LINKING AN INTEGRATED FRAMEWORK WITH APPROPRIATE METHODS FOR MEASURING QOE

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ABSTRACT

Quality of Experience (QoE) has recently gained recognition for being an important determinant of the success of new technologies. Despite the growing interest in QoE, research into this area is still fragmented. Similar - but separate - efforts are being carried out in technical as well as user oriented research domains, which are rarely communicating with each other. In this paper, we take a multidisciplinary approach and review both user oriented and technical definitions on Quality of Experience (including the related concept of User Experience). We propose a detailed and comprehensive framework that integrates both perspectives. Finally, we take a first step at linking methods for measuring QoE with this framework.

Index Terms— QoE, User Experience, Measurement

1. INTRODUCTION

In today's ICT environment, the users' expectations, satisfaction and (perceived) quality of experience (QoE), are being recognized as crucial determinants for the success of the technology, even more important than technological performance and excellence, defined as Quality of Service (QoS). Hence, the ultimate measure for future media networks and services is how the end user perceives and experiences the quality of these new services. However, the concept of Quality of Experience bears with it several problems which need to be solved in order to measure it accurately and use it to improve new products and services.

First of all, the term Quality of Experience is very ambiguous, and is attributed a different meaning depending on the background of the author(s) using it. In a technical sense, QoE is "*the overall acceptability of an application or service, as perceived subjectively by the end-user*" [1]. It is often operationalized by measuring how users perceive changes in individual technical attributes, such as video quality or image resolution [2]. In the domain of Human-Computer Interaction (HCI) however, the related term User Experience (UX) is used to address the user's perspective on QoE, which is more holistic and addresses the overall experience users have before, during and after interaction with a system [3]. As important research is being carried out in both domains, but they rarely interact, it is important to create a comprehensive framework of QoE that addresses both technical and user-centric aspects of this concept.

Secondly, there is still a prevailing gap between QoE (user perception) and QoS (service performance). As a result, one of the major challenges in tomorrow's cross-media ICT environment consists in narrowing this gap between Quality of Experience and Quality of Service with the aim of making media technologies and services really user-centric. To date, several types of research already have their focus on QoS and QoE optimization and measurement, but it still happens too fragmented. The HCI field for example has a long tradition in user-centered design, involving end-users throughout all stadia of the development process. One of the activities in this process is the iterative evaluation of the product being designed, which includes measuring the satisfaction of users with the product. Although this already puts the focus on enhancing QoE, a clear link with QoS is missing. In such a user-centered design process, user expectancies, contextual aspects and usability are often measured (related to QoE), while the more technically oriented research domains have rich traditions in measurements and monitoring on network as well as device performance level (related to QoS). This is valuable, but too fragmented research in other words, which lacks integration in a more comprising framework.

This challenge is not just a theoretical problem to be solved. For the supply-side, consisting of companies currently developing applications and services for the interactive media environment of the future (e.g. mobile internet, interactive TV, online gaming, online communities, …), the most important success factor is having an optimal match between QoE and QoS. In order to tackle this challenge, objective technical QoS metrics need to be linked and correlated to more subjective QoE measures like usability, user expectations and user experiences.

In this paper, we introduce a framework, including technical and user aspects, and link this framework with a related QoE methodology in which each of these measurements can be integrated. After an overview of

existing definitions of Quality of Experience and User Experience, we will present an integrated framework that intends to address several perspectives on QoE. Finally, we will describe our initial attempts at linking different methods for measuring QoE to this integrated framework.

2. DEFINITIONS OF QUALITY OF EXPERIENCE

Any attempt to measure something should start from a definition that describes the concept. This can then lead to a framework which offers a way to operationalize its different components. Both Quality of Experience and User Experience have recently been defined, offering a starting point for our research.

The International Telecommunications Union (ITU) defines Quality of Experience as "*the overall acceptability of an application or service, as perceived subjectively by the end-user*" [1]. In [3], we can find ISO's draft definition of User Experience, which is very similar to the ITU's definition of QoE: "*A person's perceptions and responses that result from the use or anticipated use of a product, system or service*". Both definitions clearly put the judgment if an application or service satisfies certain needs in the hands (or rather heads) of the end-user. The latter definition also explicitly mentions not only the use of the product as a source of a person's perception of it, but also the anticipated use, i.e. the user's expectations of the product.

