A Comprehensive View on User Studies: Survey and Open Issues for Mobile TV

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ABSTRACT

In the future Mobile TV will play a major role amongst traditional TV services. However, since Mobile TV brings new aspects into television, like small screens, consumption in noisy surroundings, etc., it also represents a new challenge on how to create, transfer and present content that maximizes the consumer experience. In the past, research has been often focusing on one particular aspect of this new TV scheme, as well as surveys on this research often neglected aspects that still might be of interest when trying to understand the dependencies of Mobile TV content and presentation to perceived quality.

In this survey paper we want to discuss challenges and requirements in a comprehensive way, trying to shed light on all relevant aspects of Mobile TV. The aim of this paper is to give a good overview about the state of the art with the focus of users' need and experiences. Furthermore, we want to point out interesting and open issues which are relevant for further research work.

Categories and Subject Descriptors

H.1.2 [**User/Machine Systems**]: Human Factors

Keywords

Mobile TV, Quality of Experience, User Studies, Human Centered Design, Survey

1. INTRODUCTION

Mobile TV and digital video content services represent an important business of the future. According to forecasts user demand will grow significantly by 2011 [48]. The realization of Mobile TV leads to an important change of television that we know today. Wippersberg compares the current situation to the early fifties of the twentieth century, when television started to enter our homes [30]. At this time, similar to now, the screen size was dramatically reduced leading to a completely new scenario with new problems and challenges.

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Due to different consumption scenarios and time schedules, a new concept for the content production had to be made for television. Wippersberg states that this needs to happen again for Mobile TV. As of now, Mobile TV is still in an early phase of evaluation, and mostly early adopters use Mobile TV. In order to identify those parameters that uniquely discriminate Mobile TV from standard TV, many user studies and experiments have been performed, thus gaining novel insight regarding the needs and success parameters of mobile multimedia services.

In this paper a comprehensive overview of this earlier work is given, by putting a major focus on the user's point of view, thus combining the Quality of Experience (QoE) approach with the traditional Human Centered Design approach. Furthermore, parameters depending on cultural aspects and on different user profiles are highlighted. Hereby, previous surveys are updated, e.g. a study on Mobile TV for 3D movies [59], but also technical aspects are included. As a consequence of this state of the art analysis open issues for Mobile TV are deduced and verbalised.

1.1 Mobile TV

Many user studies [48, 55, 28, 5, 2, 17, ?] show that one of the main critical aspects for the success of Mobile TV is *content*. Special made-for-mobile content results in much higher user satisfaction when compared to adopted standard TV content.

However, because of the involved costs, made-for-mobile programmes are still the exception, and generally available content is recoded for the smaller screens of mobile devices. This represents one of the reasons why Mobile TV is still in its infancy and the number of users is very limited. Evaluations showing a considerable number of consumers, like one million in Italy [20], have to be considered with care. This is due to the fact that usually persons having flat fee agreements which include Mobile TV are counted as Mobile TV users as well, even if they are not actually using Mobile TV at all.

Recently, a number of surveys has been published that offer overviews for research and development of Mobile TV. The surveys present research results from different studies. Yet they show that research on similar questions has yielded completely different results in the past. For example user studies carried out in Germany, Austria, or in South Korea show that Mobile TV will be mainly viewed during short waiting times, while in similar studies carried out in the United Kingdom or in the United States, the main application area is at home. The reason for this divergence can be understood when reading user comments recorded

during the experiments. Culture, mentality and age have a high impact on this research issue and lead to different outcomes. In the United Kingdom people do not want to disturb other people in public transports or on the street, and do not want to compromise their privacy. In the United States public transport services are not used as much as in the other mentioned countries, work and school are much more often reached by car.

1.2 Research Methods

Several research methods can be used to identify user needs and expectations, as well as informations concerning the usability of the product [19, 39, 34, 35]. In this regard, *qualitative methods* (e.g., focus groups [33, 59], [3], interviews [34, 41, 54, 60], oberservations [41, 54, 3], thinking aloud [41], probes [59, 34, 3, 41], workshops [34, 41], diaries [34, 60], scenarios [41, 63] and personas/user profiles [33, 34, 63]), and *quantitative methods* (e.g., questionnaires [33, 34, 4, 54, 3], log files [54, 60], surveys [59, 4]) can be distinguished.

The advantage of quantitative methods is that a large number of people can be comprised. However, the obtained data often mainly confirm already acknowledged concepts [59]. Qualitative methods mainly aim at identifying new concepts, and relevant needs as well as desires of the users [59]. Furthermore they provide information concerning the nature of the viewers' involvement [34]. Different types of methods are often combined [33], e.g. methods can be designed to produce quantitative and qualitative data (e.g., user surveys [39]). An overview about different methods used in a Human Centered Design process for the development of an interactive television concept can be found in [34].

