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| D2.1 Measuring User Experience methodologies and insights |

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| Editors: T. Niemirepo (VTT), M. Montejo (Tecnalia)  Contributors: VTT (T. Niemirepo, J. Heinilä, S. Muuraiskangas), Laurea U.(S. Kauppinen), Tecnalia (M. Montejo, E. Leon), Loria (A. Denis), VUB (K.Willaert), FADO (F.Reis), U. Lille (M.Bilasco), CityPassenger (B. Duval) | |
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# Executive summary

User experience is an individual and contextual phenomenon, in which emotions play an important part. An analysis on how the User Experience can be observed, measured and influenced during the actual use of a software intensive product is reported in this document. The focus is especially on the emotional factor of the User Experience.

The starting point of the analysis is the review of terms and concepts related to the field of User Experience to use a common terminology along the Empathic Products project. The term *experience* will be used to refer to a common and everyday experience, to differentiate from the concept *meaningful experience*, understood as a deep and multi-sensorial experience, enabling changes in the user behaviour. The discussion also introduces other concepts in User Experience design.

The connection of the User Experience concepts and the relevant psychological theories of emotions, motivation, and cognition are handled. Despite the difficulties of proposing unique definitions, an operational definition of *Emotions* is proposed and other affective states such as feelings, moods and affects are also reviewed. Physiological studies have provided a theoretical and practical basis to understand how the emotional, motivational, cognitive factors, among others, affect the human behaviour.

The User Experience research framework proposed by Mahlke enables a multi-component approach to emotions in human-technology interaction. This theoretical framework helps to measure emotional reactions and other User Experience components, and relate the results achieved using different tools under a common umbrella. The analysis done reviews the available tools to evaluate and measure User Experience using different approaches: physiological reactions, facial expressions recognition, gaze analysis, voice analysis, key stroke and mouse use and text analysis.

Finally, this study includes some selected examples of tools for measuring User Experience in different application domains: marketing, product design, web, smartphones, learning and digital signage.

# Introduction

We all recognize or at least are aware that emotions play an important role in our personal and professional lives. Emotions are an essential part of social interaction and regulate most of the activities we humans regularly undertake from simple conversations to business deals or house renovations. In recent years new findings about how emotions influence our conduct have motivated a renewed attention from the public, the government, and the industry into the phenomena linked to affective interaction and individual emotions. The consequence of this growing interest has been that emotions have become a crucial element in the regular operations of areas like education, advertising, or product design.

It is noteworthy that as industry progresses towards a technological paradigm in which common objects become increasingly more customized through the relationships they establish with users and customers, the importance of emotions becomes even more important. Emotions are spontaneous expressions of our states of mind and body conveying what we like and thereby mirroring our tastes and customs. Consequently, they represent an alternative source of information that could be used to enhance the interaction of computerized devices and their users.

Products that are empathic rely on this emotional character of humans and aim at improving the subjective elements that make a user and consumer experience remarkable. The assessment of emotions and other affective states such as feelings are intertwined with the evaluation of User Experience (UX) and, in fact, the latter cannot be understood without consideration for the former.

This document is a state of the art report of the main elements that constitute the experience of the user. The main purpose of this deliverable is to set out the concepts that will be used throughout the project. In addition to providing a working definition of experience and user experience Section 3 outlines the mechanisms by which these concepts can become operational and measured. Section 4 explains the reasons why emotions are an important element in the generation of an experience. Section 5 presents concrete methodologies and tools that are currently being utilized to assess UX while Section 6 translates these methodologies into actual application examples. We discuss the conclusions in Section 7.

# User experience in this project

## Defining experience

*“To a great experience one thing is essential: an experiencing nature.”*

(Walter Bagehot, Estimates of Some Englishmen and Scotsmen: 'Shakespeare - the Individual')

Because of the multiple meanings of the word, “experience” cannot be defined unambiguously without a semantic analysis. There are at least three different meanings of the word that can be mentioned. In Scandinavian languages, in Germany and in Finnish the translation of the English word ‘experience’ to ‘erfarenhet’, ‘erfahrung’ and ‘kokemus’ (to be referred as the 1st meaning) is distinguished from ‘upplevelse’, ‘erlebnis’ and ‘elämys’ (the 2nd meaning). To confuse more, the word ‘experience’ can be used in a sense of accumulated aggregation of skills (the 3rd meaning), e.g., working experience gathered during a career [1]. That is why, it is important to ensure that we are using the word in the Empathic Products project uniformly. Furthermore, it should be discussed whether the experiences (and in what kind of experiences) can be designed and whether they are sharable.

Tarssanen et al. [2] are categorizing the 1st type of experience into ‘Primary Experience’, ‘Secondary Experience’ and ‘Emotional Experience’. The primary experience focuses on receiving and processing a certain personal knowledge of experience (of the 1st type). The secondary experience consists of individual experience on the context and objects in the context with their subjective meaning and significance to a person, while the emotional experience is a personal emotional feeling.

According to the review of Tarssanen et al. [2], an experience of the 2nd style can always be seen as an experience of the first type, but not necessarily on the opposite way. Experience in the 1st meaning can lead to the experience of the 2nd type, the 2nd being stronger and more affective for a person. In addition, an experience of the 1st type refers to the past and to something that has happened to a person and known by him or her. At least, the user could have a feeling, expectation or an attitude towards the thing to be experienced based on something that is already known to her/him. This orientation may have been obtained from using other comparable systems or products sometimes in the past. In contrast, an experience of the 2nd type has a nuance of novelty and uniqueness. All experiences (regardless of their type) which people have gained and which they carry with, have an impact on their future, and cumulatively the former experiences either shut down or open up access to future experiences. Every experience lives on in further experiences.

Concerning the 2nd meaning Janhila [3] has stated that “experience is a multisensorial, positive and comprehensive emotional experience that can lead to personal change of a subject person”. The definition emphasizes that an experience (of the 2nd type) is ultimately very subjective, and therefore cannot be produced with absolute certainty. But the settings which are ideal for producing this kind of experiences can be objectively created (for example to lighten other people to experience what we are trying to get them to experience). The essential feature in their definition is the possibility of changes in human behaviour through the experience of the 2nd style. As an example given by Janhila [3] the change may be an introduction of new flavour to the kitchen after an excellent eating experience abroad, or new sporty and healthy lifestyle caused by a pleasant ‘Nordic walking’ experience received during the visit to a college of physical education.

Tarssanen et al. [2] find two categories of this type of experience: ‘Meaningful experience’ and ‘Integral Experience’. In consequence of the former a learning process will take place. In case of the latter, an internal change in subject’s way of thinking or ‘world view’ is changing. The categorization is not absolute or hierarchic but they show parallel - and partly overlapping - relations between the 1st and 2nd translations (in our notation) of the word ‘experience’.

Clearly, the 3rd translation of experience mentioned above is out of the scope of the Empathic Products project. Therefore, we will concentrate on defining the first two translations and on understanding the differences between them.

Because of the challenges related to translation and understanding of the word ‘experience’, it has been suggested to use an established expression of ‘Meaningful Experience’ when referred to strong, multisensorial experience (the 2nd translation in our notation), which is able to take a person into changes of behaviour [2]. By contrast the term ‘Experience’ is used when talking generally about experiencing the life, context and objects in the context with personal significance for subjects (the 1st translation in our notation).

It is easy to concur with the proposal above and suggest, that in the following, we would use the term ‘Meaningful experience’ referring to a deep and multisensory experience, enabling changes to one’s behaviour (in Finnish: “elämys”), and the term ‘Experience’ (in Finnish: “kokemus”) referring to a more common and everyday experience.

## Experience vs. User experience design

To clarify the concepts of ‘Experience design’ and ‘User experience design’, Paluch [4] has stated, that ‘experience design’ uses the interactions of customers with products and services to optimize the overall impressions left by these. On contrary, ‘user experience design’ takes similar approach to specific set of products - computer related ones. User Experience Design covers traditional Human-Computer Interaction (HCI) design and extends it by addressing all aspects of a product or service as perceived by users. Thus the ‘user experience’ refers to the overall impression, feelings and interactions that a person has while operating these systems. In the end this could break down to almost all electronic and mechanical products we own/use since they often rely on computers for their functioning [4]. The user experience research is focusing on the interactions between people and products/services, and the user’s experience resulting from the interaction. Doubtless, the user experience may be of subjective nature, and although it is possible, it does not necessarily lead to deep emotional feelings causing behavioural changes for the user (meaningful experiences). Still, user experience design can be extended to concern all aspects of experiencing the product or service, including physical, sensitive, cognitive, emotional, and aesthetic relations [5].

[Arhippainen and Tähti](http://www.nosolousabilidad.com/articulos/experiencia_del_usuario.htm#Tahti#Tahti) [6] define User Experience as the experience that the user obtains at interacting with a product at some particular conditions. They propose an experience model that classifies different factors into five groups:

* User internal factors.
* Social factors.
* Cultural factors.
* Context of use
* Product aspects.

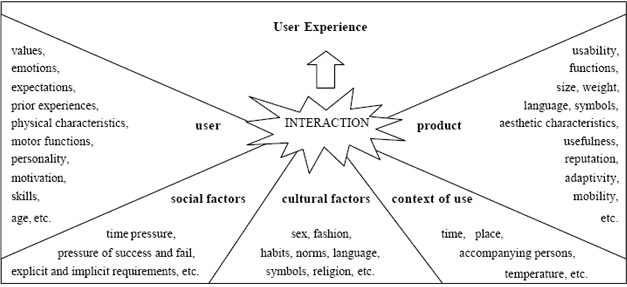


Figure 1. Factors that define User Experience by Arhippainen et Tähti

Krankainen (2002) defines User Experience as the result of an action motivated in a specific context, giving a great importance to the expectative and previous experiences of the user. In fact, she remarks the influence that present experiences can have in future ones.

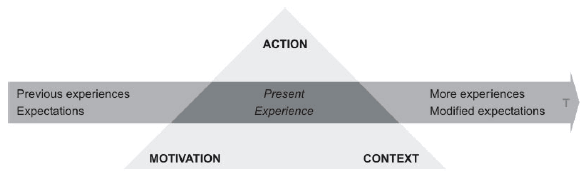


Figure 2. User Experience in the action context by Krankainen(2002).

Knapp Bjerén [7] is more precise and he defines the user experience as a “group of ideas, feelings and feedback” that the user gives as a result of interacting with a product. The experience is a result of the user objectives, cultural variables and interface design.

In the web context DNX (2005) define the good user experience as an objective they want to reach so as to generate positive feelings that make the user be “loyal” to the web site.

[Nielsen & Norman Group](http://www.nosolousabilidad.com/articulos/experiencia_del_usuario.htm#nng#nng) [9] define User Experience as the integration of all the aspects of the interaction between a company, the final users and the products or services. Although this definition may be a little slight, it is very interesting, since it makes an analysis of the interaction not only between the user and the product, but also between the user and the provider.

[Dillon](http://www.nosolousabilidad.com/articulos/experiencia_del_usuario.htm#dillon#dillon) [10] proposes a simple model that defines User Experience as the addition of three levels: action that the user takes, result that obtains and emotion that feels. The difference between this definition and the previous ones is that the author divides the interaction into two levels (action and result) and gives importance to the emotional aspects of the experience.

To summarize: because in the Empathic Products project the user interaction with computers is an essential feature, the expressions ‘user experience’ and ‘user experience design’ are crucial to understanding the nature of the technology the consortium aim to develop. We may agree, that the ‘default thinking’ in the project is user centric even in the cases the word ‘user’ has not been mentioned. Therefore, when using the expressions ‘experience’, ‘meaningful experience’ and ‘experience design’, the word ‘user’ can be thought in conjunction with them: ‘user experience’, ‘meaningful user experience’ and ‘user experience design’, respectively.