In contrast to these standardized definitions, which are limited in scope, there is still a lot of discussion in different communities about the components of the concept of experience, both for QoE as well as UX. Indeed, missing from these standardized definitions are qualifiers which allow us to measure or assess the users' perceptions and responses when using a system. If we want to match QoE with measurements that cover the whole spectrum of the user's experience, we need a more elaborate definition which can be translated into a more practical framework.

Most recently, Law et al. [3] published their survey results on a researchers' and practitioners' community definition of User Experience. They tried to elicit the requirements for a consensual definition. Five definitions were presented to the community and although their aim was not to decide on which was the best, the slightly more favorable definition describes UX as "*a consequence of a user's internal state (predispositions, expectations, needs, motivation, mood, etc.), the characteristics of the designed system (e.g. complexity, purpose, usability, functionality, etc.) and the context (or the environment) within which the interaction occurs (e.g. organizational/social setting, meaningfulness of the activity, voluntariness of use, etc.)*". This definition already offers more detailed descriptions of what can be measured, or at least which aspects have an influence on the users' experience. Interestingly, parts of this definition are also reflected in the notes which the ITU published alongside the definition of QoE [1]: "*1/ Quality of Experience includes the complete end-to-end system effects (client, terminal, network, services infrastructure, etc). 2/ Overall acceptability may be influenced by user expectations and context*". In addition to the mere subjective perception of the end-users, these notes indicate the importance of the context in which a system is being used, as well as the expectations users have about the system. We also find similarities with the definition of UX in a definition proposed by Patrick et al. [4], which states that QoE equals "*the characteristics of the sensations, perceptions, and opinions of people as they interact with their environments. These characteristics can be pleasing and enjoyable, or displeasing and frustrating*". This definition extends the notion of user's perceptions to include sensations, perceptions and opinions, and linking them with emotional qualifiers such as pleasing, enjoyable or frustrating. These more detailed – albeit not standardized – definitions offer more specific handles for methods needed to measure the level of QoE of certain systems or applications.

We can conclude that – even though at first sight there are many differences between a user and technical perspective on QoE – both technically oriented as well as user-oriented definitions acknowledge the impact of specific user characteristics (e.g. emotions, motivation, and expectations) as well as the context in which the user interacts with the application or service. However, definitions are just a first step for understanding a concept, and need to be operationalized in order to be able to measure its components. A framework can serve exactly this function. In the next paragraph we will introduce some existing frameworks related to QoE and UX, and propose our integrated QoE framework.

3. A COMPREHENSIVE QOE FRAMEWORK

Several attempts have already been made to create frameworks for both QoE and UX. However, as we have already argued, in order to be able to accurately measure a user's perception of a certain system, we need an approach that includes a technical as well as a user perspective, and this is what is lacking in most of those frameworks. Two notable exceptions are Kilkki's QoE framework [5] and the taxonomy from Möller et al. [6].

Kilkki [5] makes a strong case for a holistic approach to QoE, and even advocates establishing a specific research community dealing with these issues from a multidisciplinary perspective. He presents an initial framework which bridges different research communities, and also introduces the person as a customer, not just a user, of an application. His framework identifies the relationship between existing concepts such as QoS and QoE, as well as new concepts such as QoUE (Quality of User Experience) and QoCE (Quality of Customer Experience), but does not

explain in more detail the components of QoE itself. Nevertheless, it is an interesting high-level view showing the complexity of the relationship between QoS and QoE.

Möller et al. [6] present a more detailed taxonomy of QoS and QoE aspects of multi-modal human-machine interactions, as well as factors influencing its QoS. This taxonomy is closely related to the framework we present here, and is also intended for linking with measurement tools and metrics in order to facilitate comparable evaluations between different systems. Although there are many similarities with our framework, including a combination of a technical (QoE) and user (UX) perspective on experience, our framework tries to extend their taxonomy by including the most recent insights from HCI research, where for example user expectations, changes in use over time and different layers of context play an important role.

In [7] we have already presented an initial conception of QoE and linked it with measurement tools for use in a mobile Living Lab context. Although the results of using a mobile agent for monitoring QoS and QoE as well as contextual factors were promising, the initial QoE conceptualization needed further refinement and additional measurement tools were needed.