Currently, users generally watch television in private environments, while mobile phones are often used in public areas. There are many interesting studies about interactive television performed in a home environment, yielding results that may have a high influence on mobile television as well. Therefore publications on *interactive television* that might have an impact on Mobile TV are equally considered in this work. These additional insights can be particularly helpful for further design solutions. Finally approaches and applications that are estimated to be promising.

1.3 Human Centered Design

Several research papers show results and methods to find out more about user needs and motivation in regard to interactive television as well as Mobile TV, because the commercial success of a TV product depends on user requirements and its usability [50, 39].

Eronen [33] points out that a good usability is an essential aspect of television. This is due to the fact that Mobile TV is mainly consumed in leisure time, and users do not want to spend much time finding out how to use it. Furthermore, Eronen also states that for new devices and applications, the focus of Human Computer Interaction (HCI) research, which usually concentrates on usability, has to shift more to user experiences, which are relevant for the product use according to user needs [34]. Human Centered Design (HCD) or often called User Centered Design (UCD) involves users in the design and development process to get a better understanding about their needs, tasks and expectations [9, 19, 34]. The aspects of Human Centered Design correlates to the understanding of User Experience (UX), which Hassenzahl and Tractinsky [37] describe 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.)"*. Especially for mobile phones the user interface and their usability often depends on the usage model and its layout [59] *"and the context (or the environment) within the interaction occurs"*. Based on these factors, design solutions by prototyping can be developed, which are evaluated by their usability and how they suit user needs in the next step of the Human Centered Design process.

1.4 Quality of Experience (QoE)

Based on the Human Centered Design approach, it is necessary to search answers to the following questions: Where and when will Mobile TV be consumed? What kind of service and content should be made? How should it look like and how will it be consumed? Initial attempts for finding answers can be found in [48, 55, 25], but there is still need for refining the results, which is one aim of this paper.

The big picture from the user's point of view is given by the expression *Quality of Experience (QoE)*. QoE key factors for Mobile TV have been identified by [25, 28, 38]. In this paper we relate these factors to the Human Centered Design approach. The resulting key factors represent our view on this subject and determine the further structure of this paper:

User: The profile of typical users, including user motivation, future trends and needs.

Mobile Device: Limits and new features of Mobile TV due to mobile devices, features that are still missing.

Context, Mobile Services: The aim is to find out where, when and how long Mobile TV is consumed, and which services at what level of interactivity promise to be successful in the future.

Content: Content types as requested by users, user generated content.

Cost and Commercials: How to finance Mobile TV, fee types and amounts users are willing to pay. The role of commercials and how they need to be introduced.

Technical Performance: Which technical parameters concerning audio, video and the transmission need to be considered to enhance the quality?

In this survey we want to sort out which parameters depend on cultural aspects, and which return the same result in different types of contexts. Furthermore minimal technical pre-requisites to build a successful mobile multimedia service are highlighted and presented in more detail than in recent work in order to motivate, explain and present the open issues in that area.

2. USER

The most critical factor for the success of a mobile multimedia service is the user. He decides if and how Mobile TV will exist in the future. Therefore our first efforts are dedicated to the analysis of user needs and expectations. For that purpose a typical user profile in the current situation is discussed. Some general findings can be sorted out,

but on the other side open issues leading to further research questions can be identified.

The trend of media entertainment tends to personalized content, which depends on user needs, tastes and preferences [11]. The study [53] confirmed that mobile phones are regarded as very private devices, which the participants of the study are reluctant to share with anybody else. This result is confirmed for Mobile TV by [32] and [28], where mainly individual viewing happened. In [32] and [28] the authors noted that subjects sometimes used Mobile TV in order to separate from others, but the authors also describe situations, in particular for young users, where the experience is shared and devices are lent.

The need of personalization was also expressed by the desire for mobile device configurations. The possibility to personalize content is one reason for the growing popularity of Mobile TV. Hussain et al. [63] pointed out that traditional broadcast viewer numbers decrease, because of a regular use of Internet or Mobile TV. Another study [7] showed that Mobile TV is of interest to have an own personal Mobile TV at home or to use it as a tool to get a closer interaction with television content. Furthermore, viewers change their passive television viewing behavior to active television viewing, similar to the interactive television, where the interactive services and applications are part of the routine television [33]. Therefore, broadcast companies are interested in adapting their content to these new technologies [63]. However, the success of the services depends on user motivation and on the conformity to user needs. In this section we present several studies describing user profiles and motivation. Some studies are addressed to interactive television viewers, but the core statements are also of interest as background information for Mobile TV and give more information about the potential Mobile TV users. Resulting requirements and expectations can be considered in the design for Mobile TV.

