, the big challenge lies in the management of their low grade of concretisation and intense complexity. From other disciplines such as marketing strategy, psychology or sociology, we know instruments that help to describe this fuzzy theme. But still,

its discrete integration into product development processes and high complexity remains as one main issue.

In this paper, the challenges in design for emotions in the context of UCD are firstly examined to understand possible starting points. We give potential reasons for the insufficiency of current approaches by investigating specific challenges. Based on the findings on the present knowledge, an approach called ACADE – Application for Computer Aided Design of Emotional impressions – is illustrated. To get an overview of the different elements in its architecture, they are presented in the following. Giving a firm example, they are then linked to each other, illustrating the scientific potential of ACADE for future research in emotional.

2. State of the Art

User Centred Design is an important element in product development processes. UCD poses the user into the centre of efforts, giving systematic guidance. It 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)

Within the last decades, there has been a lot of good work taking physical considerations into account. The Inclusive Design Toolkit (Clarkson et al. 2013), the SENSI Catalogue (Biermann & Weißmantel 1997) or the DIN EN 894 (DIN 894) are only a few examples here.

Whereas many solutions for physical inclusion are provided (e.g. (Clarkson et al. 2013), (Waller et al. 2015)), still we have only few knowledge how to consider psychological inclusion.

Indeed, subjective well-being is a main issue for product design (Hassenzahl et al. 2013). From a user's perspective, it is not the physics of a product that contributes to users' happiness. Products are rather resources that address meaningful goals and what we do with products that can make us happy. (Desmet & Pohlmeyer 2013) In this regard, understanding user motivation is even more essential. It can be argued that if the product idea does not involve user values and motivations, it is not acceptable at all and the 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 & Smith 2013) like emotional relationships to the product. These processes are hard to measure but have great impact on user acceptance. In other disciplines as in market research, there are already models based on psy-

chological findings that try to overcome this issue. Some authors already refer to these (cf. (Yanagisawa 2010), (Barnes 2008)).

On the contrary, product design still demands for a strict requirements definition to ensure the value proposition and reliability of processes. Therefore, processible approaches must be provided to sufficiently support the product developer's work. The Usage Coverage Model, for instance, provides considerable support to evaluate product ranges from a usage scenario point of view (Yannou 2013). Another good example for implicit requirements' quantification is Kansei Engineering (KE). This method quantifies soft factors and especially subjective user experience ("kansei") in product design context. It examines the effects of product shape on test person's individual impression and preferences. By analysing varying product attributes and their impact on users' impressions, it is tried to translate them and to make them usable for design considerations (Guo et al. 2014), (Nagamachi 2002). The relationship between human beings and their immediate environment can thus be described in a systematic way (Lévy 2013). Nevertheless, these approaches may often seem rather arbitrary in choosing their parameters set and their results interpretation. Moreover, they tend to neglect the designer's talent of good decision making. In this paper, we pick up these findings to propose a new way in emotional user centred design.

3. Addressed Problems considering emotional factors

There is evidence that we need to focus on users' emotions in the design of technical products. Giving answer to the question why there is no adequate tool for their consideration so far, we take a closer look to its specific challenges. Therefore we summarize some of the challenges that exist both in UCD itself and its relevant enhancement for emotional inclusion. We extracted these findings during our studies examining several relevant surveys and research literature.

3.1 Usability of UCD approaches

Several studies examined the bias of user-centred design potential and its real application in the processes. For instance, Law et al. (2010) have revealed usability problems with universal design resources. They claim that evidence of a UCD approach was hardly found. There are only few concrete instructions how to introduce UCD as holistic, applicable methodology. Many product developers state that there is a lack of usability in current methods and tools (Goodman et al. 2006). Hence, our purpose is to ensure that the application still provides good, reliable output quality even though

the user of a UCD tool might change. In other words, it has to be designed in a universal manner itself.

3.2 Subjectivity of data

User centred design approaches have to deal with a high level of subjectivity. Emotions in particular are individual impressions and therefore extremely vague. The need for scalability of qualitative information, however, is very important in product development processes (Clarkson & Coleman 2015).