## Experience design modelling

Is it possible to design and produce experiences? According to Shedroff [11], “The elements that contribute to superior experiences are knowable and reproducible, which make them designable…What these solutions require first and foremost is an understanding by their developers of what makes a good experience; then to translate these principles, as well as possible, into the desired media without the technology dictating the form of the experience.” - What are the factors of user experience in empathic products?

Producing experiences, creating and getting economic benefit out of it are related to experience design strategies. The growing branch of industry worldwide and nationally is called ‘Experience industry’, which is also called as ‘Creative industries’ or ‘Experience economy’. In Finland, this branch of industry is especially strong in Lapland, where more than 15% of all places of business are related to experience industry and more than 13 % of all personnel are working on the business sector (see, e.g., Lapland Centre of Expertise for the Experience Industry, LCEEI). This is due to the significant status of tourism supported by the research and education in digital media, art and design, entertainment and cultural service production.

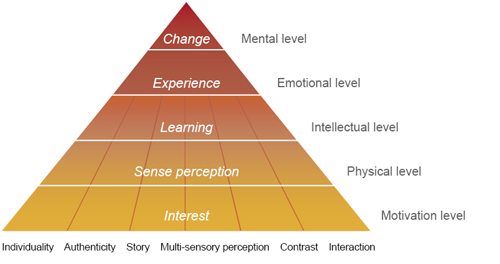


Figure 3. The experience pyramid by Tarssanen (2006).

A model (so called experience pyramid) for designing experience into products and services is based on two kinds of levels: vertical levels of subjective experience and horizontal levels of experience product/service elements [1]. The model helps to separate ‘experience’ and ‘meaningful experience’ from each other, but still binds them together. The authors state that a good experience product includes all elements of the experience at each level of subjective experiencing. Furthermore, if all elements of experience are taken into account at the first three levels, then the possibility to meet ‘meaningful experience’ by a person depends on his social and cultural background, expectations towards the service or product, etc.

Success of sharing one’s experience with others is embedded in the conscious production of experiences or meaningful experiences. Sharing may be a conclusive element in the creation of meaningful experiences which gives additional content and meaning depending on one’s personal experience [12]. ‘Co-experience’ is the user experience, which is created in social interaction driven by social needs of communication and where the participants together contribute to the shared experience [13]. If the capability of design and production of experiences is agreed (although not self-explanatorily), the embedded ability of sharing experiences, as intended in the Empathic Products project, should be treated as a technical problem, too.

Although, it seems to be possible to advance creation of favourable circumstances for certain experiences and hence to design, produce and share experiences, one cannot be sure or guarantee, that the customer’s experience is as intended. At least, a meaningful experience is a very subjective aspect comprising a complex mixture of a person’s earlier experiences, personality, values, behavioural norms, preferences, and expectations - all issues to be treated in vertical levels of the experience pyramid. - None is able to experience meaningful experiences of another person exactly in a same way.

## Elements of UX in the User-Centered Design approach

User-centered design (UCD) is an approach to interactive system development that focuses specifically on making usable systems or applications [14].

The process of user-centered design is composed of a number of key activities:

* understanding and specifying the user requirements,
* understanding and specifying the context of use,
* iteration of design solutions, and
* evaluating the solutions with the users against requirements.

By adopting this approach we end up with products that

* help users achieve their goals,
* make people want to use them and
* satisfy the users preventing them from making errors.

At least, the following elements (1-7 below) are commonly included in user experience definition in the UCD approach:

1. **Usability:** Usability can be defined as the measure of the quality of a user’s experience when interacting with a product or service. The concept of usability is defined by  ISO 9241-11: Extent to which a system, product or service can be used by specified users to achieve specified goals with effectiveness, efficiency and satisfaction in a specified context of use (ISO 9241/11, 1998). These usability measures can be used as indicators, how quality of use can be achieved by using the system / product.

The key terms are further defined as follows:

* + effectiveness: the accuracy and completeness with which users achieve specified goals;
  + efficiency: the resources expended in relation to the accuracy and completeness with which users achieve goals;
  + satisfaction: freedom from discomfort, and positive attitude to the use of the product;
  + context of use: characteristics of the users, tasks and the organizational and physical environments.

Usability is recognized as one of the most important characteristics of systems and products. Usable systems are easy to learn, efficient to use, not error-prone, and satisfactory in use [8]. High usability brings many benefits for the user and possible other stakeholders of the product. It means, e.g., “increased productivity, enhanced quality of work, improved user satisfaction, as well as reductions in support and training costs." [14].

In fact, usability cannot be defined in absolute terms since it always depends on who the users are, what are their goals and the environment of use. Nowadays, when the focus is shifting more and more from traditional desktop computing to ubiquitous computing applications (that are available everywhere and all the time) a very heterogeneous group of users’ everyday practices have to be understood and supported in the product design [16]. Especially concerning consumer and entertainment products and applications the definition of usability often expands to cover also other factors of user experience to be discussed in the following.

1. **User satisfaction and user acceptance:** User satisfaction is based on the feelings and attitudes towards the system or product to be used. User satisfaction may not always be dependent on the usability of a product. Sometimes users do not mind even major usability problems; in other cases usability problems may lead to severe user dissatisfaction. In some cases it might be necessary to include all the features in the product that the user hopes for, in order to avoid user dissatisfaction and to gain user acceptance [28]. Usually, user satisfaction has been examined with subjective measurements and measurement tools (e.g., questionnaire scales) developed for the studies (e.g., [18] & [19]). In addition to subjective measurements, a few objective measurements (in context of user experience) have been reported lately [20].
2. **Easy to learn:** At its best a product is so intuitive to use that it requires no training to use it. However, this is usually difficult to achieve in the product design. In any case the product should be so easy to learn that the resources to use the product effectively and efficiently are minimal.
3. **Enjoyability:** Besides usable, many product and devices should be enjoyable, entertaining and engaging. This concerns especially home electronic devices and entertainment products. Apart from wanting to provide users an enjoyable experience, another reason to make the interaction enjoyable can be to motivate users to explore the capabilities of (complex) devices, and thus in a playful way teach the user to learn how to use the system.
4. **Transparency:** The interaction with devices (e.g. home electronics) should be transparent. This means that users are able to perceive the most effective and efficient ways to complete their tasks successfully at a glance without having to consult procedural instructions. Transparency is the ideal relationship between the user and a disappearing tool (or product) [21].
5. **User in control:** Probably many scenarios will feature some kind of automated behaviour. Concerns about the amount of control the user will have over the system should be taken into account. Users should be provided with appropriate feedback about system changes that will give a feeling of being in control. Certainly, at least for a novice user, it might be helpful if initially the system takes control, since the user will not have sufficient knowledge of the functionality of the system and how to operate it. However, the amount of perceived control of the system should be alterable by shaping the way of interaction, either by letting the system or the user take the initiative. For many users it is important to have control over what is happening when they are using a product or a system.
6. **Social interaction and sharing:** In certain kind of products and systems, shared experiences and social interaction should be taken into the definition (e.g. co-experience [22]).

# UX and emotions

## Defining emotion

Emotion is a concept for which it is difficult to find a unique definition. To illustrate the variety of interpretations there are, in 1981 Kleingina and Kleingina identified 92 definitions of emotion in books, dictionaries and some other sources [116]. Just to name a few, we can mention that for Peter Goldie emotions are “complex, episodic, dynamic, and structured” phenomena encompassing various elements that change over time and that form part of a narrative [117], for the British psychoanalyst John Bowlby emotions are phases of an individual’s appraisals of either “organismic states” or “environmental situations” [118], for Andrew Ortony, emotions are positive or negative reactions to events, agents or objects linked to the way eliciting situations are constructed [119]. Scherer’s component process model of emotion [111] gives a useful insight what happens during an emotion episode and what are the elements involved. Scherer defines the emotion as an episode of interrelated, synchronized changes in the states of all or most of the five organismic subsystems in response to the evaluation of an external or internal stimulus event as relevant to major concerns of the organism.

Despite there being little agreement among the various theories involved in the attempts to define emotions, they usually recognize the multi-faceted nature of an emotion. It has been agreed that emotions are short-lasting (from a few seconds to minutes) phenomena characterized by the awareness of a given situation, overt expressions and behaviours, readiness to act, and physiological changes supplemented with subjective feelings [82]. Emotions are characterized as “affective state” [36], where affect is an embodied reaction to perceived stimuli and emotions reflect the affective traits of perceived stimuli.

Classical psychological theories of emotions see emotions as discrete states, such as fear or happiness. These theories list prototypical examples of emotions or formulate hierarchies of emotions. Each emotion corresponds to a unique profile in experience, physiology, and behaviour [31]. Also a basic set of six emotions (happiness, anger, sadness, surprise, disgust, and fear) is claimed to be universal, i.e., the nonverbal signals (facial expression, vocal intonations, and physiological reactions) of these emotions are displayed and also recognized cross culturally [28]. Discrete emotions approach is said to oversimplify the users’ emotional experiences. When the users’ are allowed to freely describing their affective states they tend to report that they experience many different emotions at the same time [29]. To overcome the shortcomings of the discrete theories of emotions, the dimensional theories of emotions have increased their popularity.

Many researches have given evidence that favours the idea that measures of emotional responding reflect dimensions rather than discrete states [31]. Dimensional theories of emotions organize emotions on a few fundamental affective dimensions and expressed emotion is a certain point in a multi-dimensional space. Often used affective dimensions are valence (negative-positive), arousal (calm-highly aroused), and dominance (controlled-in control) [32]. These three dimensions are also used when a non-verbal behaviour, i.e., affect displays such as facial expression, hand and bodily movements, and postural positions have been judged [33]. The valence and arousal have been found to be primary and they typically account for most of the variance in emotional judgments [32][31].

### Other affective states

In addition to emotions, Affective phenomena include feelings, moods, attitudes, affective styles, and temperament [30]. **Feeling** is one’s subjective and conscious experience of emotion [35], but emotion is not the same as feeling. Measuring the subjective experience of emotion requires that the subject is not only aware of that emotion but also that s/he can report the emotion semantically. The elicitation of an emotion can be indicated by the physiological reaction it causes without the person first has to consciously think about it. According to Mulligan, feelings are the integration of the different elements of an emotion making it available for mental representation and communication [81].

Emotion is not the same as **mood** either. Emotion does always have a target meanwhile mood does not [34]. Mood is not caused by any single one event but it is changing slowly because of many events. Mood has an influence on the emotions a subject typically is experiencing. Our mood also influences the inference we made about others’ emotions [36]: moods activate mood-congruent material in memory, resulting in mood-congruent judgments.

An **affect** is a psycho-physical event that is experienced as an emotion [28]. In other words, emotion evokes a change in the action tendencies or action readiness accompanied with physiological reactions. Emotions contribute to rational behaviour and rational decision-making [37] – even a small change in emotional state can significantly impact cognitive functions.

### Emotional needs and empathy

Emotional interaction includes two sets of emotional needs [37]. First the *experiential emotional needs* have to be met so that the interaction is considered to be motivational. The most important experiential emotional needs define the user’s need to feel that one’s emotional state is understood, to feel that one’s emotional responses are acceptable by others, and to feel connected to others.

On the other side, *emotional skill needs* are a set of basic skills for understanding others’ emotions. The most important emotional skill needs are affect perception, i.e., to understand what others do feeling, and empathy, i.e., appreciating others’ feeling and ability to communicate this understand to them. Empathy consists of both affective and cognitive components [38]. *Affective empathy* refers to perceivers’ experience of sharing the emotions they observe in social targets. *Cognitive empathy* is the ability of a perceiver to understand the internal states of targets and is often measured as the accuracy with which a perceiver can assess the thoughts and feelings a target is experiencing. Emotional skill needs are called *emotional intelligence*.