With the framework presented in this paper, we want to give more detailed insight into the different user aspects that influence or are influenced by using a specific application or system, constituting the QoE, and which can offer concrete guidance for using specific QoE measurement tools. The framework was created based on several interdisciplinary workshops including researchers from backgrounds such as sociology, communication science, (cognitive) psychology, software development, computer sciences, anthropology, human-computer interaction, and product design. Each researcher collected and presented relevant frameworks from his or her own domain, related to QoE or UX. Single components of each of the frameworks were identified, and were clustered using the affinity diagramming technique, making sure that similar concepts from different domains were combined. A preliminary framework was then created which included all the identified components. The framework was further refined by performing an extensive literature search for each of the components, which gave detailed insight into the different aspects of and relationships between the concepts. The resulting framework is presented in Figure 1. The framework consists of four main components: user, (ICT) product, use process and context. Each component consists of more detailed subcomponents, which we will explain in the next sections.

3.1. User

At first, similar to Kilkki [5], we make a theoretical distinction between a person and a user, although these are one and the same. For modeling purposes, this distinction is however useful. When using a particular technology or ICT product, an individual person is ‘introjected’ in the role of user. This usually happens at an unconscious level (e.g. when I use my computer, I will not suddenly feel less a ‘person’ and more a ‘user’). On the other hand, it can be argued that there are a number of specific characteristics and aspects that are mainly related to this user role (such as specific emotions or reactions), whereas others are more closely tied with the user as an individual person and influencing the user’s experience and interaction with the product from that level. The way a person uses and shapes a certain product (e.g. a mobile phone) and attaches value to it will probably be closely related to his or her general values, personality traits, life style, or norms at an individual and personal level. In order to be able to study these aspects, influencing the user’s Quality of Experience at an individual level, it is essential to make this distinction.

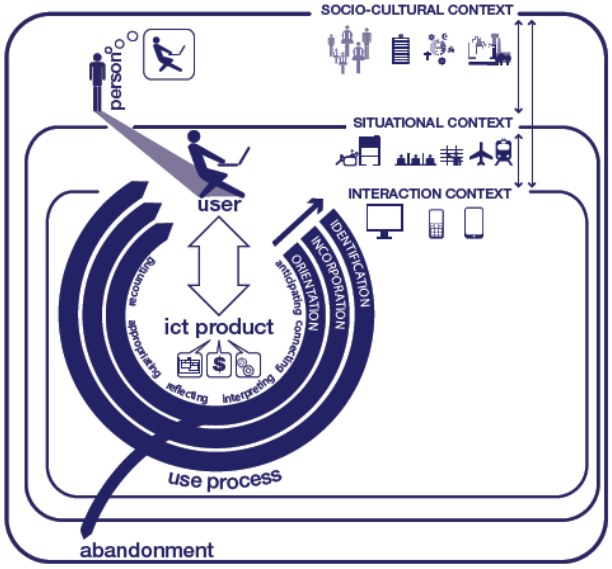

Figure 1: Integrated QoE framework

3.2. ICT product

A second aspect of our model is the ICT product. We do not only consider the technical aspects of a product, but also the economical aspects and the product characteristics (such as the user interface), represented in our framework through three visual icons connected to the ICT product.

The technical characteristics of the product include four dimensions (see Figure 2): application, network, device and context-sensor. The application refers to the software product running on the device and having the interface for the user to provide services. It works in a certain context (see further) and uses the network connection to make communication available. The device is the hardware that

runs the application and connected to the network in the given context. The user has an interaction with it via the input and the output parts. Both the device and the application have a direct influence on the QoE. The network is the infrastructure that provides communication between remote devices and applications. Finally, in ICT applications that are context-aware (especially relevant for mobile devices), the context-sensor is the entity sensing the location and environment in which the application and the device functions. The network and context-sensor(s) have an indirect influence on QoE. However, all technical components are directly related to each other.