Due to the users' heterogeneity, it is even harder to aggregate and examine emotional effects systematically. We explicitly do not question the high ability of product designers in their creative work, but it is almost impossible to really put oneself in somebody else's position. E. g. a middle aged designer may never really feel an elderly's relation to a walking aid. On the other hand, users do not have professional skills to define their implicit requirements, so the task of analysing user needs and translating them to user requirements is left to the developers. However, analysing and structuring user needs in product development contexts has been shown to be difficult. (Kujala 2008) So there has to be a strict procedural pathway that leads to objective, measurable and processible data.

3.3 Interdisciplinary nature and complexity

User centred design does not address only one research field. The topic is affected by several other disciplines such as psychology, behavioural and brain research, general medicine, sociology etc. that extremely enlarge its complexity. As emotions themselves are highly complex in structure, cause and expression, the components, parameters and restrictions need to be managed all in the same row. We have only little knowledge of their influencing factors and there is a high complexity in relevant data. However, understanding users' needs and values and translating them into design language is only the first step in user involvement. (Kujala 2008) It must be ensured that a smart and reliant information flow throughout the development processes is guaranteed.

3.4 Applicability and support throughout the whole development process

User involvement is most efficient and influential in the early stages of the development process, whereas the concretisation level in these stages is very low. Thus the process of early user involvement needs to be simple enough to be practical in product development. (Kujala 2008) On the other hand, there is a need for tools that support the developer's work in every stage of the process and allows reviews with regard to achieving the envi-

sioned objectives. After all, user-centred development is iterative in nature. So the continuous applicability of the tool in the ongoing design process is obligatory.

4. ACADE – Application for Computer Aided Design of Emotional impressions

In the following, we present a concept software tool named ACADE - Application for Computer Aided Design. As briefly introduced, there is a lack of usability in present UCD tools themselves in a time and money constraint, measurability and understanding of the applicability (see also (Goodman et al. 2006)). Furthermore, a stronger focus on user's emotional affection is highlighted, whereby we build on current findings in physical UCD (Kett et al. 2015). So we aim for a way how to assess both physiological and even more emotional factors in the context of UCD. To accurately meet the derived challenges, we identified and defined the user-product-system as given in the following. It is developed to lead to a systematic integration of subjective factors whilst considering the aforementioned issues. Applying ACADE for the product developer's purpose, he will be able to work without any deeper interdisciplinary knowledge whilst deriving more valuable output.

Therefore, we firstly introduce the general framework of ACADE introducing several specific terms. These terms will be carefully explained in the following chapters. Finally, an application scenario illustrates the work flow.

4.1 General framework of ACADE

The main view ACADE starts from is the gap between a product's and a user's perspective, the hidden structure. These two systems basically consist on two classes of parameters, resulting in four domains (see figure 1): products have characteristics that lead to unique product properties; users perceive products using their sensory systems and then generate emotions. Starting from the product, its properties mainly depend on characteristics (1). Human sensory systems get perception of the product properties (2). Finally, human emotions can only occur based on the perception of sensory systems (3).