### Empathic accuracy

Essential to the emotional intelligence is empathic accuracy, one being able to accurately judge the emotional state of others. It has been an issue to what extent empathic accuracy depends on visual, auditory and semantic information, i.e., non-verbal and verbal information, that the target produces [39]. If the perceiver has semantic knowledge about the target, then perceiver may use the semantic information and top-down, rule-based inferences about the target’s affect [39]. In other cases, the inference has to be made using the affective visual and auditory (prosodic) cues.

The use of semantic information when judging others’ emotions reveals the close connection between emotion and cognition. Auditory and especially verbal information is argued to be critical to empathic accuracy [39]. Perceivers who had been given accurate contextual knowledge for interpreting the nature of an social interaction were more accurate in inferring the participants’ context-relevant thoughts and feelings than were perceivers who had been given either an inaccurate contextual knowledge or no contextual knowledge at all [40] [36].

Positive affective cues validate and negative cues inhibit people’s tendencies to use accessible concepts to guide their memory reconstructions [36]. According to Significant Clue Theory [41], different social inference tasks each rely on one or more primary types of information (e.g., a specific comment, glance, touch, stance, twitch, laugh, gesture, stammer, facial expression, or tone of voice), without which social inference suffers. This significant clue information is generally sufficient to enable perceivers to attain a satisfactory degree of accuracy, and the addition of information in other channels provides, at best, a diminishing return. According to Diffusion Theory [41], interpretable clues should be located in many different places at once - in the things the people say, in the expressions on their faces, in the paralanguage of their voices, in the proxemics of their positions, in the extent and qualitative manner of their touching, and so on. Archer and Akert [41] summarized their findings as follows:

“…the two most important findings uncovered in our three studies: (1) that most or even all pieces of an interaction can contain the information necessary for interpretation, and (2) that interpretations based on a very small piece of an interaction can be virtually as accurate as interpretations based on the whole interaction.”

## Emotion as UX factor

The combination of cognitive and emotional components is a characteristic aspect of human thinking that is related to our evolution and development [83]. Researchers have discovered that affective states are an important neurological regulator of the relationships of humans and their environment and that normal behaviour is greatly disturbed in the absence of such regulators [84]; even decisions about the most ordinary choices in our daily life are greatly affected by the incapacity to express emotions [85]. This relationship with the environment is part of our experience as users and thus determines how we perceive, interact and perceive technology. As mentioned above the subjective considerations that include emotions and other affective phenomena are very important to attain a “good” user experience. The impressions on technology and the environment concurrently produced with emotions may have long-lasting effects on our experience and hence they are the main target of Empathic Products. In the following sections we describe elements that are influenced or modulated by emotional states and that impact on the elements of UX including cognition and learning, motivation, decision making and consumer behaviour.

### Emotion and cognition

The current research supports the notion that affect and cognition are two distinct processes [42]. The emotional system is holistic and based on affective experience, whereas the cognitive system is analytical and based on rules of reasoning. There is interaction between these two information systems.

Emotions affect to perception and cognition by directing and guiding attention and content of thinking [43][44][36]. Emotions arouse in situations where people interact with their environment, in particular social interaction with other people evokes emotions [45]. Emotions affect people’s perception of the details in the present situation [46]. The attuned emotion is a sign of individual tendency to adapt oneself to his or her environment [43]. Emotions facilitate both the speed with which observed information is processed and the likelihood that it will be processed [47]. Positive emotions facilitate the peripheral features and negative emotions facilitate the central features of the observed information.

The periphery is something that we are attuned to without attending to explicitly [48]. When using the periphery of user’s perception then the received stimuli has to be meaningful for the individual in order to evoke positive and attractive emotions to be processed more detailed [49]. Elaboration likelihood model defines that when the stimuli are processed unconsciously user takes the peripheral route, which is a mental shortcut process to accept or reject irrelevant cues. According to the limited capacity model of mediated message [50] the perceived stimuli is first processed in the automatic and unconscious short term memory and if that stimuli contain information that is relevant to the needs of the user then the stimuli is processed more detailed, i.e., it has captured the user’s attention. Stimuli that elicit emotion are also processed more easily.

Positive emotions cause broadening of thinking and reflection on the overall experience resulting in greater recall of peripheral details. Happy feelings enhance cognitive flexibility, creativity and open-minded processing. Broaden-and-build theory of positive emotions [34] suggests that positive emotions promote discovery of novel and creative actions, ideas and social bonds, which in turn build that individual’s personal resources. In other words, when giving attention to the peripheral details it can enhance positive experience at the time and make it easier to recall that experience in the future. Positive emotions also prompt individuals to engage with their environments and particularly approaching and exploring novel objects, people and situations [34]. Positive affect generally enhances thinking and problem solving.

Negative emotions draw attention to the most salient features narrowing attention to the central details of the contextual information [36]. People also scrutinize information more carefully and systematically at the time of recall [46]. Negative emotion tends to inhibit cognitive relational processing, resulting in more perceptual, stimulus-specific processing. Negative affective cues inhibit people’s tendencies to use accessible concepts to guide their memory reconstructions. This can also be seen in social interaction when the emotion of another person is not in line with how one feels, then in these situations people have difficulty to recognize the emotions of the other persons [51].

It is clear that our experience as customers or users can be affected not only by the emotion we experience at the time of interaction with an object but may have roots in an emotion associated with a past situation.

### Emotion and motivation

When people are trying to reach their goal then their affect is related to the rate at which they succeed to reduce the difference between their current situation and the desired goal [52]. If the progress to their goal is rapid then the affect is positive and if the progress is too slow then the affect is negative. And if the progress is at the level he/she expects then the affect is neutral.

One important role of emotion concerning motivation is its effect on protecting and/or maintaining an intention to proceed to reach the goal [53]. People also use volitional emotion-regulation strategies to keep up the motivation. These strategies are used to neutralize the negative states or promoting positive states during the goal-striving process. However to what extent the need for affect actually influences the motivation tends to have personal differences [42]. People who have strong need for affect tend to be more open to experiencing strong emotions and they are also more aware of emotions. People who seek emotions also tend to seek and enjoy effortful cognitive endeavours. However, the need for affect predicts only the motivation to seek positive emotions but not negative emotions.

People at different ages have different motivation to regulate their emotions. Contra-hedonic motivations tend to be more prevalent among adolescents and prohedonic motivations are more prevalent in old age [54]. Contra-hedonic motivations, i.e., to enhance or maintain negative affect, or dampen positive affect, are less related to momentary affective state than prohedonic motivations, i.e., maintain positive affect and dampen negative affect. The need to resist the hedonic motivations to feel positive emotions is related to the adolescents’ socio-emotional development tasks to establish affective autonomy from their parents and strength the feeling of independence and maturity. Whereas the elder’s’ prohedonic motivation is more related to the momentary affective state and they are more motivated especially to maintain positive affective state. In summary motivation prompts a user to act to pursue an experience and it is emotions that determine the extent of effort and the expected outcome.

### Emotion and decision making

The way emotions interplay with reasoning to help us make ordinary, financial or socially complex decisions has been investigated from different perspectives in various scientific disciplines. For example, psychologists Daniel Kahneman and Amos Tversky showed that the assumption in economics that decision making is based on rational assessment of an expected utility was flawed and was not corroborated by experimental evidence [120]. They found evidence that financial decisions were not supported by flawless rationality but rather were affected by subjective feelings, more specifically the aversion to feeling “regret”. In support of Kahneman’s analysis more recent studies show that “although economists typically assume that individuals choose among alternatives in an internally consistent way, behaviour in detailed experiments is often inconsistent with this assumption” [121].

Perhaps not surprisingly, it was a group neurologists in 1990’s who by means of the latest medical technologies started providing the strongest evidence about the role emotions play in decision making and other aspects of our lives. Studying the brain circuitry associated with fear, Joseph Ledoux from the Center of Neuroscience at New York University found that in some situations demanding immediate action our emotional reactions sometime precede a conscious evaluation of the event that elicited such reaction. Indeed, “Emotion allows people to transcend details, prioritize, and focus on the decision to be made” [121].

Antonio Damasio is a renowned neurologist who has developed a theory of how emotions influence decision making based on his studies of patients with lesions of the ventromedial orbitofrontal (VM) (an area of the brain located above the eye sockets). Various areas of the VM have been associated with cognitive and behavioural operations. While investigating the adverse effect damages to the VM area had on patient’s social behaviour, Damasio found that while the intellect of the individuals remained normal and well-preserved in terms of their language, learning, memory, attention capabilities and even their ability to solve abstract problems (using executive function tests), they became unable to observe “socials conventions”, took actions adverse to their own well-being leading to financial or inter-personal losses, and repeatedly engaged in disadvantageous actions showing disregard from previous mistakes. More importantly, Damasio also recorded abnormal emotional processing in which patients could not engage affectively in complex situations, i.e. were emotionally “flat” [122] [123]. Because defected decisions seemed not to be linked to intellectual aptitudes, Damasio concluded that the main effect of damage to the VM area was an inability to use emotions to assist decision making. Damasio then proposed a theory called the “Somatic Marker Hypothesis” (SMH). The main idea behind the SMH is that “decision-making is a process guided by emotions” [124].

Peter Salovey and John Mayer have even suggested that the ability of humans perceive and utilize their emotions is comparable to a form of intelligence, namely emotional intelligence, EI. “When people approach life tasks with emotional intelligence, they should be at an advantage for solving problems adaptively…They are more apt to integrate emotional considerations when choosing among alternatives” [125]. The initial purpose of EI theorists was to investigate the significance of emotions within the context of intelligence, paying special attention to adaptation and behaviour. However, health, personality, personal ambitions and success have also been analysed from an EI perspective. The effect EI has on people’s decisions is still being investigated [126] but as previously mentioned it is an important element of empathy and therefore a relevant in UX of empathic technology.

### Emotion and consumer behaviour

Similar to the way former assumptions about the relationship between emotions and cognition have changed in recent years, the old idea that consumer behaviour is dictated solely by rationality is no longer an undisputed fact. Numerous studies have shown that emotions influence the purchasing decision process at different levels.

There exist several theories aimed at explaining consumer behaviour that have been suggested over the years including the economic man, psychodynamic, behaviourist, cognitive or humanistic approaches. These schools of thought have been largely derived from research done on decision-making in psychology [127]. In depicting one of the humanistic approaches, namely goal-oriented behaviour, Baumgartner and Pieters [128] argue that the ultimate aim of a consumer is the being happy. There are two aspects involved in pursuing consumer’s purposes, goal setting and goal striving, and both are influenced by affects (including emotions). For example, affects can be a goal in itself, influence motivation or act as a filter in goal setting while could regulate the time spent in goal pursuit (striving).

Similarly, research shows that consumers used their emotions towards stimuli to evaluate how much they like them. Findings by Pham et al. suggest that emotions are used to perform a diagnostic about the preferences towards a target [129]. In fact not only consumers seek information that is in line with early affective responses to stimuli, but they are considered a reliable and valid information source [130].

This evaluation does not only occur when people have access to the specific attributes of the stimuli but at an earlier impression-formation stage. In fact this initial assessment of a product, sometime based on an image, elicits an affective response that determines the subsequent evaluation of detailed product characteristics [131]. Since emotions are crucial in whether we like an object or not they obviously become part of our UX.