2.1 User Profiles

User profiles describe typical users and consider information like age, leisure time activities, work and their relationship to technologies. Eronen [33] defines three main user profiles for interactive television, based on their home, work and technology orientation: *Pioneers*, *High-Fliers* and *Comfort-Lovers*. Eronen combines the result of a questionnaire study, having the main aim to find out more about the scope of the new media in Finland, and the following focus group study: The user profiles represent mainly younger users. The median age of Pioneers is 21 and they want to have the newest and fanciest electronic entertainment as possible. High-Fliers have as median age 29 and they are strong technology-oriented. They want to read personal content (e.g., emails) on their own screen. The median age of the Comfort-Lovers was 36. They are not so flexible in regard to change their life style and they prefer to use services which are comfortable. Furthermore, Eronen found that persons are generally open and interested into new technology. However they first want to wait until they know more about their personal benefit of such new interactive services.

Jumisko-Pyykkö et al. are performing research about the acceptance of 3D movies for mobile devices and pointed out in their work [59] that the typical Mobile TV user is a well-educated male, aged between 23 and 35. The main motivation to use this service is to shorten the waiting time (e.g., of a public transport), to be up to date with the daily news while users are on the way or for entertaining. In [64] the company Zukunft Digital presented that Mobile TV attracts mainly young persons, aged between 19 and 29, who are technologically interested heavy-users. A user is called heavy-user when he spends a lot of time using technology intensively. Furthermore they found out that women would like to consume different content than men except for commercials where no gender specific difference could be noticed. In [45] it is stated that *Mobile TV is attractive to one sixth of the users and is especially attractive to users between 18 and 44 years old, in Latin America, Asia and Eastern Europe.*

Rice and Alm focused their work [41] on the requirements of older adults (average age 71 years) to design an interactive television interface. Older users have often difficulties in understanding of the technical language. They prefer larger buttons and voice-activated devices. The interface design should be simple and have only limited functions.

Svon [4] analyzed how young new media responding people are and how they used it in their everyday life. Based on a study, she noted that mobile phones are widespread by young people (ages 8 to 15) and nearly all possess their own phone. The Vanguard study [4] has shown that girls use mobile phones as preferred medium in addition to computers. Television was always a constant companion for the younger people and the study has shown that the numbers of channels, the quality of the device (e.g., sound and size) as well as the comfort (e.g., sofa) are essential factors. The survey also contained explicit questions about Mobile TV, but only few responded. Reasons were that the costs of mobile phone were too high and the program offers are limited. The small number of persons using mobile television, noted that the lines were too slow and therefore it was not possible to watch TV smoothly. Generally, mobile phones are additionally used to store images, small videos or movies, music and ring tones. Furthermore, the study showed that young people used a wide range of mobile services.

Summarizing, it can be said that all studies agree about the age of the typical Mobile TV user: The user is young. The question about the sex of the typical user is not clear, it highly depends on service features and content proposed.

2.2 User Motivation

There are many occasions in which users would like to consume Mobile TV. In [48] it is mentioned that the ability to watch television anytime anywhere gives users a sense of control and security. As a global picture people want to use Mobile TV to

- kill time while waiting, i.e., for a public transport,
- kill time during extended waiting periods, i.e., waiting for friends in bars, or in a car while the girlfriend is having an appointment,
- stay up to date, i.e., with popular events or news
- create a private sphere,
- feel less lonely, i.e., lunch break at work,
- relax, i.e., at home on the bedroom or in the bath,
- be entertained,
- own, share and exchange content,

- show novelty, the desire to be the first, or
- create and consume personalized content.

Based on the traditional television, Svon pointed out in [4] that the main motivations for younger people to use television in general are for relaxing, watching their favorite shows/movies or as background medium. Also the study [53] showed that viewing television is often a background activity at home. A particular case of Mobile TV - Mobile 3D TV - has been under investigation in [59]. It has been noted that Mobile 3D TV is not likely to run in the background (only 17.3% used it as a secondary task). On the contrary, users expect a deeper immersion from this service and intend to use it as main activity.

In [45] it is stated that persons who possess a multimedia or Mobile TV device will mainly also use it as such. This means that just the fact of having the opportunity to use Mobile TV represents a motivation for its use. Studies like [28, 32, 38, 6, 50] and [60] show that users mostly want to kill time during waiting periods. Furthermore [32] the possession of content is of huge interest. It has been noticed that people will use Mobile TV for relaxing [28]. These observations lead immediately to the question where people want to use Mobile TV, because relaxing and waiting occurs in different places. It will be analysed in detail in section 4.1.

3. MOBILE DEVICE

The big change from traditional television to Mobile TV is the device itself, its small size, operability and reliability. Results from user studies in relation to mobile devices found in different countries like UK, USA, Japan, Finland, South Korea, Switzerland and Austria are very coherent and in some cases even surprisingly similar.