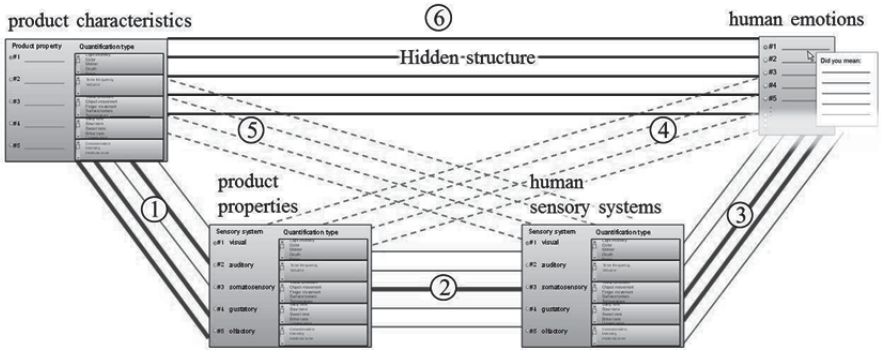

Figure 1. Schematic framework of the ACADE architecture

Within this scheme, the complexity becomes evident. Picking up the aforementioned classes of parameters within these systems, we distinguish two different component types. One parameter class is tangible and quantifiable. Product characteristics as well as human sensory systems belong to it as they are objectively assessable. The other class, consisting of product properties and human emotions, is harder to assess as it is intangible and dependent from the first class. Further, human emotions in particular are highly subjective values that complicate their aggregation.

To unveil the hidden structure we need to get the link between product characteristics and human emotions (6) which is only implicit and hard to capture. Aiming for this, we investigate the emotional profiles referring to specific product properties (4), considering other influences (5). The following chapters create a deeper insight into this architecture and its respective connections.

4.2 The input sets

Before we discuss the necessary links and the interaction design within the ACADE architecture, each of the domains and its respective information set is firmly presented. The information aggregation can either base on specific product or user information or public resources, depending on the specific use case.

Product characteristics

Due to Weber (2005), a product consists of product characteristics and product properties. Product characteristics can be directly assessed by the product developer and widely consist of metric scalable values. The product properties, however, are indirect parameters as they cannot be assessed

immediately. The shape of a pencil, for instance, consists of several properties, e. g. roundness or volume. But each property consists of a bundle of characteristics such as texture, length, height, radius etc. and can thus be indirectly described. So the product characteristics set is the domain that finally defines the product. The product matures along the process, but even at the beginning, the main features can be roughly described (e.g. in CAD models).

According to this, ACADE provides an interface to easily apply findings in product characteristics expressions. Targeted measurable characteristics variations can be designed and visualised e.g. in CAD using parametric modelling.

Product properties

As in the case of product characteristics definition, we also use Weber (2005) to define a property of a product. Properties of a product are indirect parameters and cannot immediately be set by the product developer. In some cases, they can be described by a composition of metrics or proportions, but in some they are cannot. They result as a sum of product characteristics and can thus not be directly be determined by the product developer. As there are several different product properties that can depend of more or less the same set of characteristics, they are also indirectly dependent from each other. This leads to a high complexity and sensitivity of the properties set. The single dependency of a product property from a certain characteristic is however definable.

There, ACADE supports the designer, providing guidance and sufficient complexity reduction throughout the product description model. With regard to the characteristics variation, ACADE translates the product characteristics to properties referring to mathematical relations that can be introduced easily.

User's sensory system

The human body is a complex system that we are still not able to fully understand from a scientifically point of view. Many disciplines like biomedicine, neuroscience or biochemistry try to unveil the magic of human abilities and therefore, they obtained extremely valuable insights through intense research within the last decades. The five human sensory systems (sight, hearing, taste, smell, touch) were already introduced by Aristoteles in the antiquity (Serres 1998) and further specified by numerous successors later on (Jütte 2005). We now have comprehensive knowledge regarding our sensory systems. This leads to a profound understanding of the human perception and sensory processing. Although there are still huge white

spots on the landscape, we can use the present findings to improve our understanding of the user from a product developer's point of view. Therefore, it is necessary to translate and to simplify the findings of neuroscience and medicine to a level so that this information can be used. Despite this simplification, the parameters to describe the human sensory system must remain of general use so that they still represent the whole capacity and abilities of respective users.

Balters et al. (2015) say that this Information about human sensory systems needs a proper use in product development processes and thus needs to be translated. They therefore suggest to reduce the knowledge of the five human sensory systems to a certain bundle of few, metrically valuable parameters. Examples of these parameters are given in figure 2.