# Methodologies to measure UX

To measure emotions as part of the user experience we need to concretise the object to be measured. There are different instruments to measure emotions including self-questionnaires or behavioural ratings which can only provide a partial view on the whole emotional experience. According to the model proposed by Scherer [11], the components of the respective states of the emotion episode are summarized in the following table.

|  |  |  |
| --- | --- | --- |
| **Emotion function** | **Organismic subsystem** **and major substrata** | **Emotion component** |
| Evaluation of objects and events | Information processing (CNS) | Cognitive component (appraisal) |
| System regulation | Support (CNS, NES, ANS) | Neurophysiological component (bodily symptoms) |
| Preparation and direction of action | Executive (CNS) | Motivational component (action tendencies) |
| Communication of reaction and behavioural intention | Action (SNS) | Motor expression component (facial and vocal expression) |
| Monitoring of internal state and organism-environment interaction | Monitor (CNS) | Subjective feeling component (emotional experience) |

Note: CNS = central nervous system; NES = neuro-endocrine system; ANS = autonomic nervous system; SNS = somatic nervous system.

Table 1. Components of the emotion episode by Scherer(2005)

The different components of an emotion episode have their own representation and manifestations. It follows that the central feature of human emotion is its multi-component character. Only the assessment of changes in all the five components involved in an emotion episode can provide a comprehensive measure of an emotion. Such a comprehensive method for measurement of emotion not yet exists but these five components of emotion may be taken as a basis for the discussion of emotion measurement approaches as part of the overall UX.

Mahlke & Minge[112] and Mahlke [113] introduced measurement approaches to measure the emotion components of the Scherer’s component process model. To assess **subjective feelings** the individual him/herself is the best source of information. Widely used self-assessment test is the SAM (Self-Assessment-Manikin) which consists of pictures of manikins for each of the dimensions valence, arousal and dominance. The user selects the manikin whose appearance corresponds best to his/her own emotion. As a non-verbal assessment the SAM is supposed to be culturally independent. To assess **cognitive appraisal** different questionnaires are common but also thinking aloud method is widely used. The advantage of the thinking aloud method is that it does not restrict the user’s description of his/her reaction in to any predefined frame.

One widely used method to measure **physiological reactions** is the measure of electrodermal activity (EDA). Common parameters are skin conductance response, skin resistance response and skin potential response. The EDA is especially used to measure the valence of the stimuli. Also the heart rate recording is used to measure the arousal and mental workload and pupillometry, i.e., the dilatation of the pupil, is used to measure mental workload. To measure **behavioural tendencies**, i.e., expressive behaviour, the commonly used indicators are speed of reaction, the accuracy of reaching a goal, the number of errors and the number of creative ideas during interaction with the system. Measurements of **motor expression** make use of facial and body expressions, gestures and speech characteristics. To assess facial expression the Facial Action Coding System (FACS) is commonly used. It is based on six basic emotions that are considered to be cross cultural: fear, anger, joy, disgust, grief, and surprise. The analysis of speech characteristics concentrates on speed, intensity, melody and loudness. Empirical research suggests that these speech features are highly correlated with experienced emotions and are therefore good indicators for emotional reactions [113].

The measurement approaches differ in many ways from each other. The measurements of subjective feelings and cognitive appraisal use subjective methods, while the measurements of physiological reactions, behavioural tendencies, and motor expression use more objective methods. The measurement of subjective feelings, cognitive appraisal, and physiological reactions are obtrusive, while the measurements of behavioural tendencies and motor expressions are unobtrusive. The pupillometry, which measures physiological reactions, may be unobtrusive. If the measured data is to be used at the time of the use of the system, only the objective and unobtrusive measurements are usable to catch the emotional state of the user but the UX cannot be measured directly. As Scherer [111] stated:

*While both nonverbal behaviour (e.g. facial and vocal expression) and physiological indicators can be used to infer the emotional state of a person, there are no objective methods of measuring the subjective experience of a person during an emotion episode.*

To understand how the emotional reactions are related to the user experience we need a framework that explain the role of the emotion in the user experience. In the Chapter 5.2 we present one research framework that helps us to measure the emotional reactions and other user experience components.

## Methodology for needs analysis and identification

User Involvement is an active process to involve stakeholders[[1]](#footnote-2) in different tasks of a project for the purpose of identifying their needs and preferences and use this information to develop new products which will cover the real needs of the clients including effective and easy-to-use designs.

This methodology is based on ISO 9241-210: 2010 Ergonomics of human-system interaction – Part 210: Human-centred design for interactive systems. Some important advantages of this ISO regulation relate to the design of products, systems and services that consider the context of use and the target group in an iterative design process with an intensive user involvement component. In accordance with this idea the procedure is divided into 4 phases:

* Phase 1. Understand and specify context of use
* Phase 2. Specify user requirements
* Phase 3. Produce design solutions
* Phase 4. Evaluate the designs

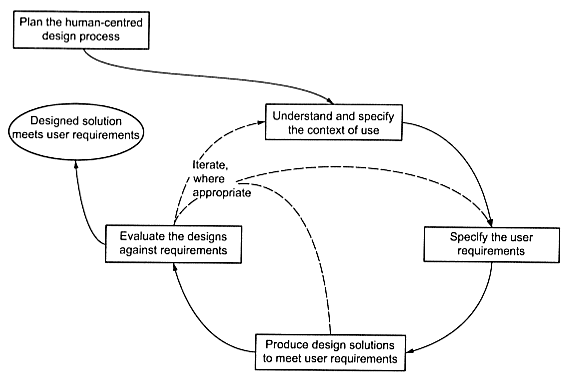


Figure 4. Need analysis identification phases.

In relation to the operational methods to elicit the user needs, the process is commonly structured in the following tasks:

1. **Requirement analysis**: Requirements are analysed to identify target users, the context of use of the client, and the most appropriate techniques of user involvement. This task includes the literature review about the target of users’ needs; the state of the art analysis about the related technical fields and the definition of the inclusion criteria for the stakeholders to be observed and interviewed during next task.
2. **Observation sessions** aim to identify uncover/unmet needs for the users. Observation could be immersive (doing the same activities as the users) or indirect (just taking notes during observation). Indirect observation could also include testing selected products to identify the problems in their utilization and propose design improvements.
3. **User interviews**: interviews with final users and stakeholders allow the collection of information about the products that the user tested and about the needs or problems they have already identified.

It should be noted that all the collected information should be treated according to the ethics and privacy regulations.

## Measuring the UX

Mahlke [113] proposed a UX research framework that takes a multi-component approach to emotions in human-technology interaction research. This approach was defined by Scherer [111] and that was discussed in the Chapter 5. In his framework Mahlke defines perception of non-instrumental qualities and emotional user reactions as separate aspects of the user experience which are linked to the perception of instrumental qualities (Figure 5). The perception of instrumental and non-instrumental qualities as well as emotional user reactions determines the consequences of the user experience.

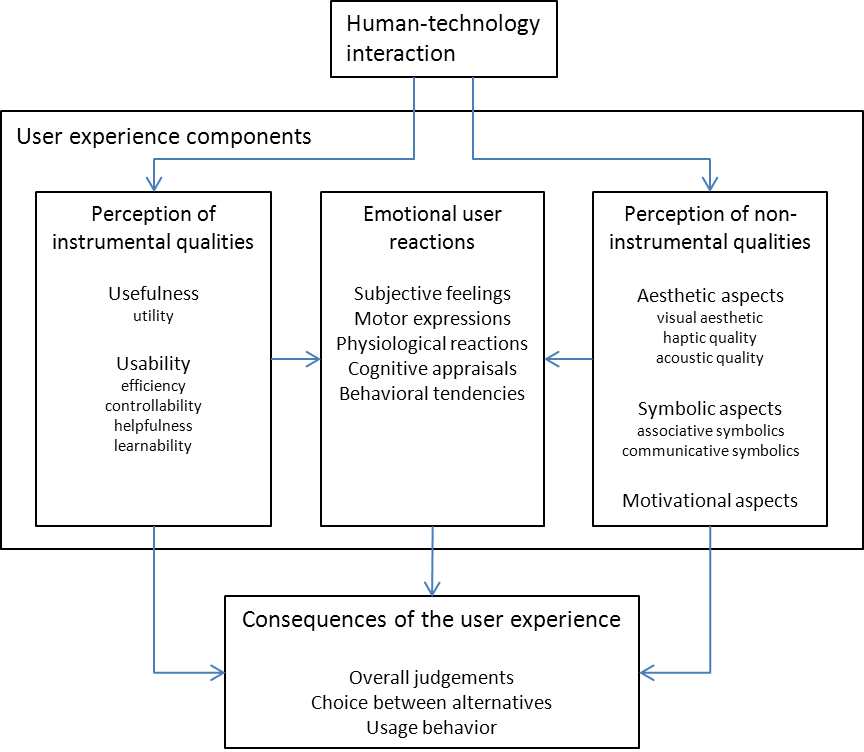
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Figure 5. UX research framework by Mahlke(2008).

In this framework the human-technology interaction determines the perception of the instrumental and non-instrumental qualities and the emotional user reactions are influenced by both the instrumental and non-instrumental quality perceptions. Also no direct link between non-instrumental and instrumental quality perceptions exists. The emotional user reactions are seen as intermittent factor between the perception of instrumental and non-instrumental qualities and that enables the indirect mutual influence of both types of perceptions on each other. All three user experience components have an influence on the consequences of the user experience. Main results of the Mahlke’s research are as follows:

(1) instrumental and non-instrumental qualities are perceived independently,

(2) emotional user reactions are determined by instrumental and non-instrumental quality perceptions, and

(3) consequences of the user experience are influenced by all three components of the user experience.

Clearly the emotion is an elementary component of the overall user experience and with that we can make assumptions of the other components involved in the UX. For example, the perception of a positive non-instrumental quality may cause a pleasant emotional episode which in turn may influence the perception of instrumental qualities. The aim of the Empathic products project is to measure the UX at the time of human-technology interaction so the objective and unobtrusive methods should be used to measure the user’s emotional reactions. These objective and unobtrusive methods were discussed in the Chapter 5. With these methods only some aspects of the emotion episode may be measured and the measurement, at its best, can give only a useful hint about the emotional component of the user experience.

Perception of instrumental qualities may be measured, e.g., by the speed and accuracy of performance. That is, how many errors a user makes when accomplishing a task and his/her ability to recover from errors (helpfulness), or a casual user’s ability to remember how to use a system after a period of time (learnability). Also how willing the user is to discover alternative ways to use the system and get his/her task done (controllability), how quickly the user can accomplish the task (efficiency), and how willing the user is to use the system again to accomplish some task (usefulness).

Perception of non-instrumental qualities are quite difficult to measure objectively and unobtrusively, i.e., without asking the user directly. Non-instrumental qualities of an interactive system satisfy user needs that go beyond the mere instrumental value of the product. Non-instrumental qualities have an important role to attract the targeted users to start to interact with the system. So one measureable indicator is the amount of the first time users the system succeeds to reach.

## Tools for evaluating and measuring user experience

Here we present tools that can be used to measure and evaluate user experience. The focus is on the tools that can provide information on the user experience at the time of the use of the system.

### Psychophysiological measurements of user experience

In case of objective user experience studies in human-computer interaction (HCI), the utilization of physiological measurements has been reported (e.g., [20], [24]). The measurements consist, e.g., of recorded skin conductance, heart rate and blood volume pulse sensing. According to many of the studies alike, the difficulties in using the results of physiological signal measurements in user experience studies are dealing with the relatively complicated set up of the measuring systems and time consuming analysis of the results (e.g. interpretation of human mental process together with physiological signal levels). Also, this kind of experimentation requires specific circumstances - therefore, it is comparatively difficult to use these methods when the users are outside the laboratory and not on the go. Combination of objective physiological measurements with other methods (questionnaires) has been introduced in [20]. According to their findings, physiological (experience) data is found to be affected by the conscious quality changes in signals to be sensed in the tests. On the other hand, subjective sensation (personal feelings) and physiological information measures do not always concur, though this may also be due to the fact that the users are either not aware or they cannot remember subjective assessments afterwards when asked [20].

