Chapter 4
Factors Influencing Quality of Experience

Ulrich Reiter, Kjell Brunnström, Katrien De Moor, Mohamed-Chaker Larabi, Manuela Pereira, Antonio Pinheiro, Junyong You and Andrej Zgank

Abstract In this chapter different factors that may influence Quality of Experience (QoE) in the context of media consumption, networked services, and other electronic communication services and applications, are discussed. QoE can be subject to a range of complex and strongly interrelated factors, falling into three categories:

U. Reiter (✉)
Department of Electronics and Telecommunications, Norwegian University of Science and Technology, Trondheim, Norway
e-mail: ulrich.reiter@ntnu.no

K. Brunnström
Visual Media Quality, Acreo Swedish ICT AB and Mid Sweden University, Stockholm, Sweden
e-mail: kjell.brunnstrom@acreo.se

K. De Moor
Department of Telematics, Norwegian University of Science and Technology, Trondheim, Norway
e-mail: katrien.demoor@item.ntnu.no

K. De Moor
iMinds-MICT, Ghent University, Ghent, Belgium

M.-C. Larabi
Université de Poitiers, Poitiers, France
e-mail: chaker.larabi@univ-poitiers.fr

M. Pereira and A. Pinheiro
University of Beira Interior, Covilhã, Portugal
e-mail: mpereira@di.ubi.pt

A. Pinheiro
e-mail: pinheiro@ubi.pt

J. You
Christian Michelsen Research AS, Bergen, Norway
e-mail: junyong.you@cmr.no

A. Zgank
University of Maribor, Maribor, Slovenia
e-mail: andrej.zgank@uni-mb.si

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human, *system* and *context* influence factors (IFs). With respect to Human IFs, we discuss variant and stable factors that may potentially bear an influence on QoE, either for low-level (bottom-up) or higher-level (top-down) cognitive processing. System IFs are classified into four distinct categories, namely content-, media-, network- and device-related IFs. Finally, the broad category of possible Context IFs is decomposed into factors linked to the physical, temporal, social, economic, task and technical information context. The overview given here illustrates the complexity of QoE and the broad range of aspects that potentially have a major influence on it.

4.1 Introduction

In the context of media consumption, networked services, and other electronic communication services and applications, the human experience may be influenced by various and numerous factors that impact QoE. Some of these are more straightforward and their impacts have been thoroughly described and quantified. However, others are situation-dependent, are more difficult to describe, or are effective only under certain circumstances, e.g. in combination with or in absence of others. The Qualinet White Paper on Definitions of Quality of Experience defines these factors influencing QoE as follows:

Influence Factor (IF): Any characteristic of a user, system, service, application, or context whose actual state or setting may have influence on the Quality of Experience for the user [1].

In this sense, the Influence Factors discussed here are the independent variables, whereas the resulting QoE as perceived by the end user is the dependent variable. A certain set of Influence Factors may be described by users in terms of their impact on QoE. This means that users are not necessarily aware of the underlying IFs, but they are usually—to a certain extent—able to describe what they like or dislike about the experience.

In the following, we will group and discuss Influence Factors into three categories, namely Human IFs (HIFs), System IFs (SIFs), and Context IFs (CIFs), and we will give examples and in-depth explanations. However, the IFs must not be regarded as isolated, since they frequently interrelate, see Fig. 4.1. For example, HIFs and CIFs might determine in which way and how much the set of SIFs actually impacts on QoE: the same video clip might leave a totally different quality impression when watched on a mobile phone while riding on the bus than when watched on a TV screen in the user's home.