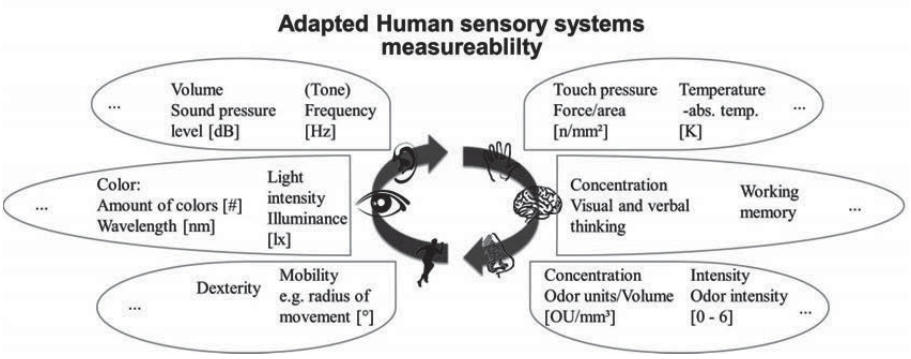

Figure 2. Examples for the sensory system parameter set (based on (Balters et al. 2015), (Clarkson et al. 2013))

In ACADE, we want to use the scheme of the human sensory systems to define the relevant bio-/physiological parameters influencing the user's perception. The product developer is guided through the set to calibrate it, e.g. asking for vision in several sensory ability (light intensity, colour perception etc.) regarding the target group. On the other hand, the product developer can better understand and describe product perception in regard to the cause of users' impressions. This part is not implemented yet.

User's emotions

The user's emotions are the last link of the ACADE system. At the same time, it is one of the most important modules as it enables the introduction of feelings and subjective impressions of the user regarding a product in a certain usage scenario or even before, in the very first sight. In the field of psychology, or even in engineering psychology, the focus lies on the causes

and the history of origin of impressions. In addition, they look at deeper structures in human perception processing, decision making and social behaviour (e.g. (Ekman 2004)). There, emotions or feelings can be systematized in multiple ways, e.g. in positive and negative expressions. (Desmet 2012) (Perez Mata & Ahmed-Kristensen 2015)

For our purpose, we look at the taxonomy from a product utilization point of view. As the knowledge of emotions, its causes and impacts is the focus of different sciences, ways and means have to be defined to break down these findings both in a correct and manageable way. So the basic quantity of emotions needs to be fully included and assessable (Desmet 2012). It is essential to ensure the universal and unique comprehensibility and to be able to measure the degree of each emotion. Furthermore, any random test person must be able to assess and to quantify it by a clear and easy question. On the contrary, the set of emotions has to be of great use in the industrial environment of technology companies.

Due to their highly generic character, we use profiles of adapted impression differentials (Frey 1993). This method suggests a set of opposite impression pairings that specify a consumer segment (e.g. modern/traditional, playful/functional or comfortable/athletic). The system user can thus derive evaluation criterions for targeted groups. It is common in the industrial environment regarding marketing strategy. Therefore, a procedure to automatically design, generate and evaluate impression surveys is implemented in ACADE. The users' impressions given by product variations can thus be easily gathered in test environments and reliably entered to the system.

4.3 Working with ACADE

ACADE offers several functionalities to support product developers to include emotional aspects into their design considerations on a systematic basis. As the topic is highly complex both in its inner and outer structure (see chapter 2), the focus was set on a high level of usability for the designer. This intent is on the ease of use of the application front-end itself, on the extraction and retrieval of information and the analysis and visualization of the output. On the contrary, it remains on being of observing nature so it does not replace the designer’s talent for good decision making. In the following we describe the general process how to work with ACADE to improve emotional understanding in interdisciplinary product development environments.

We use an accompanying example to illustrate the ACADE general workflow. Nowadays, there is a huge variety of keyboards models in the market of PC accessories. So the initial task was to gain insight into user's implicit

emotional requirements regarding specific keyboards' properties. Therefore several impressions such as comfort or aesthetics based on visual perception were assessed.