Mandryk et al. [27] have provided an overview concerning psychophysiological measurement techniques of user experience in a few case studies of entertainment technologies. As usual, they found correlations between subjective data and physiological measures for each participating individual, but the correlations were not consistent across participants. The difficulty might have been that the experimental situations were impacting the physiological measures and the subjective ratings in such a way they had not anticipated. - This further confirms the doubt stated before, that it is very challenging to carry out physiological measurements reliably in this connection.

Emotions are an important factor of user experience. One sort of emotion is frustration. To test the ability to recognize individual’s emotions from the physiological signals, Scheirer et al. have publishes a paper on “Frustrating the user on purpose” (!). In the arrangement they gathered physiological data with video and behavioural data and combined them with real world events. BVP and skin conductivity signals were registered and used in the analysis whether the frustration levels of the users could be distinguished automatically from the signals. Frustration is said to be one of the human responses caused by a delayed reward of one’s response (a behaviouristic view). To simulate this, a computer game was launched, where the goal was to complete a series of visual puzzles as quickly and accurately as possible in order to win monetary reward. But the computer mouse was manipulated to cause extra delays at certain intervals. The correspondence between the physiological signals and subjective data were present. The authors argue that over time a computer system could learn an individual’s patterns of frustration and other emotion related responses. (Scheirer et al. 2002) In future, this kind of continuous human factors analysis could be utilized by human computer interaction designers when trying to affect to the user experience in situ. - Computing that relates to, arises from, or deliberately influences emotion or other affective phenomena is called Affective Computing [29].

It is important to note, that even quantitative user experience evaluation and measurement methods are not necessarily objective. They have been considered often as if they were same issues. An example of quantitative and subjective evaluation and measurement techniques are the questionnaires using numeric scales for analysing, e.g., usability and user’s experience of a system to be studied.

According to the analysis of Ward et al. [24] concerning the difficulties of physiological signal interpretation in usability evaluations show, that physiological readings might help identify features that users fail to mention in feedback reports, either because they have forgotten or because they thought it insignificant. On contrary they report several cons and difficulties in their use. For example, physiological readings tend to be inconsistent and there may be large differences between individuals in their degree of physiological response. Even within individuals, the same experimental conditions may give very different skin conductance readings on different occasions. Moreover, interpretation of signal responses in terms of users’ internal mental experiences causes further problems.

### Facial expression recognition

To support natural way of interaction between a computer and a human user the computer has to have the ability to understand user’s emotional state in real-time. The most expressive way humans display their emotions is through facial expressions. The computer has three tasks when performing the automatic facial expression analysis (AFEA) [55]. First, it has to detect the face region from the input images or video frames. Second, it has to extract the facial expression features. And third, it has to map those facial expression features to the emotions they express. The prominent face areas to look for the facial features of emotions are eyes, eyebrows, nose, mouth region, and chin [56]. Widely used emotional classification of Paul Ekman describes six universal basic emotions [57]: joy, sadness, surprise, fear, disgust, and anger. This classification is based on the assumption that emotional expressions have corresponding prototypic facial expressions.

In real-time systems the face detection should be robust to arbitrary head movement. The methods to detect the head pose can be categorized as 3D model-based methods and 2D image-based methods [55]. To estimate the face geometry and to track the facial features an explicit 3D wireframe face model is used. In this 3D model a generic face model consisting of surface patches is warped to fit the facial features that are defined on the model. Another used 3D method to detect the head motion in real-time is cylindrical head model. Applying the active appearance model the cylindrical head model is mapped to the face region which is detected by face detection and the head image is projected onto the cylindrical model.

Tian et. al [58] presented their 2D image-based real-time system where relatively low-resolution face images taken from the input video stream is used for head pose detection. First a background model is estimated from an input video sequence. With this background model the background subtraction is performed and the resulting foreground regions are used to detect the head. Head pose is estimated from the gray-scaled head image using a three-layer neural network. After the head image is processed by the neural network the result is one of the three possibilities: head pose is (1) frontal or near frontal view, or (2) side view or profile, or (3) others, i.e., no enough facial features. The neural network based facial expression classifier was then applied only to the frontal or near frontal view faces. Their experiment with the system and PETS2003 (Performance Evaluation of Tracking and Surveillance) dataset Scenario A shows that the head detection and head pose estimation worked well. The expression recognition results show that without knowing the absolute neutral face for each subject, it is difficult to recognize the expression in low intensity.

Cerezo et al [59] created a 2D image-based real-time facial expression recognition system that uses standard webcam. The expression recognition is based on facial features’ tracking and the emotional classification is based on the variation of certain distances and angles from the neutral face and it recognizes the six basic universal emotions by Ekman [57]. The system considers a face to be found when the user sits steady for a few frames and the face is found in the image within those frames. The user must start the session with a neutral face so that the system is able to define the initial user’s face region to start the search of the facial features. The face region is divided into three sections: eyes and eyebrows, nose, and mouth region. First the system detects the nose region and calculates the mean of all the face features inside that region and hence finds the center point of the face which is the face tracking point. This tracking point helps the system to follow the user’s face and detecting the facial expression features even if the user moves. It is also used to constrain the image region to process in the facial expression recognition phase. In their validation test with 399 images from the database the system recognized best joy, disgust and neutral emotions. The system also recognized anger, sadness and fear quite well. The surprise emotion was hardest to recognize.

Anderson et al [60] present their fully automated real-time expression recognition system which recognizes only frontal views of face. The user is supposed to be in front of a computer screen and his gaze is directed at the computer. The system has three main components: a face tracker, an optical flow algorithm and an expression recognition system. The face tracking component is based on a ratio template algorithm which matches ratios of averaged luminance using a spatial face model. The algorithm is modified with the inclusion of golden ratio face mask. Combined with the information given by the modified ratio algorithm also other image measures like simple morphological eye and mouth detection, image motion data, matching history, and matching density are used to locate a single face in the scene. After the face has been located by the face tracking component then the optical flow algorithm determines the motion of the face. Motion information is used for expression recognition and it is based on the assumption that facial motion patterns of the six base emotions are the same for everybody. After the facial motion detection the motion signatures is used by the facial expression recognition. The detected average facial motion features over 16 facial regions are given as inputs to the classifiers for different emotions. The classifier that gives the strongest response determines the expressed emotion. The response must be over preset threshold or otherwise the motion is labelled as nonexpressive.

Khan et al [61] used infrared measurement of facial skin temperature variations for facial expression recognition. The use of facial thermal features is based on the fact that contraction or expansion of the facial muscles causes fluctuations in the rate of blood blow accompanying thermo-muscular activity. And further, the significant blood flow redistribution takes place with a change in emotional condition and level of anxiety. Measuring the changes in facial thermal features is a non-invasive way to detect the facial expressions of emotions. In their experiment Khan et al first determined the Facial Thermal Feature Points (FTFP) in their subjects’ faces. First they captured the subjects’ normal thermal faces with infrared camera. Then the subjects were asked to pretend and express happiness, sadness, disgust, and fear. The neutral face thermograms were used as a reference for comparison with the intentional expressions of emotions. Each thermogram was divided into grids of squares, and the highest temperature in each square was recorded. These measurements are the Thermal Intensity Values (TIV). With multivariate analysis they measure the variation in TIVs and they found 75 squares, i.e. FTFPs, undergoing a significant thermal change. The analysis of the data revealed that classification of facial expressions cannot be based on TIVs on any specific part of the face although upper part of the face reveal more significant thermal changes with a change in facial expression than the lower part of the face. The automatic face expression classification would involve thermal variation data from several major locations on the face. The experiment showed that the expressions classification rate is better than the rate obtained due to chance alone but more samples are needed to train the classifier and verify the classification results.

### Gaze analysis

Eye gaze direction has a strong influence on facial expressions and eye gaze analysis may give additional information when detecting facial expressions of human emotions. Zhao et al [78] made a webcam based system that combines facial expression recognition and information on eye gaze direction. To evaluate the facial expression recognition they used 240 images where 2 males and 2 females performed six different facial expressions in a laboratory environment. The facial expression recognition was made with and without the information on the eye gaze direction. The recognition of anger, fear, and sadness improved significantly when also eye gaze direction was taken into account. Gaze analysis gives information on the motor expression component of emotion. Measuring the gaze direction can offer supplemental information on the facial recognition of emotion. Gaze can tell also about the motivational aspect of non-instrumental qualities: direct gaze tells about approach-oriented emotions while the avert gaze tells about avoidance-oriented emotions.

Murphy and Isaacowitz [80] conducted a research on how the age affects to the gaze patterns when recognizing facial emotion expressions. Previous researches on age-related differences in emotion recognition have found that older adults showed a preference toward happy faces and away from angry ones. Also older adults’ deficits in recognizing negative emotions (anger, fear, and sadness) were related to over-attention towards the lower halves of faces while the negative emotions are best recognized from the eye region of faces. The experiment confirmed that younger adults orient their gaze more towards the eye region than older adults, and accurate emotion recognition requires attention towards both the eye and mouth regions of the face. In their experiment they found that the older adults did look less at the eye region than the younger adults, and this was also found in the previous eye-tracking studies. This behaviour is explained with the assumption that the older adults tend to regulate their emotions more than the younger adults and that tendency make them shift their attention away from negative stimuli. Based on their experiment Murphy and Isaacowitz suggested that age-related gaze patterns may depend upon the specific emotion being recognized. Gaze-patterns can be used to recognize behavioural tendencies, i.e., the motivational aspect of emotional reactions as a UX component, but it should be taken into account that these behavioural tendencies are age-related. So before making any judgment about the meaning of the user’s gaze the user’s age should be resolved.

Hyrskykari [79] used eye tracking to identify the focus of user’s visual attention when she uses iDict which is an Attention Aware System (AAS) gaze-aware application. The user’s eyes are tracked during s/he is reading a document wrote in a foreign language and the reading path is analysed. The user’s eye movement during reading is used to infer the user’s point of attention. When the user hesitates while reading a word or a phrase the embedded dictionaries are automatically consulted and an instant translation is provided as a gloss above the difficult section of text. If the user turns his/her eyes at the right part of the application window then an entry from the dictionary is shown in the Dictionary Frame. The application gives user visual feedback on the detected location of the gaze in order to help the user to maintain his/her attention. In iDict the eye tracking is used to measure the efficiency aspect of the usability as a part of the UX, i.e., the system reacts when the user hesitates about continuing reading. Analysing the eye movements the system gets information on how the helping tools the system offers are used. So the helpfulness aspect of usability component is also measured.

### Audio analysis

Voice is a major channel for communication, capable of quickly conveying a large amount of information. This includes emotional content [114, 115] in linguistic and paralinguistic, or nonverbal forms. Research on the automatic recognition of emotions in speech has emerged in the last decade and recently online speech processing for emotion recognition has been proposed.

Vogt et al [107][108] created a framework, called EmoVoice, for vocal emotion recognition from speech in real-time. This framework includes tools that allow recording a database of emotional speech and training a classifier to recognize emotions from users’ speech. The trained classifier module can be used by other applications via socket communication. A set of 1451 acoustic features is derived from pitch, energy, voice, quality, pauses, spectral and cepstral information as conveyed in the speech signal. No semantic or word information is used, which makes the emotion recognition process faster. In the systems where emotion is recognized from speech the acoustic features are the more classically used [109]. The EmoVoice system is trained to recognize emotion classes based on pleasure and arousal in Mehrabian’s PAD (Pleasure, Arousal, and Dominance). EmoVoice measures the motor expression component of emotional user reactions as a part of the UX. If the measurement indicates pleasure then it is possible to make assumptions that positive motivational state and positive subjective feelings are involved in the UX.