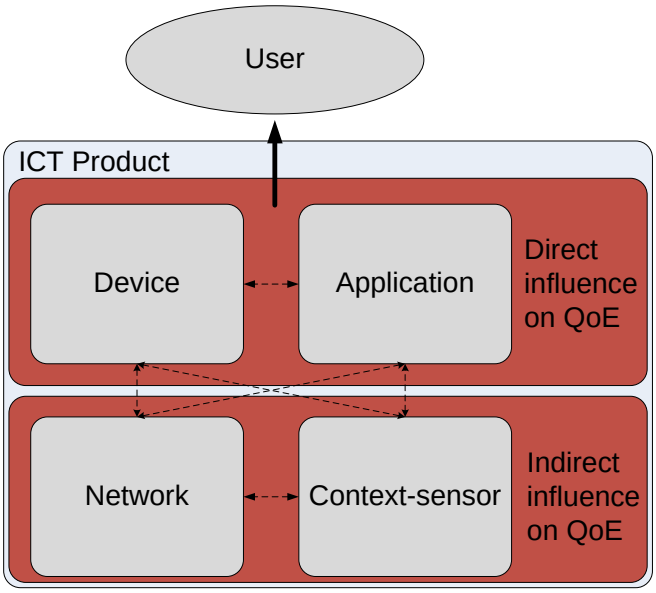

Figure 2: Technical dimensions of integrated QoE framework

The economic dimension of the ICT product relates to some of the key concepts of marketing [8], such as the product- and brand strategy, the pricing strategy, the positioning of the product in the market, and the market segmentation and identification of target groups. It comprises marketing-mix related aspects such as the traditional 4P's: Product, Place, Promotion and Price. The economical aspects of an ICT product, such as pricing and branding, can have a high impact on QoE, e.g. for many services that have complex pricing structures or brands like Apple that have established a very loyal customer community. This aspect is closely related to the notion of Quality of Customer Experience, introduced by Kilkki [5].

The product characteristics of an ICT product that have an assumed impact on the quality of the user experience can be classified as either instrumental product qualities or non-instrumental product qualities [9]. Instrumental product qualities are related to the user's goal achievement and include qualities such as utility, efficiency, functionality, effectiveness, usefulness and ease of use. The non-instrumental product qualities are especially related to user experience. Mahlke groups non-instrumental product qualities under three labels [9]: aesthetic qualities, symbolic qualities and motivational qualities. Aesthetic qualities are those qualities that yield a sensual experience. The most important perceptions in human computer interaction are visual, haptic and acoustic. Symbolic qualities refer to the symbolic dimensions of a product's appearance and relates to communication (those qualities contributing to the message that a product communicates, e.g. related to expression of personality or group membership) as well as association (those qualities concerned with personal memories). Motivational qualities deal with aspects that stimulate users to use a product, such as novel features. Although there are several other frameworks that classify and describe product characteristics, we think that Mahlke's approach is the most comprehensive, and most useful for including in our framework. Many of these concepts are also included in the taxonomy of Möller et al. [6].

3.3. Use process

The third component of our framework is the use process, referring to the fact that a user (preferably) does not interact just once with a product, but will do so on a regular basis. It is important when measuring QoE to realize that the user's perceptions can change over time, and are influenced by his or her prior expectations about the product.

Often a person already comes in contact with a product before actually using it. Before people start using a particular product or service, they tend to already have some kind of preconception (consisting of thoughts, feelings, expectations, ...) concerning this product, influencing their expectations about using the product for the first time [10]. This preconception can be based on a variety of sources, such as previous experiences with a similar product or with the product's brand, stories and experiences from other users, advertisements, personal skills or the lack of relevant skills to use the product.

After a user has adopted a product, and is using it more or less regularly, the actual use process starts. Karapanos et al. [10] make a distinction between micro-temporality and macro-temporality of the use process. Micro-temporality refers to the use process at a specific moment in time, describing how experiences are formed, modified and stored. This is usually short and well delineated, related to a certain experience (e.g. one use session). McCarthy and Wright [11] describe this experience by six sense-making processes the user goes through: anticipating, connecting, interpreting, reflecting, appropriating and recounting. These six processes explain how users actively construct an experience, and are included in our framework as different steps in one use-session.

Macro-temporality on the other hand refers to prolonged use over a longer period of time, consisting of different use sessions. As a user has more experience with the product, familiarity of the user increases, and this has an impact on how the product is being used. Karapanos et al. [10] argue that "the product qualities that make initial experiences satisfying do not necessarily motivate prolonged use". They describe three phases a user goes through when adopting a product: orientation, in which the user has her initial experiences with a product; incorporation, where the user tries to give the product a meaningful place in her life; and identification, where the user integrates the product in her lifestyle and it becomes part of her self-identity. In each phase, different product qualities have an impact on the user's Quality of Experience. These three phases are represented in our framework by visualizing three layers in the use process a user can move through.

A concept which is often missing in both micro-temporal and macro-temporal perspectives on use process is non-use or abandoned use. In the first case (non-use), it is useful to study reasons why people who form a-priori expectations of a product, with the intention of using it, consequently do not adopt or start using the product. In the second case (abandonment), there are users who have started using a product but stop using it for some reasons. Getting a better idea of how these reasons relate to product characteristics can help in the design of products that are better suited for these users and will stimulate its continued use. For this reason, abandonment is explicitly addressed in our framework.