3.1 Screen and Phone Size

In many cases the first reaction of new Mobile TV users is *"but the screen is so small!"* (see an example in Figure 1). Whereas users want the screen to be as large as possible, they do not want their phones to be too big [25]. Larger image sizes and landscape oriented use of the display might be preferred [25, 47]. On the other hand, in particular female users do not want the weight and size of the handset to be increased [21]. Qualitative and quantitative studies about the resolution have been performed in [22]. It has been found out that image resolution reduction leads to a loss of visual detail and that images should not be smaller than 168×126.

Figure 1: A Mobile TV device.

3.2 Battery and Memory

Beside the screen size, the limited battery life has been identified as a main barrier in [32, 28, 25, 21, 47]. High battery consumption of Mobile TV compromises mobile phone functionality. As a consequence, time-slicing for DVB-H transmissions has been developed, resulting in power savings up to 90% [46]. This is due to the fact that the receiver part of the device can be put into a low-power sleeping mode during time slices that transmit content the reciver is currently not interested in. The increase of battery lifetime and the decrease of battery consumption is subject of current research.

3.3 TV Buttons

In [25, 36] and many other studies a major result is given by the fact that Mobile TV must be easy to use. People are not willing to navigate through menus and therefore the need for special TV buttons on the phone has been expressed. In particular the sound management, which is analyzed more in detail in the next paragraph must be quick and simple.

3.4 Sound Control and Headphones

As already mentioned above the sound control is very important for the Mobile TV user, i.e., people do not want to miss an announcement from the public transports and need to turn down or off the sound rapidly. Two studies provide more indepth results on this issue, one has been performed in Japan [31] and the other one in Belgium [42]. Both studies, though having been carried out in different cultures, return the same result: the involved subjects did not want to use headphones when consuming Mobile TV. In both experiments headphones were distributed to the participants, but they refused to use them. Reasons for this behavior can be various. On explanation is due to the fact that headphones are seldom used when consuming traditional TV. Therefore people simply do not associate television with headphones and do not think about using them. This is in contrast to the consumption of music with mobile players, where headphones are the rule rather than the exception. Other reasons include the fact that some people do not want to carry more than the mobile device with them, others may want to remain in contact with their surrounding. The specific circumstances defining the willingness to wear headphones actually represent an open issue that is worth further exploring. One aspect might be that the acceptance of headphones may depend on the user profile.

The implications of these studies are quite important and have influence on a variety of issues. It seems that content, at least for a significant user group, has to be produced in a completely different manner. When remembering old silent movies, Mobile TV actors must show a new profile. In China a made-for-mobile soap opera has been produced [18]. It contains very little dialogues and limited gestures. An actor told the press: "*Your emotions should come only from facial expressions.*" News transmissions today are usually presented by a talking head, a scenography that does not make sense when there is no sound. If research results of [31] and [42] are confirmed by further studies, then the traditional talking head for news content should be substituted by a sequence of images, probably supported by some textual information.

Not all the users reject headphones and there are situations where users do definitely want them. An example is

given in [32] where a boy describes a situation in which he uses the headphones to become unavailable for his younger sister and brother. According to Oksman et al. [60], Mobile TV is not often used without headphones in public places and transports in Finland.

As a consequence, the above described different preferences represent a big challenge for the future Mobile TV content producers.

4. CONTEXT, MOBILE SERVICES

Most user studies are composed by questions regarding the mobile service. Researchers and companies want to know which service may be consumed at what time, how and where. The ideas and concepts for Mobile TV are the same in all studies, but user priorities are often completely different. The culture of the country in which the study has been performed and the age of the test subjects are the predominant factors leading to this discrepancy. Bernhaupt et al. [54] found that the usability of services influence user ratings. The rating was higher if it was easier to use. Also the study [6] noted that success of a service depends on an easy and intuitive use.

4.1 Physical Context

The location where Mobile TV will be used is one of most controversial issues. In some studies performed in the UK [28], South Korea [28] and Belgium [42] it is revealed that people clearly want to watch Mobile TV at home. In other studies performed in Germany [5, 2], Austria [47], or Japan [31] the main use case is during waiting times or on the way.

At home people want to relax, create a private sphere for a short time, i.e., to calm down for some minutes when arriving at home from work before starting to play and chat with their children. Home is the most likely location in studies performed in the UK, USA and Belgium. In the UK and in Belgium people are afraid to disturb the others and on the other hand want to keep their privacy. They do not want strangers to observe what they currently see on their screens. In the USA people mainly use the car to go to work or at school, hence they do not have the opportunity to watch because they drive. The persons in the back of the car can use it, but in this case the transport happens in a private place similar to home. In studies performed in countries where public transport is used a lot, and the education to behave in a polite way is not as strong as in the UK or Belgium, the main scenario is during waiting times and in public transportation. In South Korea [28] home and commuting use were identified with more weight on home use. It is even mentioned that their study reveals that both are likely to be significantly culturally dependent. Jumisko-Pyykkö et al. [59] found that the majority of respondents use mobile TV with 3D content in lounges (e.g., airport) or public transport. Furthermore, hospital and home have also been noted as attractive location for watching Mobile TV. This means that future research and service providers must investigate very carefully the cultural background of the user they want to reach with their product. It is not enough to rely on one well performed and described user study to know why and where the future will use the service, business success will depend on this choice.