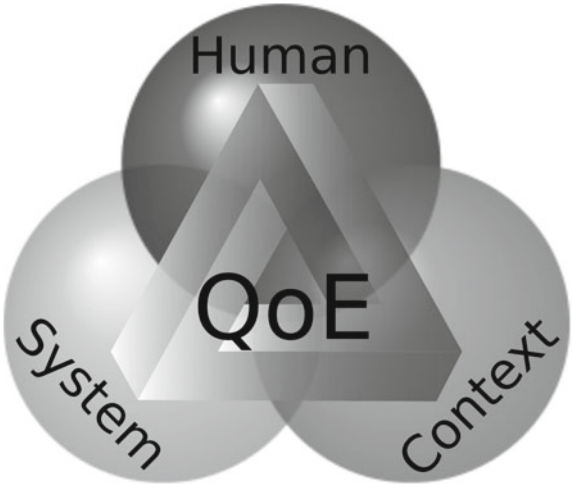

Fig. 4.1 Factors influencing quality of experience might be grouped into human, system, and context influence factors (IFs). These groups of factors frequently overlap, and together have a mutual impact on QoE

4.2 Human Influence Factors

> A Human Influence Factor (HIF) is any variant or invariant property or characteristic of a human user. The characteristic can describe the demographic and socio-economic back-ground, the physical and mental constitution, or the user's emotional state [1].

HIFs may bear an influence on a given experience and how it unfolds, as well as on its quality. They are highly complex because of their subjectivity and relation to internal states and processes. This makes them rather intangible and therefore much more difficult to grasp. In addition, HIFs are strongly interrelated and may also strongly interplay with the other IFs described in this chapter. As a result, the influence of human factors on QoE cannot only be considered at a generic level.

At the theoretical and more conceptual level, the importance of human factors and their possible influence on QoE is often emphasized [2–6]. Moreover, at a more specific level, some studies have investigated the influence of specific human factors on perceived quality [7] and QoE [8]. In most empirical studies however, human factors are only taken into account to a limited extent. Common examples of HIFs usually include gender, age, expertise level (expert vs. naïve). As a result, due to their inherent complexity and the lack of empirical evidence, it is still poorly understood how human factors influence QoE.

In this section, we give examples of human factors that may influence the perceptual and quality formation process. More concretely, we consider relevant factors at both low- and higher-level processing [4]. Following the definition of HIFs, we distinguish between (relatively) stable and variant characteristics of human users.

It is, however, important to note that the overview presented here cannot be considered as exhaustive and that the distinction between stable and variant factors should not be seen as a black versus white one.

Low-level Processing and Human IFs

At the level of early sensory—or so-called low-level—processing, properties related to the physical, emotional and mental constitution of the user may play a major role. These characteristics can be dispositional (e.g., the user's visual and auditory acuity, gender, age) as well as variant and more dynamic (e.g., lower-order emotions, user's mood, motivation, attention). At the same level, characteristics that are closely related to human perception of external stimuli might bear the strongest influence on QoE.

In the human visual system (HVS), visual sensitivity might be the most important factor influencing visual quality. Traditional psychophysical studies assume that visual sensitivity to external stimuli is determined by the spatial and temporal frequencies of the stimuli [9]. Additionally, due to the non-uniform distribution of photo receptors (i.e., cones and rods) on the retina, the HVS has the highest sensitivity around the fixation point of the eyes (fovea) and drastically decreases away from this point. As the visual sensitivity mechanism always plays an essential role in the perceptual viewing experience, QoE of visual content can significantly be improved by taking it into account. For example, visual sensitivity models have been widely applied in many advanced video/image compression algorithms and quality assessment methods [10]. Similarly to the HVS, auditory quality and QoE depend on the sensory processing by the periphery of the human auditory system (HAS) [11]. Here, too, auditory processing models are also widely applied in audio coding and even signal-based quality prediction models.