ElectroEmotion [110] is a system that uses EmoVoice for vocal emotion recognition. It is an interactive environment that includes a public walk-up-and-use multimodal interface which enables affective interaction with voice and hand gestures. The main purpose of ElectroEmotion is to collect a multimodal corpus of emotion data. The system prototype is intended for a single user and it includes portable input devices to record voice and gesture signals, a projection screen and loudspeakers. The user’s audio input is visualized on the screen as rows of 3D columns changing in the X and Y dimensions. The time is on the Z axis. The relative height of the columns is the intensity of the measured acoustic feature. The ElectroEmotion system concentrates on measuring non-instrumental qualities of UX components. The system gives information on the aesthetic visual and acoustic aspects of the non-instrumental qualities of the UX by measuring the time the user plays with the system while the system gives visual and auditory feedback. At the same time the recorded user’s voice makes it possible to analyse the emotions based on the acoustic features of the voice, i.e., the motor expression of emotion.

### Key stroke/mouse use

An alternative unobtrusive and non-invasive approach for emotion recognition is the analysis of the mouse and keyboard actions, which can be used to analyse correlations with affective state. The following methods require only the keyboard and sometimes additionally the mouse, the logging software and classifier algorithm. The analysis is not done online in the following cases.

Zimmerman et al [62][63] used keyboard and mouse for measuring mood (in two-dimensional space defined by valence and arousal). The data was collected during e-shopping event. For example, time of the mouse button down, mouse position x and y coordinates, which key was pressed, number of mouse clicks per minute, average duration of mouse clicks (from button down until button-up event), total distance of mouse movements in pixels, average distance of a single mouse movement, number and length of pauses in mouse movement, number of events, maximum, minimum and average mouse speed, keystroke rate per second, average durations of keystroke (from key-down until key-up event) and performance were recorded. The accuracy was 5 ms. Even though the data analysis was not conducted to the end, they found out that affective and neutral group had differences in the data. They were not specific in their papers about the following analysis (e.g. the used parameters and classifiers). Connection between emotions and motor system, and thus computer interaction, was explained by Zimmerman et al [63] referring to Clynes’ [64] stating that “*There is a class of qualities which is inherently linked to the motor system… it is because of this inherent link to the motor system that this class of qualities can be communicated. This class of qualities is referred to commonly as emotions*”. The measured speed of reaction time and time spent on every action give information on the behavioural tendencies and motor expression aspects of the emotional reactions component of the UX. Also the measured errors and corrections are indicators of the system usability aspect of the overall UX.

Vizer et al [65] studied the relation between cognitive and physical stress and keyboard actions and developed a method for cognitive and physical stress classification from free text input. The basis of their studies lays on the deception detection studies of Zhou [66][67] and on the earlier studies stating that there is variability in typing patterns in security applications, some of it has to be explained by the effect of stress on that. Stress causes changes in the use of backspace, delete, end, and arrow keys. When the data is normalized, also the changes in time per keystroke and lexical diversity were detected in both cognitive and physical stress situations and change in pause length for the physical stress.

Epp et al[68] classified 6 emotional states using fixed text from Alice’s Adventures in Wonderland (AVG 166 characters) that was collected periodically in real-life setting. Several keystroke parameters were extracted and decision tree classification algorithm was used, The modelled emotional states included confidence, hesitance, nervousness, relaxations, sadness and tiredness. The extracted parameters included 1) The mean duration between 1st and 2nd down keys of the digraphs, 2) The mean duration of the 1st key of the digraphs, 3) Standard deviation of the duration of the 1st key of the digraphs, 4) Mean Duration between 1st key up and next key down of the digraphs, 5) The mean duration of the 2nd key of the digraphs, 6) Standard deviation of the mean duration of the 2nd key of the digraphs, 7) The mean number of key events that were part of the graph, 8) Standard deviation of the number of key events that were part of the graph, 9) The mean duration between 1st and 2nd down keys of the trigraphs, 10) The mean duration of the 1st key of the trigraphs,11) The mean duration between 1st key up and next key down of trigraphs, 12) The mean duration between 2nd and 3rd down keys of the trigraphs, 13) Standard deviation of the duration of the 2nd key of the trigraphs, 14) Standard deviation of the duration between 2nd key up and next key down of trigraphs, 15) The mean duration of the third key of the trigraphs, 16) The mean duration of the trigraphs from 1st key down to last key up, 17) The mean number of key events that were part of the graph, 18) Standard deviation of the number of key events that were part of the graph. The collected data was not analysed online. They also collected random free text input from 10 minutes time (AVG 169 characters) but it was not sufficient for making classification due to high deviation and in future higher number of characters should be collected.

### Text analysis

The experience of the user is also conveyed by the textual content of his utterances. The earliest aspect that is investigated in literature is the sentiment expressed by a user through an opinion, that is how he feels or more specifically how he feels about a certain topic. The most general task is to find whether a text conveys a positive, negative or neutral sentiment. This task is at hand when there is a need to determine the opinion conveyed by the texts produced by a user or a community of users: detecting hostile messages and flame wars [104], determining whether movies are appreciated [106][100] and thereby trying to predict movie success [98][102], opinions about products [91] including predicting sales [94], assessing citizens satisfaction of public policies [92] and predicting election results from Twitter [105][[2]](#footnote-3). The field of sentiment analysis is relatively recent, but it is very rich and growing fast.

The term sentiment in the expression sentiment analysis is a bit misleading though, it refers to polarized elements in a text and not to the general meaning of sentiment as an emotion, which is closer to the topic of emotion detection. Moreover in the literature, opinion and sentiment are often used interchangeably, an opinion being a sentiment about something. Sentiment analysis is related to subjectivity analysis (that is whether a text expresses a subjective or objective point of view), however a sentiment is not necessarily expressed through a subjective assessment, and not all subjective assessments express a sentiment. The following table shows examples of objective and subjective sentences that can convey a sentiment or not. The sentence "This car is red" is a purely objective sentence without polarized information, while "This car is broken" is also an objective sentence but which contains a negative sentiment about the car. The sentence "I think that this car is red" is a subjective sentence expressing a belief but without polarization, while "I love this car" is also a subjective sentence but which conveys a positive sentiment.

|  |  |  |
| --- | --- | --- |
|  | *without sentiment* | *with sentiment* |
| *Objective* | This car is red | This car is broken |
| *subjective* | I think that this car is red | I love this car |

Table 2. Examples of subjectivity and sentimental sentences

The most complete definition of the sentiment analysis task is probably provided by [95] in which an opinion is defined as a quintuple (e, a, s, h, t) where e is the name of an entity, a an aspect of this entity, s is a sentiment about a, h is the opinion holder and t is the time when an opinion is expressed by h. For instance in "Linux configurability is loved by geeks", the entity e would be Linux, the aspect a would be the configurability of Linux, the sentiment s would be positive, the holder of the opinion h would be geeks, and the time t would be the time of utterance, that is (Linux, configurability, positive, geeks, now). The sentiment analysis task is then to output for a given text or sentence the set of opinions that this text conveys.

The sentiment defined as a polarity is a worthwhile metrics of the user satisfaction, however in some domains, we might want to explore more fine-grained metrics. The topic of emotion detection goes deeper in the description of the user feelings, it consists in finding the emotions that are conveyed by a sentence or a document. It can be considered as a more specific and harder task than sentiment analysis: sentiment analysis is restricted to two or three classes (positive, negative, neutral) while emotion detection consists in finding emotions from a larger set of emotions and those are more complex than polarity. Typically, the set of emotions which is the most used is the Ekman's model [89] that contains seven emotions (joy, sadness, fear, disgust, anger, surprise, interest), sometimes restricted to six, five or four emotions (joy, sadness, anger, fear). For instance the sentence ''Trolley Square shooting leaves 6 dead, including gunman'' could be said to convey a mixture of sadness, fear and anger.

It is interesting to compare the domain of application of emotion detection with regards to sentiment analysis. Emotion detection is mostly at hand in domains that really carry strong emotional content such as fairy tales [86], dream diaries [90], mood in blog posts [97], news headlines [103], interaction with virtual agents [99], suicide notes [101], etc. Actually, in any domain where emotion detection is relevant, it is possible to carry a sentiment analysis task. However emotion detection is much more subtle and cannot be applied in all domains where sentiment analysis is relevant: the set of emotions needs to be chosen according to the domain. For instance, in the tutoring domain, Ekman's emotions do not seem to address correctly the experience of the student, it is unlikely that the student will feel anger or sadness per se. [93] propose instead to consider cognitive-affective states described by the valence of the experience and its relationship to the learning effects (constructive learning or un-learning). A similar claim is made in [88][87] in which cognitive-affective states like boredom or frustration are proposed. Interestingly these cognitive-affective states can be expressed in terms of valence/arousal, and then in this domain a sentiment analysis task would also be perfectly relevant.

To summarize, both sentiment analysis and emotion detection are interesting measures of the user experience, however emotion detection may not be relevant in all domains and it is moreover widely acknowledged to be a more complex task than sentiment analysis. On the contrary, sentiment analysis is a relatively easier task, which can be applied in most domains but only provides binary polarity information about the user experience.

# Examples of measuring UX by technical tools

This chapter presents some examples of the application of technology-based tools to measure and evaluate the UX in different application domains.

## Marketing

Sensory Logic is a neuromarketing research firm that is currently a technology-based tool for marketing purposes. The company (<http://www.sensorylogic.com>) is using Facial Coding Action System for emotional UX source and it has been exploited e.g. in market analysis and in working environment where the analysis was combined with filling out a questionnaire [133]. In details, it can be used while studying what effects certain product brand has on the consumer. For example, what kind of reception a certain ad gets among three segments: recent purchasers (Owners), people who were indifferent to the brand (Apathetics), and those who would not consider it (Rejectors). The facial data can be collected in three different ways: during 1) online surveys where participants are emotionally analysed via webcam, 2) focus groups where participants’ responses are captured using e.g. FocusVision cameras or 3) individual interviews involving stimuli exposure, questions, ratings, and probes.

## Product design

The creative process of product design often consists of four phases: problem definition, idea generation, idea selection and idea communication. Product prototypes and artefacts can be developed during different phases and used for different purposes (e.g. idea generation, communication).

In line with an user centered methodology outlined earlier in this deliverable many different creativity techniques can be used within the different phases of product design. Often it becomes important to assess the look & feel, the quality or the acceptance of a product using a different technique than an interview.

An example of a creative technique is using a cartoon based mood assessment test. ’PICK-A-MOOD’ is the name of such as test. This test has been developed and validated at Deft University of Technology and Eindhoven University of Technology with the double goal in mind [132]. First it can be used as a tool for measurement (i.e. to enable researchers to measure the moods of their respondents) and second as a tool for communication (i.e. to enable people to communicate their mood in social interactions), hence the instrument was not specially designed for product design purposes but nevertheless very useful within this context as it requires little time and effort of the respondents. The mood that the use of a particular prototype/product induces can be a valuable criterion for selecting ideas or assessing the quality of your final prototype/product.

The use of cartoon characters enables people to unambiguously and visually express or report their mood in a rich and easy-to- use way. The instrument consists of three characters that each express eight different mood states, representing four main mood categories: energized-pleasant (excited and cheerful), energized-unpleasant (irritated and tense), calm-pleasant (relaxed and calm), and calm-unpleasant (bored and sad). Hence it is based on the bi-dimensional structure of arousal and valence.