4.2 Temporal Context

In order to setup adequate program and to be prepared for high bandwidth peaks, it is interesting to know when Mobile TV is likely to be consumed and for how long time. Many studies have been published on that purpose and it is very interesting to notice that nearly all recent studies agree about the consuming duration and the times. It was always stated that Mobile TV content must be short, initially starting by approximately 10 minutes [47], and being reduced from year to year, reaching now a length of 1 to 3 minutes for one content type [2]. There are exceptions of maximum 7 minutes for particular contents. The same effect happened for the total amount of consumption per day. It is estimated to be between 5 and 40 minutes per day in [48]. According to [6], results show that users spent approximately 20 minutes a day, and the watching time is different to the traditional television peak hours. Reasons are that the participants watched Mobile TV while traveling or also at work to inform about the latest news. However other studies do even agree on the prime times:

- Early in the morning,
- at lunch, and
- early in the evening, before dinner.

The early evening prime time is the most popular [6]. In [31] Japanese test persons stated that this is due to the higher number of free places to sit in public transport. In contrast, watching Mobile TV in the morning while standing in the bus is highly uncomfortable. The lunch break at work or in the courtyard of the school reached the second place. Nearly all studies like [5, 47, 44] agree about these prime times. But they also agree on the fact that with respect to traditional television consumption, times will perform more variations. Jumisko-Pyykkö et al. [59] found out that Mobile 3D TV is suitable for time filling situations and stated that the most interesting option to use it was during a long journey. Other options were to use it while a waiting situation, commuting, short coffee or lunch breaks. Furthermore, they pointed out that the optimal length of viewing was from a couple of minutes to 15 minutes.

4.3 Interactivity

The success of Mobile TV depends on the proposed features and if they meet the user expectations. In Section 2 it is stated that one important user expectation is the interactivity. In this section the current standards for Mobile TV formats are presented and then possible scenarios depending on the amount of possible interactivity are discussed.

4.3.1 Transmission Schemes

We identified three different types of technologies for delivering Mobile TV: broadcasting, satellite-based and telecom-based technologies. Digital Video Broadcasting for Handheld (DVB-H) [12] represents the most common format in Europe to deliver Mobile TV. It offers high downstream data rates and time slicing is implemented to reduce power consumption of small handhelds. Interaction can be realized by combining DVB-H with other technologies. The satellite-based DVB version is DVB-SH is specified in [14]. MediaFLO is a competitor to DVB-H with its origin in the Unites States proposed by the company Qualcomm. FLO stands for Forward Link Only, therefore the transmission

path is one way [51]. Qualcomm has performed a comparison between DVB-H and MediaFLO [52]. The Asian competitor from South Korea is called Digital Multimedia Broadcasting (DMB). S-DMB stand for operation via satellite while T-DMB defines the terrestial mode and is specified in [13]. Multimedia Broadcast Multicast Service (MBMS) is a telecom-based broadcasting service specified in 3GPP technical specifications [1]. Telecom-based alternatives are Broadcast and Multicast Services (BCMCS) and Time Division-Synchronous Code Division Multiple Access (TD-SCDMA), which is a 3G standard mainly present in the People's Republic of China.

4.3.2 *Features and Services*

On the one hand, traditional broadcast programs can be accompanied by supplementary features like chats, voting, SMS and quiz games, on the other hand, applications like video on demand systems eventually including navigation and search or platforms for user generated content can be implemented. Innovative approaches are presented in [49] where the mobile device is used as a secondary screen for navigation, here previewing content in short clips while using the TV for the main program. Furthermore the content can be manipulated to make it more interesting to share it with other people. Hence interactivity plays an essential role for designing interfaces according to HCI. Jumisko-Pyykkö et al. [59] found that users prefer a simple and intuitive navigation and search function to find the desired content easily. This result is confirmed by Bernhaupt in [54]). Hussain et al. [63] state that it is essential for the success of Mobile TV that users can easily find what they search for. Based on the study for interactive television [41], it is shown that also older users prefer a simple and easy navigation. Furthermore, they noted that the keys should be easily distinguishable and they liked to be guided through the various steps. The evaluation of [54] confirmed that guided navigation was easier to follow also for a younger user group. In [40] it has been shown that the usability of an IPTV community platform is crucial for its acceptance. In addition, Jumisko-Pyykkö et al. [59] point out that pausing and resuming a program should be possible as well as loop streams. Interaction opens the way for new business models. In contrast to the commonly used flat fee model, it is possible to pay for each single content consumed. Currently this is a common practice for selling pornographic content. A very interesting and not defined issue concerning interactivity is in the field of the digital rights management (DRM) for mobile devices. Interactivity enables the user to share, split, combine and edit the content what leads to many open questions in this area.