Higher-level Processing and Human IFs

Top-down—or so-called higher-level—cognitive processing relates to the understanding of stimuli and the associated interpretative and evaluative processes. It is based on knowledge, i.e. "any information that the perceiver brings to a situation" [12]. As a result, a wide range of additional HIFs are important at this level. Some of them have an invariant or relatively stable nature. Examples in this respect include first of all the socio-cultural and educational background, life stage and socio-economic position of a human user.[1] Especially in the context of studies investigating the monetary dimension of QoE (e.g., willingness to pay [13], see also Chap. 7), the latter is of crucial importance. The above mentioned HIFs are strongly connected to a set of other human characteristics, which can also be considered as relatively stable. These include, for instance, the norms and beliefs that one has, which are often determined at a higher level and therefore strongly linked to the wider social and cultural context. Another higher-level characteristic that is often related to the

[1] Note that the socio-economic aspects are also considered to be part of the CIFs, demonstrating that some factors are very hard to disentangle and categorize. This is reflected in the overlapping areas of IFs in Fig. 4.1.

viewing or hearing behaviors when consuming multimedia services, is guided by the attention mechanism. Attention is a cognitive process of selectively concentrating on certain external objects (e.g., visual or auditory) while paying less or no attention to others [14]. Objects might be salient not only because of their characteristics but also because surrounding objects are not.

Other relatively stable HIFs that we will now shortly discuss include individual values, needs and goals, motivations, preferences and sentiments, attitudes and personality traits. QoE in general and the relative importance of specific QoE features in particular, may be strongly impacted by a human user's goals and corresponding values and needs. Several classifications have been proposed in the literature: in [15] a distinction is made between terminal and instrumental values. The former are linked to ultimate life goals (e.g., happiness, pleasure, comfortable life) and the latter correspond to modes of behavior and more pragmatic goals (e.g., cheerfulness, ambition). Hassenzahl [16] distinguishes between "be-goals" and "do-goals" that people want to fulfill in this respect (see Chap. 3 for a more extensive discussion). Such goals are underlying drivers of human behavior and orient people's motivations. In the literature, it is argued that motivation is very personal and subjective and may vary in terms of level and orientation (i.e., nature and focus) [17]. A common distinction that is made in motivational research, is the one between intrinsic and extrinsic motivation. Whereas the former implies that something is done because it is "inherently interesting or enjoyable", the latter refers to "doing something because it leads to a separable outcome" [17]. Chapter 25 of this book briefly discusses the importance of intrinsic motivation in relation to quality of gaming. In general, however, and although previous research on human motivation has shown that the type of motivation may strongly influence performance and QoE [17], the influence of motivation on QoE is still a largely unexplored territory.

Preferences and attitudes can also be considered as rather stable factors that may influence QoE at a higher level. Scherer [18] defines preferences as "relatively stable evaluative judgments in the sense of liking or disliking a stimulus, or preferring it or not over other objects or stimuli". Desmet [19] refers to such intentional and dispositional (dis)likes oriented towards a specific object or event as "sentiments". Preferences differ from attitudes (i.e., "relatively enduring beliefs and predispositions towards specific objects or persons" [18]), which have a cognitive (i.e., beliefs), affective (i.e., associated feelings) and motivational/behavioral (i.e., action tendency) component. Attitudes, the external and internal variables that influence them and their translation into behavioral intentions, have been extensively studied in research on technology adoption and acceptance. However, only a limited number of studies so far have explicitly investigated the influence of specific attitudes on QoE. In [7], it was shown that attitudes and perceived quality are related. In the same study, the possible influence of personality traits was also investigated. Personality traits have been defined as "consistent patterns of thoughts, feelings, or actions that distinguish people from one another" [20]. In the literature on human affective states, the concept of 'emotional traits' is also used to address the characteristics of someone's personality that are dispositional and enduring [19]. In the study of Wechsung et al. [7], no direct link between personality traits and perceived quality was found. Another study [21] investigated the impact of users' cognitive styles—which are linked to personality aspects—on perceived multimedia quality (and more specifically, the level of understanding and enjoyment). However, no strong correlation was found.