Information aggregation & preparation

To examine the impact of product characteristics changes on users' emotions, several product variants have to be prepared. Within ACADE, an interface to a CAD programme is created to visualise these different product variants using parametric models. Furthermore, a modular system to create and to run the specific emotional surveys is proposed (see 4.2). In this way, the product developer can easily assess and combine the certain aspects he is interested in. Due to its structure, automatic links facilitate both the creation and the analysis of the specific application in the following. Next, a guide leads the user through the system building, linking the components of different domains to each other. The high complexity of the system is thus manageable.

In the application scenario, 20 types of keyboards were emotionally valued by 12 test persons. This composition shows sufficient sample size and to keep complexity low for a first assessment (cf. (Huang & Guan 2014)). The persons had no relevant previous experience and were only briefly introduced into the field. The more, the pictures used within the test had no brandings as they were designed using CAD software. So it was ensured that prejudices were widely minimized and the emotions of the test persons were spontaneous. We asked the test persons for several impression pairings, regarding the specific product variations. In this case, an ordinal scale ("few" to "high") was chosen for the test persons to improve interpretability whilst enabling mathematical translatability using nominal scaling (1 to 10) for analysis.

To better illustrate the use case, we now reduce it to the product properties parameter "roundness". This was previously defined as the function "curves (proportion) = the amount and size of radii in the design in comparison of lengths and widths" (several characteristics, standardized to values from 0 to 5). As it is initially computed via mathematical ratio, it is also possible to transfer it into hard product characteristics values (as used in CAD programmes).

Figure 3 illustrates the so designed problem field, examining match-making and structural regularities within the data sets of products properties variation and their impression profiles from the survey.

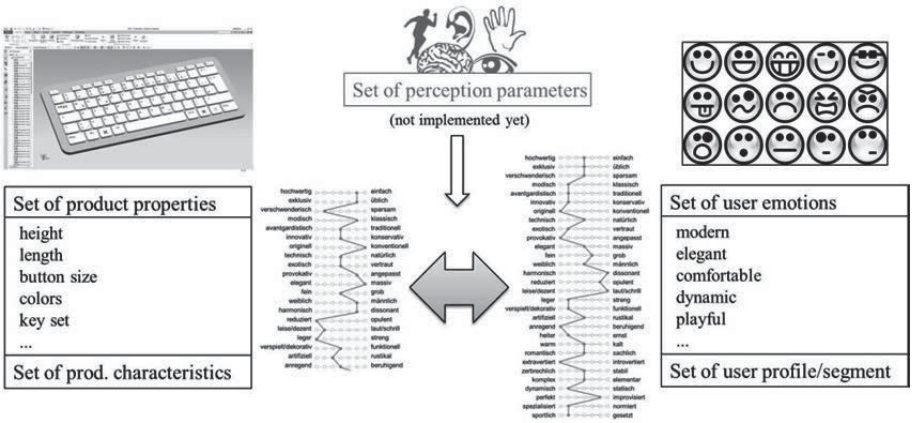

Figure 3. Schematic operation process for calculations in ACADE, example for keyboards

Problem analysis

In figure 4, typical interim results of ACADE are illustrated. Two emotional impressions, "comfortable" and "aesthetic", are given. Regarding the first graph, it may appear to be the best to realize as much rounding as possible to maximize a comfortable appearing of the product. But if we also consider the second graph, aesthetics, there is initially an unambiguous result.

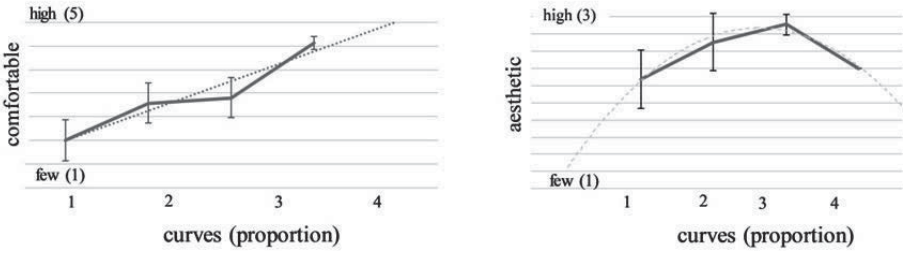

Figure 4. Dependencies between user's emotions and product properties and their trend curves (survey: keyboards n = 20; participants p = 12)