The way and the amount of interactivity proposed by a service has high impact on the content needed, therefore this section is highly related to the next one where content parameters are discussed more in detail.

5. CONTENT

Interesting or entertaining content represents the main attraction for users. Platforms like YouTube in comparison to other services offer very bad quality but its success is due to the content that makes users forget about the lack of quality. Therefore findings about preferred content types are described in this section. Of course originality will be very important and represents always like for the traditional television an open issue, but in this section it is presented about what has been thought till now.

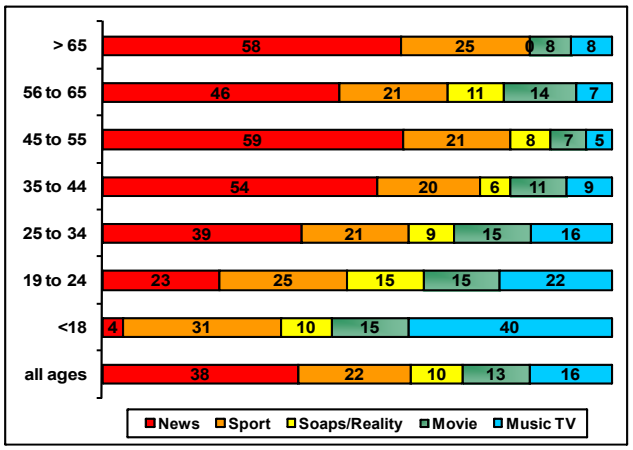

Figure 2: Results of Mobinet 2005 by A.T. Kearney and University of Cambridge - Content type

Similar to the survey [48] we divide the content types in two categories: The professional content that we already know from the traditional television, as well as user generated content.

5.1 Professional Content

Jumisko-Pyykkö et al. [59] mention that several Mobile TV studies found out that the most interesting genres are news, music, sport, and live broadcasts. This is confirmed by many other studies like [44, 47, 5, 2]. In the study of [6] 131 phone users were asked about the content they consume (see Figure 2). Interestingly, the results reveal a relationship between the preferred content type and the age of the users. Again news is the most desired content considering all ages. This choice is even emphasized for users older than 25 years, but for younger people sports and movie TV are of main interest. In Section 2 we presented a profile of a typical Mobile TV user, being a young and technically interested person. Therefore it could be interesting to perform research on Mobile TV content focused on young people.

In addition it is interesting to know that according to [8] news, soap, quiz and sports are those genres during which participants talk most while watching and have the highest desire to share the viewing experience for traditional TV. Generally it can be said that people expect to watch the same content as it is proposed for standard television but this content needs to be adapted for the small screen and the viewing conditions. A still unsolved problem is given by the question how to compose made-for-mobile sports content, for instance soccer matches. On the one hand it is necessary to show the whole scenery of the match to understand what is going on, on the other hand it is necessary to show very small details like the ball to be able to follow the game. In their evaluation about interactive television, Bernhaupt et al. [54] noted that users were interested in local news or weather forecasts. Furthermore, Jensen [29] shows the different new offers which interactive television can provide to their viewers. For example content (like text, graphics or video) can be laid over the currently displayed video content with further interactive functions, to provide a space for

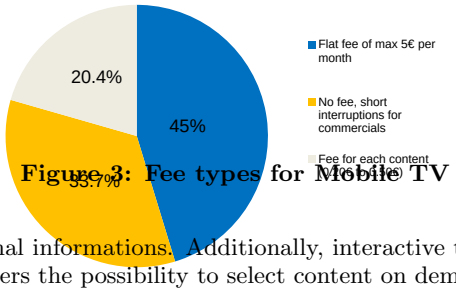

Figure 3: Fee types for Mobile TV

additional informations. Additionally, interactive television gives users the possibility to select content on demand, and provides space for a wide range of content types (e.g., news, movies or music). Personalization of the content becomes more important, e.g., viewers can modify a program or the system individualized content based on viewer needs.

5.2 User Generated Content

Following [32] people want to possess and create content. Platforms like YouTube are likely to have success even for mobiles. Users wants to create their own content and to share it with other users in mobile communities [3]. Therefore, mobile phones can be also used as tools for creation and editing personal multimedia content. Like already mentioned in Section 4.3 Cesar et al. presented an architecture for media content selection, organization where additionally users are allowed to personally enrich the content with great success. Field trials performed in the UK and in Belgium showed the same result. Summarizing, it can be stated that sharing user generated content can generally be considered as a user expectation.