It can be argued that another set of influencing factors at the human level have a more dynamic and even acute character. At the level of human affective states, the influence of moods and emotions on QoE (and vice versa) has increasingly gained research interest [7, 22–24] (see also Chaps. 3, 8 and 9 of this book). Although both are characterized by their relatively short duration, moods usually last longer (ranging from hours to days) than emotions (ranging from seconds to minutes). Moreover, moods are neither triggered by one particular object nor oriented towards it [25]. Emotions in turn are momentarily reactions, that are oriented towards a specific object or event. Previous research has pointed to the influence of different affective states on perception (for instance, on the time spent on processing mood-consistent details and on evaluative judgments [26], on the motivation to process information and attention to details [27], and on perception of time [28]). Next to these affective characteristics of a human user, several other factors that have a variant and unstable character may bear a significant influence on QoE. These include for instance previous experiences, (prior) knowledge, skills and capabilities, and expectations. Previous experiences can relate to lived, previous experiences, and memories based upon those experiences (see also Chap. 2, in which different levels of memory are discussed in relation to the quality perception process), but also to indirect previous experiences (e.g., through stories from others) and these—in addition to other sources—contribute to the relevant knowledge that a human user has. Similarly, expectations may also be based on a range of sources. In [29], expectations are defined as "pre-trial beliefs about a product or service and its performance at some future time". A difference is made between different types of expectations. In [8], the influence of expectations (related to the type of access network used) on QoE was investigated and shown. However, only a limited number of studies so far have investigated the influence of expectations on QoE (see e.g. [30]), or explored how the test setup may influence expectations [31]. Prior knowledge and skills may also influence QoE and the related quality formation process. As was mentioned above, in subjective testing, a distinction is often made between expert test subjects (due to their specific prior knowledge and experiences) and so-called naïve users. Whereas the former tend to be more critical and answering in a more consistent way, it has been shown in some studies that the latter are less focused on impairments and tend to give higher ratings [32, 33]. In a recent study [34] in the context of HD telephony services, participants were categorized into six user segments with different characteristics in terms of their prior knowledge, but also their attitudes towards adoption of new technologies and socio-demographic and -economic position. The results pointed to significantly different quality ratings between these segments and call for a combined approach to take HIFs into account. Next to knowledge, skills may also bear a strong influence on QoE, for instance in the context of gaming: a lack of skills to master the controls of a game may lead to frustration and prevent the player to make progress. This was one of the findings from a field study on QoE in the context of a location-based real-time mobile Massively Multiplayer Online Role-Playing Game (MMORPG) [35].

The above mentioned aspects may, but do not necessarily, have a direct impact on QoE. They can also bear an indirect influence on QoE through affective factors, attitudes and preferences, etc. In addition to the aforementioned criteria and factors, Human Influence Factors are intimately linked to technical characteristics of a system. These are the focus of the next section.

4.3 System Influence Factors

System Influence Factors (SIFs) refer to properties and characteristics that determine the technically produced quality of an application or service [1].

Whereas Chap. 6 describes the difference between technically produced quality, perceptual quality, and QoE, here we will discuss in more detail the classification of SIFs into content-related, media-related, network-related and device-related SIFs.

Content-related System IFs

The content itself and its type is highly influential to the overall QoE of the system, as different content characteristics might require different system properties. For auditory information, the audio bandwidth and dynamic range are the two major SIFs, and their requirements vary with the content itself, e.g. for voice/spoken content versus musical content.

When it comes to visual information, the amount of detail as well as the amount of motion in the scene is important. To a large extent this has to do with HIFs such as contrast sensitivity and visual masking, but also with the fact that current compression techniques are affected by these. Furthermore, it is also influenced by the content itself [36], as well as influenced by the higher-level processing as described above in Sect. 4.2. In 3D image and video content, the amount of depth is an aspect that also influences the quality and especially the viewing comfort [37]. Aspects of 3D video are discussed in more detail in Chap. 20 of this book.

Media-related System IFs

The media-related SIFs refer to media configuration factors, such as encoding, resolution, sampling rate, frame rate, media synchronization [38]. They are interrelated with the content-related SIFs. Media-related SIFs can change during the transmission due to variation in network-related SIFs [39].