Due to the equality of scales, we can now combine the two graphs, leading to a pareto optimisation problem (figure 5). We assume equilibrium between the emotions "comfortable" and "aesthetic" (a). These assumptions might suit, considering that we have no further information of our focus group. But with additional knowledge about their preferences, there is a different outcome. If we consider comfort being twice as relevant as aesthetics, there remains the same design recommendation (b). But let us say there is

a focus group attaches great value on aesthetics instead of comfort, we may have to set different product properties due to different expectations (weights) (c).

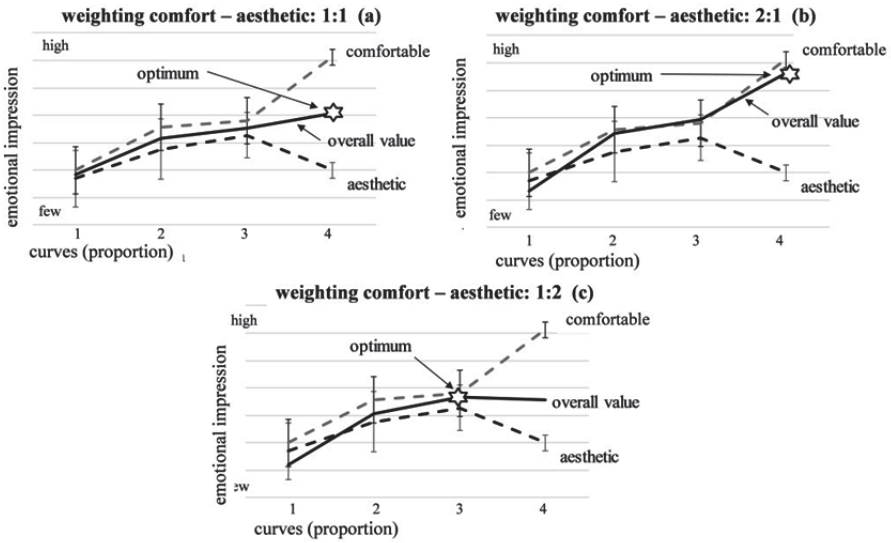

Figure 5. Calculation of design optima based on emotional profiles and the target group's preferences

Due to this quantification and visualisation of dependencies between the different parameters, the product developer is able to calibrate his product to the extend he wishes, whilst ensuring all interdependencies, special function courses and restrictions. The aforementioned link between product properties and characteristics, e.g. "roundness" and "radii", allows concrete suggestions for the product shape or appearance, supports discussions and design decisions. Moreover, considering sensory perceptibility, special focus group can be checked due to the clustering method (see chapter 4.2, Frey 1993). Rather than just pre-defining a focus group based on e.g. anthropometric data, the definition of focus groups can also be computed by similar product characteristics - user's emotions profiles, offering an ex-ante point of view.

4.4 Graphic user interface & visualisation

Great interest was set on the usability of ACADE for the product developer himself. So the tool presents a core unit, a CAD plug in and a survey de-

signer. After starting the programme, the product developer will get guidance throughout the process. In figure 6, an interface of ACADE is illustrated, showing the interaction between visual problem analysis (background) and product properties variation (foreground). The links between different domains can thus be examined and sensitivity analysis on user emotions can be processed. The more, functional dependencies between emotions and product properties can be assessed.