6. COSTS AND COMMERCIALS

Costs and commercials are a very hot topic for Mobile TV. Someone must pay for the service. If interactivity is offered instead of simple broadcasting, users can skip commercials, but commercials are needed to finance the service. In [44] test persons could choose between a flat fee of at most 5 Euros per month, a free Mobile TV service with commercial interruptions like for traditional TV and the possibility to pay a small amount of money (between 0.20 and 0.50 Euros) for single contents. The flat fee was the most attractive option for the test users chosen by 44.9%, followed by 33.7% chosing interruptions through commertials, and 20.4% preferred to pay for single contents (see Figure 3).

All in all people are not willing to pay much for Mobile TV [42, 17, 47]. A user study considering the future of commercials for Mobile TV has been performed by Zukunft Digital [64]. Similar to the other content the result is that only made-for-mobile spots are likely to have success. Additionally it has been found that men and women have different tastes and expectations, that short interruptions for commercials do bother less than for traditional TV, and interactive elements should make sense and have a defined goal. Furthermore, results from [64] confirm the position presented in [48]. It has been found out that advertisement is likely to be considered being as entertaining as the other content and consumed in a similar way. Consumers of interactive services will only watch what they want to see, but the effect of the advertisement will be much higher due to the possibility of more accurate tracking and measuring.

7. TECHNICAL PARAMETERS

Many reviews agree about the fact that for Mobile TV, specific made-for-mobile content must be produced, but except for [25] we could not find any indication on how this should be done. Therefore we want to complete the overall picture by adding some recent results showing the importance and influence of technical parameters.

7.1 Response Time and Channel Switching

Especially for live sport events the immediacy of the content delivery is very important. Consider the case that there is a significant time delay of several seconds between the transmission of standard TV and Mobile TV. An audience seeing the scoring of a goal in an important championship with noticeable delay is likely to be severely annoyed, even if this delay is as low as 15 seconds. In such a situation, viewers of the delayed presentation may hear cheering from their neighbours, but still themselves wait for the goal.

Response time is even higher for transmissions over satellite, but in this case it does not matter that much because until now the main usage scenario is in cars in rural areas. The same problem exists for channel switching, people do not want to wait too long [28] for the presentation of the new channel. Providing low response times for channel hopping, being at least comparable to the ones known from standard TV, still represents an important open issue for Mobile TV.

7.2 Text Quality

In this section a simple way of improving Mobile TV quality is presented. Knoche has found [24] that when transcoding a video from standard TV to Mobile TV, the text size from news tickers usually becomes too small. As a consequence the perceived Quality of Service can be significantly improved by simply increasing the text size of a news ticker (see Figures 4 and 5 as an example [24]).

Figure 4: Recoded video with original news ticker font

Figure 5: Recoded video with increased font size

7.3 Framerate

When bandwidth is limited a video cannot be transmitted with both full picture quality and smooth motion. Instead, a compromise for the encoding parameters has to be made, which on the one hand satisfies the bandwidth restrictions, but on the other hand optimizes the perceived quality of the

video. This compromise may well depend on the content to be encoded. Therefore it is necessary to know for which content type the fluid motion is more important than detailed picture quality or vice versa. In [56, 43] it has been found out that good picture quality with a low framerate returns generally better results than high frame rate with lower picture quality. The result of the user study performed in [56] state that for situations with limited bandwidth budget, for news and comic contents containing little motion, the frame rate should be reduced to 5 frames per second, while for a typical advertisement and soccer game, a value of 10 frames per second should be used.

Figure 6 taken from [56] shows the quality perception for different frame rates in relation to the amount of temporal activity indicating the amount of color changes over time. It can be observed that for low temporal activity (below 8.7) the optimal frame rate is 5 frames per second while for high temporal activity it is 10 frames per second. The curves representing 15 and 25 frames per second result in lower quality parameter values.

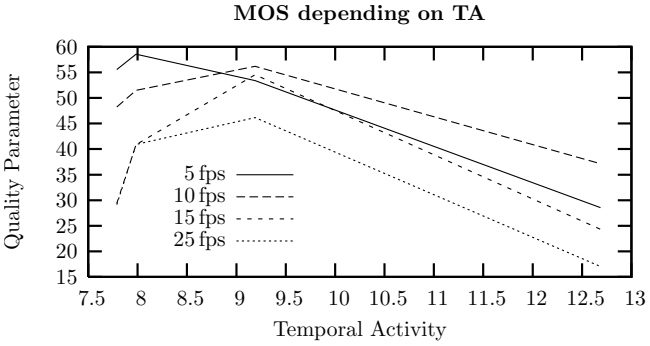

Figure 6: Temporal activity (TA) versus mean opinion score (MOS)

Furthermore in [43] it is described that impairments after scene changes are noticed less often than impairments in other parts of a video.