In most cases the resources for distributing media are limited. There are both economical as well as hardware-related reasons for limiting the size of media. This is usually accomplished by applying compression, which can be either lossless or lossy. Lossy compression gives higher compression rates at the cost of quality. However, the influence depends on the principle the lossy coding is built upon. For instance for image and video, block-based compression techniques as in JPEG, and MPEG4/AVC a.k.a. H.264, are the most common. For stronger compression, these will usually give visible blocking (rectangular shaped) distortions and blurring, whereas wavelet based techniques mostly give blurring distortions as in JPEG 2000 (cf. Chap. 19 for more details).

For audio, the coding also depends on the content type and service/application scenario. Telephone codecs (such as G.711, G.729) are used for voice-only scenarios (e.g. VoIP). Better QoE can usually be achieved if wideband codecs (e.g. AMR-WB) are supported over the complete transmission chain. Several lossy compression codecs are used for audio media (MP3, AC-3, and Vorbis). For lossy compression, perceptual coding based on psychoacoustic principles is a widely used method. The sampling rates and resolutions vary between codecs and their usage scenarios, and are compromises between codecs' rates and achieved quality. Delays are highly undesirable in conversational communication services (see Chap. 11). The media synchronization can have an important influence if the media (e.g. movie) contains audio and video [40].

Network-related System IFs

Network-related SIFs refer to data transmission over a network. The main network characteristics are bandwidth, delay, jitter, loss and error rates and distributions, and throughput [41, 42]. The network-related SIFs may change over time or as a user changes his location, and are tightly related to the network Quality of Service (QoS).

Network-related SIFs are impacted by errors occurring during the transmission over a network. Especially in case of delay, the impact of SIFs also depends on whether the service is interactive or more passively consumed (see Chap. 11), as for instance in telephony versus radio broadcast, or video conferencing versus streaming video. In an interactive, e.g., conversational service, delay may have a negative impact on QoE. The delay can present a major limitation if older mobile network technologies are used for real-time audio applications such as VoIP. Streaming video and IPTV are examples of services with more passive consumption, but depending on how they are distributed over the network, they will be very differently affected. Most often the video is deliberately delayed by using strategically placed buffers in order to be more resilient towards network capacity variations and errors.

For User Datagram Protocol (UDP) and Real-time Transport Protocol (RTP) based transmission, the most severe errors are packet losses [43]. The visibility of these mostly depend on the applied concealment at the receiving end, and on the content and the coding scheme itself: larger parts of the image might disappear in a blocky fashion for some time (see Chap. 19). Speech is often presented in bursts during the VoIP service. Therefore, the packet loss distribution plays an important role. The same level of packet loss can result in a more severe impact if audio is used for some additional processing, as in the case of spoken dialog telephone systems [44].

Recently, the popularity of over-the-top (OTT) streaming video, e.g. Youtube or Netflix, has increased very rapidly. The distribution method is TCP- and http-based (Transmission Control Protocol and Hypertext Transfer Protocol, respectively), and here the influence of packet loss and bandwidth limitations is quite different. Network problems will result in freezes without loss of content in the video. Freezing also has a bad influence on the experienced quality [45], but can be avoided by using adaptive or scalable codecs in conjunction with OTT video services [46].

Device-related System IFs

Device-related SIFs refer to the end systems or devices of the communication path. The visual interface to the user is the display. Its capacity will have a tremendous impact on the end-user experience, but the content and signal quality will interact with it. For instance, if a high-quality, high-resolution (here meaning in terms of number of pixels) image is shown on a low resolution display with few colors, most of the original intent of the image might be lost. However, if a low resolution image is shown on a large high resolution display, most likely a very blocky and blurry image will be displayed, but the end result will be highly dependent on the final image scaling procedure. For an in-depth treatment of the influence of scaling and display rendering, as well as the influence of the dynamic capabilities of the screen for reproducing motion, see e.g. [47].