3.4. Context

The fourth and final aspect of our framework concerns context. Although experience is an individual phenomenon, contextual factors are important influencers of Quality of Experience and User Experience [3]. As such, context is an essential component of a QoE model, but is often formulated very vaguely or used as a container concept for various intangible aspects of factors influencing product use. Furthermore, context is often analyzed post-hoc, where for measurement purposes we need an upfront view on the specific context. Finally, depending on the research community, context is often thought of as static, whereas we already described the dynamic nature of the use process (and thus the context). We therefore need to organize the different dimensions of context in our framework in a dynamic way, so it can help us to determine which elements can be measured in relation to QoE in advance.

Most useful to our framework is the model of context described by Mantovani [12], which integrates different levels of context. He represents the different processes of context in three layers in a hierarchical way from a very local individual level towards a societal level. The first and top level is the construction of social context, where the interplay between societal structure and action of the members of society within and with this structure leads to the creation of a shared history. The second level describes context as situations and the interpretation of situations in everyday life. These situations are created by interaction between the opportunities of an environment and the already available interest of the actors. Finally the lowest level is the local interaction with artifacts (i.e. the actual system, application or product), where users, tools and tasks interact with each other. The three context layers (socio-cultural, situational and interactional) are closely interrelated, as Mantovani states that "the user-system interaction nests within everyday situations as situations nest within social contexts" [12]. This is represented in our framework by using recursive arrows between the different context layers.

It is important to note that in our framework context is not to be viewed as mere information, but as a relational property which arises out of the activity. In our view, a user's internal characteristics (motivation, intention, values, goals, ...) and the product's or context's external characteristics (location, social aspects, technical components, ...) are both necessary and co-exist. In contrast to the view that context is only external, surrounding the user, our view on context is that these internal aspects meet the external aspects from the start of an activity all the way through to the end. The relation between a user's internal characteristics and the external characteristics emerging out of the action is the actual context that needs to be taken into account.

4. LINKING METHODS WITH THE QOE FRAMEWORK

Using this detailed framework of the different components of the user's Quality of Experience, we can identify which methods are useful to measure the different aspects, as well as determine relevant influences of the user's QoE.

When we relate current methods for measuring QoE with our framework, we see that they are mainly focused on the relationship between the technical aspects of the ICT product (e.g. device characteristics such as display size or application characteristics such as video resolution) and the user aspects (mainly satisfaction). The main method used for assessing QoE of e.g. audio or video quality is using participant ratings via MOS (Mean Opinion Score). Attempts to objectify these subjective measurements lead to methods such as Peak Signal-to-Noise Ratio (PSNR), Moving Pictures Quality Metric (MPQM), or Media Delivery Index (MDI) [2]. Our framework shows that, however useful, these measurements only address the QoE of a system or application partially, and do not take into account aspects such as context or use process, or more subtle aspects of a user's emotions or a person's values.

In the domain of HCI, on the other hand, many methods exist to measure product characteristics in relation to user's emotions and values (e.g. the AttrakDiff questionnaire or emo-cards [13]). More recently, experiments using psycho-physiological measurement tools (such as Galvanic Skin Response (GSR) or heart rate measurements) intend to objectively study user's emotions while interacting with products [13]. Again, these instruments are useful but also address only parts of our framework and do not include the technical product aspects.

The framework presented in this paper can help to classify these different methods in relation to the distinct components of QoE that can be measured, similar to what Möller et al. [6] have done with their taxonomy. However, we have shown in this paper that a more detailed framework can bring to the surface subtle aspects of QoE that need to be taken into account, and for which the most suitable tools, methods or metrics need to be determined.

5. CONCLUSION AND FURTHER WORK

In today's ICT-environment, it is no longer sufficient to measure only 'technological' performance or Quality of Service (QoS) since it is not the final goal anymore. The central goal should be to deliver high Quality of Experience (QoE) to the user. During the development of new systems and applications, it will be crucial to gain adequate insight in the user's expectations regarding Quality of Experience, its different components and its relation with technical performance metrics.

In order to achieve this, a multidisciplinary approach is called for, including both technical and user aspects. We argued in this paper that those two domains need to be brought together, and concepts as well as methods need to be combined in order to fully understand and improve a product's Quality of Experience. The integrated framework presented in this paper provides a detailed look at the different components of QoE, from both technical as well as user perspectives, offering concrete information on how they can be measured.

Currently, we are setting up several experiments with a number of these methods, in order to gauge their suitability in different use cases (such as games or IPTV services). In future publications, we will report on these experiments, and complete the framework by linking specific methods to each aspect of the QoE model.

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