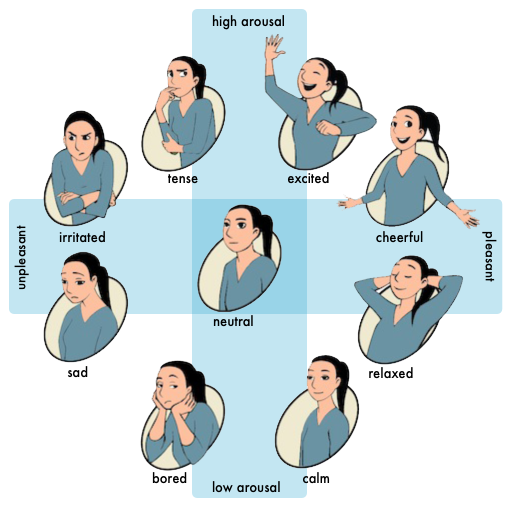


Figure 6. PICK-A-MOOD cartoon characters.

## Services

This section includes two concrete examples on how UX and especially emotional UX can be used for improving services.

In the Castel Detect solution, the emotional UX is detected during the phone call from the voice and language parameters. The personnel see online the current emotions of the customer and this enables personnel to react to the customer emotions accordingly (<http://www.casteldetect.com/>). Caster Detect is able to detect stress, anger, enthusiasm, contentment and even learn new emotions.

Emotion detection has also been used in interactive voice detection systems for adapting the human-computer speech dialog if e.g. angry response is detected [134]. The system is detecting three levels of anger (no, low, high) using prosodic features, lexical features and dialogue history features of the previous dialogue prosodic. The system changes the wording of the dialogue or directs the call to a real person when anger is detected.

## Web and Smartphones

**Mobile devices usability**

Nowadays, the multiplicity of devices, especially mobile web connected (smartphones, and tactile tablets) devices, means that users can access information and services everywhere and at any time. This strong presence raises the question of the usability of these devices to measure user experience.

Before building solutions to measure user experience, there are many questions about mobile device usage we must address. Hereafter, we present a synthesis of mobile usability studies made by Jeff Sauro [138]:

* Web connected “smartphones” represents around 50% of US's and 62% of UK's mobile phones.
* Tablets are owned by around 20% of the US population over 18 and some data suggest that they are more similar in their usage to desktop computer. Most of people use full-size tablets at home and in the evening.
* Regarding apps, most people have over 20 apps but most people forget what apps they have downloaded.
* Users who own both a tablet and a smartphone were significantly more likely (63%) to indicate increased overall mobile spending than owners of smartphones only (29%).

From these data we can extract some relevant information for the measuring of user experience with mobile devices. First of all, even if very similar from a technological point of view, web connected smartphones and tablets are rather used for different tasks and in a different context. Indeed, data presented by J. Sauro show that tablets are mostly used at home and can replace desktop computers. On the other hand, smartphones are more represented than tablets in the US and Europe population and have the advantage of the mobility of use.

To conclude, measuring user experience with web connected mobile devices requires making a distinction between 1) smartphones: UX measured in various contexts (place, time, outdoor/indoor...) and 2) tablets: UX measured mostly at home and in the evening.

**An example of measuring user behaviour with mobile phones: some constraints**

In this section we review an example of the use of mobile phones to measure user behaviour by Teeuw, W.B. et al. [135]. These authors have proposed to measure and analyse user behaviour in order to influence travel behaviour with mobile phones. Their approach provides feedback to the traveller, by information sharing or by providing positive incentives to traveller, to improve mobility in a city. Travel behaviour is influenced by a personalized approach based on the fact that the information is targeted on individual travel behaviour.

As perspectives, the authors present advances in the analysis of human behaviour by the integration of many real-time sensors from mobile devices and also city infrastructures. They also consider research on the role of mobiles in ambient environments, specially the possibility for environment to trace mobile (e.g. Bluetooth). The authors also highlight the power management problem specially when GPS is used. They finally discuss about the problem of the protection of personal data. Thus, even if mobile devices are promising to measure user experience (sensors, connection with networks...) one must keep in mind that protection of personal data and, mainly, power management remain a great challenge.

**Smartphones/tablets based games: some use cases**

The first example we would like to emphasize is the educational game designed for mobile devices (tablets or smartphones) and the work by [136], which consist in evaluating the implementation of the game and exploring player's aptitude about the game. Among other results, this work shows that eye-tracking can provide important information from the quality of the game design. However, the authors note that eye-tracking data must interpreted with care and complemented with other methods. They suggest that game designers should include eye-tracking in their toolbox and use the possibilities it provides. Interestingly, web connected mobile devices such as tablet or smartphones are now equipped with webcam and the question of their use to measure eye-tracking can be raise. Other information provided by the various sensors encountered on such devices can be used to complement eye-tracking (e.g. accelerometer, position of fingers and pressure on the surface, etc.). The authors have also pointed out the influence of the test platform (the model of tablet). This first example illustrates that usual tablets or smartphones provide various sensors that should be exploited to render user experience.

The second example we wants to cite is the enrichment of mobile gaming by adaptive mobile cloud computing [137]. In this paper, the authors propose to dynamically adapt the richness and complexity of graphic rendering, through a rendering adaptation technique, depending on the network and computing constraints. They demonstrate that the user experience is significantly improved by their adaptation technique. This work is an example of how mobile web connected applications can be dynamically adapted to improve user experience depending on technical constraints (e.g. network and cloud computing capabilities). The domain of Cloud Mobile Media (gaming or others) should be highly demanding in measuring user experience on mobile devices.

**Conclusions**

In term of mobile web connected devices, we must make the distinction between tablets, mostly use at home, and smartphones which are more employed in a mobile context. Both devices should be considered for the development of empathic products but certainly for different tasks.

In case of a mobile use (e.g. smartphones), some constraints must be kept in mind, such as the battery consumption and the privacy of personal data. This is specially the first point that would require care in the development of empathic products.

Gaming is an interesting domain providing use cases and showing the consistency of mobile devices to measure user experience thanks to the multiple sensors (camera, accelerometer, pressure sensitive surface, microphone...) that could be used to develop empathic products. Thus, mobile devices are not only capable to measure user experience in multiple contexts, but these devices are also equipped with sensors that can be switched to intelligent interaction technologies to capture the intentions and emotions of users. The provided feedback can be used to enhance the empathic application. Then, the adapted empathic application can be evaluated by the same way and so on, following an iterative development. Movements of the device (measured through the accelerometer or camera, accuracy of pressure point on the sensitive surface, ambient noise are example of data that can be exploited to adapt an empathic application for mobile devices.

## Learning

Design interactive (designinteractive.net) has developed Affective Virtual Environment Training System. The system is used for eliciting a more realistic training environment using emotional induction techniques that is required in some professions in a state of emergency which is essential e.g. in military or pilot training [139] [140]. The emotion detection is done using VRSonic’s RADIS (Real-time Affective State Detection and Induction System) which detects emotion from face and voice [141]. The extracted features from speech signal include pitch, energy, formants, Mel-Frequency Cepstral Coefficients (MFCC), and speech rate. From the real-time video input geometric and holistic features are extracted. The extracted feature vector was classified by the Support Vector Machine (SVM) to detect the trainee's affective state.

## Digital Signage

A Digital Signage in a public space has to meet some requirements before it is able to deliver its message to a user. If the user passes by the digital signage without even looking at it then there cannot be any interaction either. If the implementation of the digital signage does not pay attention to the emotions and intentions and needs of the user then the user’s motivation may easily die down and s/he gives up using the digital signage. Moreover a digital signage has to overcome the “Display Blindness” [70] effect, i.e., people tend to ignore public displays intentionally or subconsciously because of information overload that makes them highly selective and ignore large amounts of information. Next we present current examples of digital signages. The UX research framework in the Chapter 5.2 is referred when evaluating how the systems try to measure UX and its components.

**Looking Glass**

Looking Glass [71] is an interactive public display installed in a shop window. It piques the attention of the passers-by by showing their images on the screen and mirroring their incidentals movements to communicate its ability to interact. This design is based on the fact that humans are sensitive to recognize human motion even peripherally and even more so when their own movements are shown on their screen. In an experiment [71] it took only about 1.2 seconds from the users to recognize that their own movements are shown on the screen. Often passers-by recognized the interactivity only after they already had passed the screen. This observation made them come back which is called a *landing effect*. This observation is consistent with the limited capacity model (see Ch. 2.2.1) where the stimuli are processed unconsciously and if the stimuli have some meaning to the individual then it is processed more accurately consciously.

In the experiment the user’s image was displayed on the screen when he entered inside one meter from the camera. This sudden change on the screen may elicit the surprise effect [69] and so attracts the user’s attention. Another detected way to catch the attention of the passers-by was the *honeypot effect*. This effect took place when other passers-by noticed the interaction of some other people. By watching the interacting people the observers learned themselves how to use the interactive screen and thus it made it easier for them to start interacting with the screen.

To motivate the users to continue to interact with the display in this Looking Glass experiment the users were offered a simple game where they played with animated balls. One finding in the experiment was that almost no passer-by interacted alone. This may be due the nature of the interaction. It is too embarrassed to play alone a computer game in front of a shop window in a public place doing extensive hand gestures.

Showing the user her/himself on the screen uses self-expression symbolism to evoke a user her/himself related symbolic aspect of non-instrumental quality component of the UX (see Chapter 5.2). It also elicits positive behavioural tendencies, i.e., the motivational component of emotional reactions as part of the UX. These are measured by the numbers of the users stopped at the screen and how quickly they recognized themselves on the screen. The learnability aspect of the UX was measured by observing the passers-by watching other people interacting with the system and how quickly they felt that they have learned the game and came along to the game.

**Avatar by Emotion AI**

Avatar by Emotion AI [72] is a digital character that uses intrinsic human response mechanisms to catch the attention of the passers-by. On the digital signage is shown a human like avatar whose gestures and facial expressions are generated automatically in real time. Avatar technology uses camera attached to the screen to track the passer-by’s location nearby the screen. It uses, e.g., the position of the nose to determine which way the person is looking and then the angle between the avatar’s eyes and the person’s eyes can be calculated and determine if the eye-contact has been made.

To pique the attention the avatar watches the passers-by and changes its posture and eye-direction to indicate to human individual that it has something to say. Avatar utilizes the human beings’ capability to register small movements in their peripheral vision and need to turn and see what it is. When the eye-contact with the user has been made, the avatar can deliver its message. To keep up the interaction the avatar expresses non-verbal human traits like gestures, breathing, blinking eyes and changing posture to engage the audience also emotionally to the interaction.

This system is based on the perception of non-instrumental qualities of UX when it tries to arouse interest among passers-by. It measures the user’s presence and gaze-direction to find out when the user is experiencing willingness to listen its message. To evoke positive emotions the system’s avatar mimics human gestures and postures. These evoked emotions are not measured.

**ReflectiveSigns**

ReflectiveSigns [73] is a public display that measures audience’s reactions to the presented content in different contexts and learns audience’s preferences from the measured reactions and so in the future it is capable to present content more effectively in a particular context. After presenting particular content, the audience reactions are measured with sensors and a learning mechanism is then used to learn the connection between the content and reactions in a certain context. The purpose of this content adaptation to the user in a certain context is to increase the usefulness aspect of the UX. The nature of the interaction between the sign and the audience is incidental at the beginning, but as soon as the audience understands the connection between their reactions and the content on the sign, then the interaction may be called classical, i.e., conscious interaction. So at the beginning the measured UX is more the perception of non-instrumental qualities, and they are supposed to elicit such an emotionally positive UX that the user continues to interact with the system.