In recent years the technical development of displays has been progressing very fast, both on the TV side and the mobile side. One important trend, especially in the smartphone market, is the increase in display resolution. Also, the colors and brightness have improved. On the TV side, the development is taking place in larger steps over several years or even decades, e.g. the transition from standard definition TV to high definition TV. The most influential trend in recent years, with a substantial influence on experience, are stereoscopic 3D devices, see Chap. 20 of this book. The basic principle is to present two views of the same scene. Depending on how this is done technically, many device-related IFs will be present [48–50]. For instance, leakage of one view into the other a.k.a. crosstalk will lead to visible ghosting [51, 52].

The 1.75 billion mobile devices (e.g. smartphones, tablets) sold throughout the world in 2012 [53] greatly outperformed the numbers of any other terminal equipment types in usage. In regard to devices' form-factor dimensions, the built-in loudspeakers represent only an average possibility for playing audio. The main progress in the area of input devices is the increased usage of touchscreens, which are addressing the human tactile modality. The touchscreen as an input device can present a limitation, if the user needs to input a larger amount of information. The state-of-the-art mobile devices with multi-core processors and advanced Graphics Processing Unit (GPU) can deliver a substantial amount of computational power, but at the cost of autonomy. Mobility, which is a Context IF, thus strongly influences various characteristics of devices.

4.4 Context Influence Factors

Context Influence Factors (CIFs) are factors that embrace any situational property to describe the user's environment [1].

CIFs have been considered in different multimedia applications and services [54–59]. In most of these works, context factors appear mixed with *human* and *system* factors, thus without any structure or categorization. However, different literature places a strong emphasis on multimedia quality progress, resulting in a properly structured categorization of the different kinds of influence factors. In the case of CIFs the latest and most complete categorization was proposed in [60].

Following previous work described in [61–65] and mobile work contexts, the CIFs were broken down in [60] in terms of physical, temporal, social, economic, task, and technical characteristics. These factors can occur on different levels of magnitude (micro vs. macro), behavior (static vs. dynamic), and patterns of occurrence (rhythmic vs. random), either separately or as typical combinations of all three levels. Furthermore, in [66] another context categorization is presented. Six different context categories are defined: personal context, social context, event-based context, application based context, historic context, and intra-user context difference. However, according to the present factors' categorization, the application-based context data shall be considered as a *system* factor. The variability of categorization is confirmed in [67] where the following CIFs are considered: those capturing the physical environment (e.g. home, office, mobile, or public usage; space, acoustic, and lighting conditions; transmission channels involved; potential parallel activities of the user; privacy and security issues) as well as the service factors (e.g. access restrictions, availability of the system, resulting costs).

Modelling CIFs might provide a selection of appropriate quality levels for the given experience, improving efficiency and reliability of the application/system, or adapting the content characteristics. The importance of CIFs knowledge on the provided Quality of Experience can be understood with the following examples: long duration content is not interesting at lunch time on a weekday, music with a fast beat is better than slow music in a gym, and advertisements in a social network shall typically consider the user profile. Moreover, different contexts might change the user profile (e.g. using a service at home or at work).

Following the idea of CIFs, context-aware multimedia services/infrastructures have attracted considerable research activity in recent years [59, 68]. For instance, an infrastructure for context-aware multimedia services in a smart home environment is proposed in [59]. Such a system is supposed to be adaptive to typical preferences of the multimedia system user, like for example, record the favorite TV programs of the family members, show suitable content based on the user's social activity (e.g. holding a birthday party), and show content in an appropriate form according to the technical capabilities. The multi-layered system is based on the triptych for context: aggregation, reasoning and learning.

The description given in the remainder of this section is based on the context factors categorization proposed in [60], whereas links to the categories of [66] are also given.