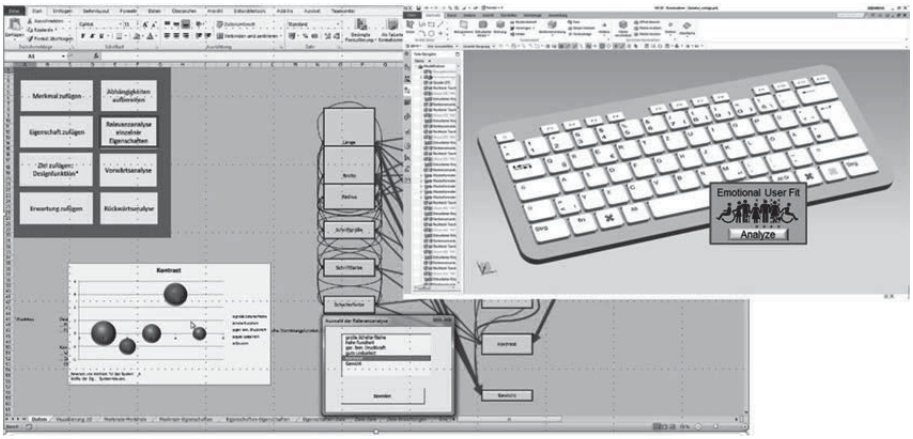

Figure 6. Prototype of the ACADE interface - an example of interaction analysis

5 Conclusion and Outlook

There are many reasons to focus on user's emotional perception of technical products in UCD environments. Although a lot of good approaches to include physiological heterogeneity do exist in product design considerations, the psychological view still needs more attention.

Often, it is hard to make decisions only based on implicit information. Even though the designer can make good decisions based on his own well trained emotional perception ability, he might not be able to do so for whole target groups. Moreover, the communication between different parties in the interdisciplinary field needs improvement. In the field of UCD, it is obligatory both to manage the future users' and the developer teams' heterogeneity. So a reliable objectification of subjective information becomes necessary.

ACADE is a tool that systematically processes and links subjective and implicit information to objective, measurable data that can be used as basis for good decision making in product design. Therefore, a set of systematic design variations of a product is created to observe and quantify subjective

user emotions. Based on these data sets, links and structures are unveiled using mathematical analysis. The programme's architecture was therefore divided in four domains: product properties (measurable and adjustable), product characteristics (implicit and dependent), user's sensory system (measurable and quantifiable) and user's emotional impressions (implicit and subjectively quantifiable). ACADE provides statistical data and mathematical treatment to support the objectification of emotional perception. It is based on standardised information gathering, ensuring constantly high process quality and complexity management. Information can be extracted and retrieved, optimisation problems can be easily visualised as basis for multidisciplinary discussion. The programme further offers a platform for reflection and product design review procedures throughout the whole development process. It does not replace the product designer's essential talent for good design but it supports communication, visualization and emotional understanding in interdisciplinary teams and decision making. Moreover it offers potential for reasonable match making between target users' implicit expectations and their reflection on the product.

The concept of ACADE is not matured yet. On an operational level, we need to prove how to implement and to link emotional classification from a psychological and a marketing strategies' point of view to truly close the communication gap between the different domains. Additionally, only standard statistical methodology (multivariate analysis) was applied. Other mathematical approaches like artificial neural networks or fuzzy logic and robust sensitivity analyses for statistical significance may be implemented thoroughly to assess how the most profitable way of result processing for interdisciplinary issues looks like.

In general, we need more application scenarios for a robust reasoning. In this manner, an adaptation of findings of one product category for another, related one, is still outstanding. The influences of the usage environment and the different motives for using a product, for example, are not assessed yet. This paper already highlights the potential of the approach for UCD research, but some dark fields remain.

In the terms of UCD strategies, where target groups can be either singularly or more holistically examined, ACADE supports the decision making with convenient and transparent data analysis. It extends existing approaches of UCD including emotional aspects. The given example illustrates both the relevance of a careful treatment of user's profiles and requirements and the high value of ACADE to address this challenge. It is only one possible application, how ACADE supports strategic product design decisions. Its application in product development environments can be extremely extended to

support decision making in product development throughout the whole process. It enables the transparency and the traceability of decisions in a highly implicit domain. Barriers in communication caused by the interdisciplinary of decision-makers may be reduced. Moreover, it forces the product developer to look at his product to be designed through the emotional profile of the user. With ACADE, an important step forward to a holistic, interdisciplinary UCD is given.

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