7.4 Shot Types versus Resolution

Knoche et al. [23] investigated the effect of different shot types in relation to low resolutions, being typical for mobile devices. For news content the medium shot which portraits the upper half of a subject's body should be used, but for football content a shot showing less detail in preferred. Furthermore it has been found that for a young audience extreme long shots can be used when the resolution is 240×180 or higher. By choosing a lower resolution the perceived quality could be poor. Knoche et al. considered in [26] the problem described in 5. For sports events like soccer or ice hockey matches, very large or extreme large shots need to be used, to enable the user to follow the game. These shots have the drawback of showing less detail, therefore the ball or the puck of the match cannot be identified in many cases. In [55] it is mentioned that this happens to almost anyone watching ice hockey. Knoche proposed in [26] a zooming scheme where participants could switch between original and zoom enhanced soccer footage at three sizes with the result that zoom factors between 1.14 and 1.33 were preferred for all sizes. Furthermore it was added that the optimal zooming coefficient depends on the target display size.

7.5 Viewing Distance, Size and Definition

The viewing distance for Mobile TV is at arm length. It does not depend on the size of the screen, the content or the resolution. In [27] it has been evaluated that preferred viewing distances are between 25 cm and 50 cm with an average of 32 cm. It is stated that "*Mobile TV viewing distances might depend more on the posture of people within a given environment*".

Analysis about the dependencies between size and resolution returned the following result. A resolution requires a minimum size. More in detail: A minimum size of 19.6 mm was required for a resolution of 120×90. Preferred sizes for 120×90 and 168×126 are 32.6 mm and 37 mm.

7.6 Audio-Visual Quality

In section 3.4 it has already been discussed that there are many scenarios where people will not use any headphones [31] and [42]. In this case the question about Audiovisual quality is superfluous. In Section 5 has been stated that news, soap, quiz and sport are those genres during which participants talk most while watching [8], at the same time these are the contents that people want to consume for Mobile TV. This knowledge leads again to the open question if audio-visual quality investigations do make sense for Mobile TV. Nevertheless there are situations at home or during the lunch break where audio-visual quality could matter and in fact according to [59] users noted that a criterion of a device according to Mobile TV is the good audiovisual quality.

7.7 Codec and Bitrate

Jumisko et al. [58] tested different codecs for audio/video material for mobile devices. Six different content types have been under investigation at QCIF format and bitrates in a range from 80 to 128 kbps. By summarizing all results the H.264 codec returned the best quality.

In order to reduce server bandwidth for a true video on demand system a new concept called Low Start has been presented in [57]. It consists in encoding the first part of the movie with a lower bitrate than the rest. Action movies encoded with different Low Start parameter values for mobile devices has been shown to an audience with the result that a short low start with high bitrate reduction is preferred to a lower bitrate reduction for a longer period of time. The result has been confirmed by performing the MSE [16], SSIM [**?**] and VQM [62, 61] of the test sequences with the MSU Video Quality Measurement Tool [10].

In [15] the bitrate has been set to a maximum value and is then decreased step by step in order to find the minimum bitrate for mobile phone, PDA and laptop videos still rated as acceptable by the test persons. For PDAs the limit has been identified by 50% of the original bitrate of 448 kbps and even more for mobile phone and laptop.

8. CONCLUSION

In this work we analysed results of studies performed for Mobile TV from the user perspective, combining the Human Centered Design with the Quality of Experience approach which includes following key aspects: User, Mobile Device, Context/Mobile Services, Content, Cost and Commercial as well as Technical Performance. This is due to the fact that is increasingly necessary to consider and to in-

clude user needs and expectations into the design process of a successful product.

We started with a detailed analysis of potential end users and identified differences caused by cultural aspects, user profiles and others. In our survey we realized that recommendations about interface design or usability evaluations of different prototypes are rarely found. Furthermore we present a wide range of technical aspects that need to be considered to create and propose a successful service. During this work we deduced some important open issues that represent the focus of our further research.

User: Studies do not agree about the gender of the typical user profile and it seems to by highly related to the content and service proposed.

Mobile Device: The acceptance of headphones is not clear and further research will be done to investigate more in detail headphone acceptance and the consequences for the content production in case of headphone rejection.

Context/Mobile Services: Studies show that user priorities often differ from currently offered services and features.

Content: Users want to share and modify content on their mobile devices.

Cost and Commercial: The interplay of commercials and fee types is sot solved yet. It will probably depend on the quality and originality of the produced commercials.

Technical Performance: According to sport, the quality of the presentation is not good enough. For live broadcasting and channel switching the response time is still too high.

Currently there is a lot of information available for Mobile TV, but the list of open issues above shows that there are a lot of interesting and crucial open issues to solve in further research.

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