Physical context

The physical context describes the characteristics of location and space, including movements within and transitions between locations; spatial location (e.g. outdoor or indoor, in a personal, professional or social place), functional place and space; sensed environmental attributes (e.g. peaceful place vs. noisy place, lights and temperature); movements and mobility (e.g. sitting, standing, walking or jogging); artifacts. The personal context described in [66] can be partially included here, namely at the user location, user activity[2] and user physiological information level. Several works use the physical context to model the application quality. User's preferences can vary in different contexts, such as location, time, movement state and temperature. For example, someone jogging might prefer hip-hop over classical music. A survey showed that activity significantly affects the listener's mood [56]. Authors in [54] use this finding and conclude that context information is an important element for a music selection recommender that suits the listener's mood. They propose to group the users under similar context conditions to find implicit and more applicable perceptual patterns. Through mining integration of both context information and musical content, appropriate ubiquitous music recommendations are provided. Hence, physical factors like heartbeat, body temperature, air temperature, noise volume, humidity, lighting conditions, motion and spatial location are used to get similar user clusters. These physical context factors also allow for context-specific processing to increase QoE, e.g. the adjustment of screen brightness on a mobile, depending on lighting conditions. Moreover, the use of spatial context is proposed to provide a better visualization and tracking in multi-camera video surveillance systems in [69, 70].

Temporal context

The temporal context is related with temporal aspects of a given experience, e.g. time of day (morning, afternoon or evening), week, month, season (spring, summer, fall or winter) and year; duration (see e.g. [71] or Chap. 10 for aspects of content duration, and Chap. 2 for memory effects), and frequency of use (of the service/system); before/during/after the experience; actions in relation to time; synchronism. It is quite common in literature to include physical and temporal contexts in the same category. For instance, the categorization in [66] includes the temporal context in the personal context, namely the time of the system access and the task list influence. In fact, these two context categories' influences are typically highly correlated. Moreover, a historic context is considered, that uses the subject's past context information stored in a database similar to a user profile or a resource profile (e.g. Twitter offers a

[2] User activity context may be strongly related to task context, for instance when the user tries to achieve a certain goal.

rich source of user context in terms of current and past activities; the last 10-min physiological or one's ambient data stored in a smartphone). Authors in [66] also define a sixth category that can be considered inside the temporal context, defined as the intra-user context difference. This sub-category results from the change in one particular user's context throughout a day. This separation is considered because every user might access different services or communicate with different categories of people during different periods of a day. Returning to the music recommender example [54], factors like time of day and season were also considered.

Social context

The social context is defined by the inter-personal relations existing during the experience. Hence, it is important to consider if the application/system user is alone or with other persons, and even how different persons are involved in the experience, namely including inter-personal actions. Moreover, the cultural, educational, professional levels (namely hierarchical dependencies, internal vs. external), and entertainment (dependent of random or rhythmic use) also need to be considered. In [66] also the contact list, social ties through social nets and interactions, and types of shared information are considered. Furthermore, in [66] another category defined as event-based context (e.g. appointments, or meetings) can also be considered as a sub-category belonging to the social context.

In [58], the analysis of the user's social context permits to infer interesting data about the user's interests via information provided spontaneously by the user himself, and analyzing behavior and habits of his friends' network. Along the same lines, several research efforts intend to understand and to automatically extract from the social information deposit the users' relationships, interests, and even their mood. More recently the new Google "Search, plus your world,"[3] makes intrinsic integration of the user's social environment for the searching mechanisms. Some contemporary context-aware recommenders attempt to enhance recommendations with more considerations of environmental metadata [72, 73].

A combination of physical and social context is proposed in [74] to foster a more efficient delivery of mobile services. That model exploits the fact that a very lightweight component such as the mobile nodes, can be deployed to monitor socio-technical information in three main areas: user physical location and activity (running, driving, …), user social context (friends, common interests, …), and service usage (frequency of use, last login, …). A solution for IPTV services personalization based on context-awareness relying on physical, temporal and social categories, is introduced in [55–57] by a real-time gathering of context information on the user, his environment (devices and network) and the service.

As the previous examples have shown, the social context becomes very important at the recommendation level. Content recommendation based on the gathered context information allows guaranteeing better users' experience. Collaborative recommendation, where the user recommends items that are consumed by other users with similar preferences, can also be made possible.