The only sensor to measure the audience’s reactions in the current implementation is the face detection that is used to measure the audience’s view time, i.e., to measure the audience’s motivation to attend to the display. Also when some content is shown the number of faces looking at the sign is measured. Cameras were installed on the top of the signs. All contents are presented without audio.

**Interactive Public Ambient Displays**

Interactive Public Ambient Displays [74] observes the passers-by via a motion tracking system and adapts its content to the contextual cues of audience such as body orientation and user distance. The contextual cues are used for implicit interaction. For explicit interaction the system uses simple hand gestures and touch screen input. Explicit interaction is to handle individual’s personal information and the implicit interaction is with public information.

Interactive Public Ambient Displays is designed to provide information in the user’s periphery of perception. Its interaction framework consists of four continuous phases and the user’s current phase depends on the distance from the display. The phase changing is signalled using implicit interaction such as body movement, body location, and head orientation. The farthest phase is Ambient Display Phase that is a neutral state showing a range of categorized information simultaneously with updates occurring slowly. The next phase toward the display is the Implicit Interaction Phase which is activated when the system recognizes from the user’s body position and orientation that the user is ready to receive information. If the passer-by approaches the display and provides an implicit cue such as stopping in front of the display then the system enters into Subtle Interaction Phase where the public information is augmented with user’s personal information, if available. The duration of this phase is no more than one minute that is enough time for the user to make some explicit actions to select and navigate an information source. At this phase the presented information is not too personal because the display is still shared with other passers-by. The nearest phase is the Personal Interaction Phase where the user is moved closer to the screen and is able to touch his personal information items on the screen. The user is at this phase so close to the display that his body can help to occlude the view of their personal information.

The system measures only the distance of the user and try to recognize him/her. Based on the measured distance of the user the system increase the private nature of the displayed content at the same time when the user comes closer. When the user is far the displayed content is public in nature and the system try to evoke UX that is based on the symbolic and aesthetic aspect of non-instrumental qualities to evoke such emotional reactions that make the user to experience curiosity to come closer. Making the content of the interaction more private when the user is coming closer to the display the system makes her/him experience subjective feelings and behavioural tendencies which are aspects of emotional reactions that increase the positive user experience. This UX contains also the perception of instrumental qualities, i.e., the system is experienced more useful.

**eMir**

Electronic Mirror System, eMir [76], is a digital signage that shows short videos of human faces expressing different emotions as reaction to audience’s detected emotions. The system observes the audience with camera installed on top of the sign and uses face detection software to find out if someone is watching the display. The software is able to determine gender and emotion from the facial expression. It is capable to recognize five emotional states of the users: a neutral state, happiness, sadness, angriness and surprise. The gender may be undefined, female or male. Thus there are altogether 15 different scenarios that might occur. The system tries to find out the emotional state as well as the gender of the watcher and using this information it tries to react in such a way that encourages interaction. The basic idea is to use videos of human faces to mirror the users’ emotion and gender and hence attract the users’ attention and lead to the interaction.

The implementation of eMir is based on the psychological human trait that faces tend to attract people attention. So eMir’s display shows a life-sized human face with natural movements and expressions to catch an eye-contact with a passer-by. In the next step the display’s friendly face smiles to passer-by to make her/him to feel comfortably. And then the possibility to interact with this friendly face on the display is expecting to appeal to peoples’ curiosity. The system is based on the perception of non-instrumental qualities of UX. The visual aesthetic aspect is used to attract the passer-by and when the system detects that someone is watching then it shows emotionally appealing videos of human faces to increase the emotionally positive user experience. The system measures the emotional state of the user and adapts the showed videos to that state.

After one month experiment the findings were promising. Most users react with curiosity to the display and try to interact. The effect was stronger when the presented face is familiar to the user. The friendly empathic faces had a positive effect on the atmosphere. But the experiment also reveals the fact that some users reject such a system because a negative attitude towards cameras, they didn’t like to be observed.

**Contact Exploiting Display**

The goal for Contact Exploiting Display [77] is to utilize the human emotional, cognitive and physical state for improving the efficiency of outdoor advertising. The target is an advertising display that reacts in adaptive way to users’ psycho-physiological states. The advertising displays address to two kinds of adaptations. The first is adaptation to the active environment and the second is adaptation to the individual user. Adaptation to the active environment means adaptation to many people in front of the display and the relationship among them. If the system detects that there is only one passer-by then a reactive advertisement is shown. If in front of the display there are a manageable number of passers-by then an initial for an interactive game is given. Adaptation to the user means balancing the content of the display according to the user’s cognitive-emotional state. The user’s awareness of the content is detected from his gaze and the user’s approval of the offered interaction is detected from his facial expressions. For example, if there are indications of the disapprovement of the offered content then the system can transit the content from informative toward more entertaining.

The measured number of people in front of the display has an impact on the content and also on the UX the system tries to bring about. If more than one user is observed then the desirable UX is just to have fun with an interactive game. If only one user is observed then a reactive advertisement is shown. The reactivity means that the system is measuring the motor expressions of the user's emotional reactions. If the measured emotional reactions do not indicate positive UX then the content is changed toward more entertaining. The cognitive appraisal aspect of the emotional reactions component is measured from the user's gaze direction and it is then used as an indication of the user’s attention on the content of some specific display regions.

In a prototype of Contact Exploiting Display a vision-based sensing framework was used because it allows collection information about user positions, orientations, movements and facial expressions as well as the environment features. To pique the audience’s attention a dynamic image of rotating car is shown that implicitly reacts to the passers-by. The subsequent content depends on whether the display caught their focus and if the user is attentive and what is the detected user’s emotions. The aim is to motivate the user to continue using the display. So if the user is expressing more or less neutral emotions then s/he is able to explore the car from the desired viewing angel. But expressions like smiling and anger lead to a funny animation of the car. That is the actual content of the message is delivered only when the user is in the right mood.

# Discussion

The concept *User Experience* used in this project is defined as to be something that has a meaningful and affective content having a nuance of novelty and uniqueness which can lead to a personal change. Due to the subjective nature of the meaningful experience it cannot be produced the same way for every subject. UX design has to take into account not only the HCI design issues but also the overall impression and emotions resulting from the interactions between the user and the product. It is worth noting that the experience the user has about the product evokes also emotions towards the provider of the product. In order to design and implement products that produce better user experience we have to understand the human factors behind these experiences. Also to know the elements of the user experience makes it possible to measure them.

Psychological studies have provided a lot of theoretical as well as practical information about the emotional, motivational, and cognitive factors that affect human behaviour. Understanding these human factors gives us a good basis to build computational models for empathic interaction between human user and computer. While there is not just one commonly approved theory of emotions and their effects on human behaviour, we can build on the concrete discoveries made in the psychological experiments showing plausibly how different emotions have been elicited and measured.

The more classical emotion theories see emotions as discrete states, i.e., at a given moment a person is experiencing just one emotion which has a unique profile in physiology and behaviour. However subjects have reported that they may experience many different emotions at the same time. This result is explained by the dimensional theories of emotions so that the emotions are organized on a few fundamental affective dimensions and expressed emotion is a certain point in a multi-dimensional space. In both cases, a common attribute for the affective states is that they are expected to elicit physiological reactions that can be observed as overt expressions and behaviours. Overt emotional expressions enable emotional interaction between people. Human being has an emotional need to feel that his/her emotional state is understood and accepted. On the other hand human being has also skills to understand others’ emotions, i.e., to be empathic towards others. Empathic accuracy tells how well one has succeeded to judge the emotional state of others.

The aroused emotion has also the power to direct and guide the person’s attention and cognition even if the person is not him/herself aware of his/her current emotional state. Especially the periphery is something that we are attuned to without attending to explicitly. So, e.g., in a public space a signage we want the user to pay attention to must not be disturbingly noise or colourful but rather stay in the periphery and express cues about its content, and if they are meaningful for the passer-by, they evoke positive and attractive emotions and the signage captures the passer-by’s attention. In general, stimuli that elicit emotion are also processed more easily. To motivate the passer-by to continue the interaction may need a different approach. Just trying to keep the user happy and in a good mood may not always be a good motivator, although positive affect generally enhances thinking and problem solving. For example, there is evidence that motivation is less related to momentary affective state among adolescents than among elderlies. In other words, the elderlies are more willing to receive positive affect stimuli that maintain their positive affective state, whereas the adolescents are willing to receive stimuli that strength their feeling of independency and maturity.

A central feature of human emotion is its multi-component character. According to Scherer [111] an emotion episode has five components with their own representations and manifestations. All of these components cannot be measured in the objective and unobtrusive way and it follows also that the user experience cannot be fully measured without asking directly the user. However there are measurement tools that can be utilized automatically during the human-technology interaction. These tools can offer a good estimate of the emotional component of the overall user experience and that may enable the system to function more empathic way.

Facial expressions are widely used source for measuring users’ emotions. Automatic facial expression analysis can be made with the image data received with a basic web camera. Paul Ekman’s classification of six basic emotions based on prototypic facial expressions as well as FACS are widely used methods to classify the observed facial features. Current systems that recognize emotions from facial expressions seem still to be in their early experimental phase. Typically they require that the user’s neutral face has been recorded first to be used when recognizing the changes in the facial features. Facial expression recognition technology is in the rapid development phase so it is reasonable to expect that soon this technology is mature enough to be used in real time systems in real life situations to recognize users’ emotions. And already today the facial expressions recognition is used in commercial systems by, e.g., *Sensory Logic* who uses the automated facial recognition in combination with filling out questionnaires. Eye gaze direction analysis is a good addition to the facial expression analysis. Also eye gaze direction can be detected with webcam based solutions. Also current eye gaze systems typically require some kind of calibration before they can be used.

The connection between emotions and motor system is utilized in the systems that measure how a user uses keyboard and mouse during data input. Differences, e.g., in typing patterns and keystroke frequencies and mouse clicks are found between affective and neutral groups when recorded performance logs were analysed. If the analysis is conducted online then it may be feasible that the system measures the changes in the use of the input devices and predicts, e.g., the user’s current stress level and also whether it is increased or decreased. Also the textual content of the input is analysed to find out whether a text conveys a positive, negative, or neutral sentiment. Compare to audio analysis where no semantic or word information is analysed but classically only the acoustic features of speech is used to make it faster to recognize expressed emotions. In the system of *Castel Detect* the calling customer’s emotional status is measured immediately from the voice and language parameters and in that way the personnel can quickly adjust their feedback according to the customer’s state. Textual input with written words makes it easier for expression sentiment analysis to determine the user’s opinion about the matter in hand. Knowing the user’s opinion or the changes in it offers the system a hint of what kind of the feedback the system may give to the user in order to make the user to continue the conversation.

New smart phones give a whole new perspective to UX measurement by offering a mobile and always accompanying measuring station where sensors can be attached and it has means of communicating with its environment utilizing its collected information to improve user experiment. They give the user the opportunity to be aware of the possibilities in his/her environment but also the environment can be aware of the user – as far as the user allows. Typically the possibilities of the smart phones are found first by the game makers but also a new way to implement any application that needs information outside its own boundaries may benefit, e.g., the new adaptive mobile cloud-computing where the use of an application is not restricted in any particularly place or in any particularly smart phone and hence increases the experiences of freedom of the user.

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1. Stakeholder: individual or organization having a right, share, claim or interest in a system or in its possession of characteristics that meet their needs and expectations (ISO 9241-210: 2010). [↑](#footnote-ref-2)
2. Note that predicting election results from Twitter is still a controversial topic (see [96]) [↑](#footnote-ref-3)