[3] http://www.google.com/insidesearch/plus.html

Economic context

Costs, subscription type, or brand of the application/system are part of the economic context. Chap. 7 in this book focuses on QoE from a business perspective and discusses more details of its influence. Network cost information (e.g. relative distances between the peers) is used in [75], jointly with some physical and social factors, to enable network optimization strategies for media delivery.

Task context

The task context is determined by the nature of the experience. Depending on this, three situations may arise: multitasking (potential parallel activities of the user [67]), interruptions, or task type. For example, a recent paper by Sackl et al. investigates the impact of additional tasks on perceived quality in a QoE evaluation experiment in which the effect of video stalling is explored [45]. The authors conclude that an additional task does not have an influence on the perceived quality, independently of the difficulty (hard or easy) of that task, as stalling did affect the perceived quality to a similar extent under both task conditions. However, the relationship between QoE and task may not be this simple *per se*: Reiter et al. have previously shown in a series of experiments that a challenging task can indeed have an effect on perceived quality in an interactive scenario, especially when both the main varying (or salient) quality attribute and the task are located in the same modality [76–78]. According to these studies, inner-modal task influence (or distraction) is significantly greater than cross-modal task influence. This is also suggested by the common theories of capacity limits in human attention [79].

Technical and information context

Finally, the technical and information context describes the relationship between the system of interest and other relevant systems and services including: devices (e.g. existing interconnectivity of devices over Bluetooth or Near Field Communication, NFC), applications (e.g. availability of an application instead of the currently used browser-based solution of a service), networks (e.g. availability of other networks than the one currently used), or additional informational artifacts (e.g. additional use of pen and paper for better information assimilation from the service used). Characteristics like interoperability, informational artifacts and access, or mixed reality also need to be considered.

4.5 Conclusions

The above discussion of factors influencing the user's individual Quality of Experience of a device or service demonstrates that QoE can be influenced by wide a range of factors, which are complex and strongly interrelated. It is currently still poorly understood which factors influence QoE under which circumstances, how exactly they influence QoE, and what their possible influence implies for the field of QoE research.

Table 4.1 Overview and examples of potential IFs

IF	Type	Examples
HIF	Low-level: physical, emotional, mental constitution	Visual / auditory acuity and sensitivity; gender, age; lower-order emotions; mood; attention level
	High-level: understanding, interpretation, evaluation	Socio-cultural background; socio-economic position; values; goals; motivation; affective states; previous experiences; prior knowledge; skills
SIF	Content-related	Audio bandwidth, dynamic range; video motion and detail
	Media-related	Encoding, resolution, sampling rate, frame rate; synchronization
	Network-related	Bandwidth, delay, jitter, loss, error rate, throughput; transmission protocol
	Device-related	Display resolution, colors, brightness; audio channel count
CIF	Physical context	Location and space; environmental attributes; motion
	Temporal context	Time, duration and frequency of use
	Social context	Inter-personal relations
	Economic context	Costs, subscription type, brand
	Task context	Nature of experience; task type, interruptions, parallelism
	Technical / informational context	Compatibility, interoperability; additional informational artifacts

We classified IFs into *human, system* and *context* influencing factors. With respect to HIFs, we have discussed both, variant and relatively stable, factors that may potentially bear an influence on QoE, both in the context of low-level or bottom-up processing and top-down, higher-level cognitive processing. SIFs were classified into four distinct categories, namely content-, media-, network- and device-related IFs. Finally, the broad category of possible CIFs was further decomposed into factors related to the physical, temporal, social, economic, task and technical and information context. Table 4.1 provides a checklist containing the most important IF examples for the practitioner to cross-check when designing QoE experiments and reporting.

Although the overview given in this chapter should not be considered as exhaustive, it illustrates the complexity of QoE and the broad range of aspects that potentially have a major influence on it. The amount of factors with influence on QoE results in a very difficult modeling and in a high level of subjectivity. However, the knowledge of these factors and an appropriate categorization might provide patterns and tools that allow to predict or even to improve the level of QoE. A challenge for future research is to develop adequate methodological approaches to take into account relevant influencing factors and to better understand their interrelations.

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