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Evaluating Ubiquitous Media Usability Challenges: Content Transfer and Channel Switching Delays

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Abstract. As ubiquitous media is developing rapidly, new HCI challenges emerge. In this paper, we address usability issues related to the transfer of content between fixed and mobile devices, as well as channel switching delays on mobile devices. We first provide an extensive review of the field. We then evaluate four relatively novel approaches for initiating a transfer of video content from a mobile phone to a TV screen. Seen from a user's point of view, familiarity and comfort are found to be important decision factors when selecting a preference among the proposed methods. Furthermore, we identify a threshold level above which people appear to be annoyed when switching between TV channels on a mobile device, and investigate factors that may influence the perceived acceptability of such delay.

Keywords: Mobile media, content transfer, channel switching delay, user studies, simulated environment, WoZ.

1 Introduction

TV broadcasters are no longer only focusing on traditional TV sets when broadcasting content. For instance the British Broadcasting Corporation (BBC) [1] and Zweites Deutches Fernsehen (ZDF) [2] explicitly guarantee that their audience can get free access to services in ways and on devices that suit them - acknowledging that users want potential access to media at all times. In order to facilitate this, BBC as well as ZDF have launched in 2007 large media portals: the 'BBC iPlayer' [3] and the 'ZDF Mediathek' [2] both enable users to watch live TV as well as programs from the past week from e.g. internet-connected computers, set-top boxes, and mobile phones.

Broadcasters' intention of supporting multiple platforms and devices makes good sense as ubiquitous computing is becoming increasingly widespread and popular. A 2-month study of 11 mobile information workers in a large IT company in Finland showed that work-related tasks on a daily basis were heavily distributed between a wide selection of devices (e.g. desktop PCs, laptops and various handhelds). By doing so, the workers reported to benefit in terms of efficiency, multitasking, personal ergonomics, privacy and security. [4]

Similarly, Dearman and Pierce interviewed 27 workers and found that ubiquitous computing is not only present at work but also in private homes. In average,

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interviewees had one laptop/desktop PC at work/school, one laptop/desktop PC at home, one cellular device and at least one portable device (typically a digital camera or an iPod). The majority of them even had a laptop PC dedicated for bringing between work/school and home on a regular basis. The interviewees argued that several reasons exist for using multiple devices: form factor, device affordances, portability, and task completion time. In addition to switching between devices for different tasks, participants reported to increasingly engage in activities that span devices (e.g. using a laptop PC in combination with a desktop PC). [5]

In both studies, synchronizing information across devices was reported as a challenge for users. In order to cope with this, they used a combination of portable media, Emailing, shared directories and server-based services.

Combining the ubiquitous computing scenarios with the broadcasting of content to different platforms and devices enables 'ubiquitous media' as defined in [6]. In this paper, the typical ubiquitous media environment includes a TV, a laptop PC and a Smartphone on which users can either watch on-demand- or live-TV. As reported in [4] and [5] an unresolved usability issue exists however when trying to merge a media experience across devices: the synchronizing of information.

In addition, although a lot of focus has been placed on usability of mobile TV, an open issue exists still for what concerns acceptable response times for channel switching [7]. Providing low response times comparable to those known from standard TV is important, but the definition of 'low' remains unclear.

In this paper we therefore address those two unresolved usability issues related to the successful integration of TV and mobile devices: Video transfer across devices and TV channel switching delays on mobile phones.

1.1 Outline

In the next section, we provide an overview of previous research within the integration of fixed and mobile devices as well as TV channel switching delays. We then describe our study design, methodology and results for our two conducted experiments addressing these issues. We finally discuss the results and applied methodologies and provide a general conclusion opening for potential future work.

2 Previous Work

2.1 Integration of Media-Displaying Devices

Ubiquitous media and multiple-device environments have recently come to the close attention of scholars of various areas. In particular, the use of various devices in the home environment has been the focus of the ethnographic study reported in [8], which investigated media habits at home. After having identified the current and ideal home media use of 27 families, the authors designed an experimental mobile device acting as a second screen to control the TV channels as well as displaying photos on the TV screen. Sharing media content and especially broadcast multimedia files (including

long sequences) across devices with peers seems in fact to be one of the strongest drivers for mobile multimedia usage [9].

More concrete empirical studies have dealt with the integration of mobile devices with television sets. For instance it has been proposed to "put the EPG onto everyone's mobile phone" in order to personalize a shared TV in a typical family home [10]. According to the families interviewed during the ethnographic study, being able to access the EPG on their own mobile device and to personalize it allows family members not only to manipulate it without disturbing other TV viewers, but also to help resolving some conflicts with regard to the control of the TV.

A tendency emerging from the literature is that so far most studies have integrated mobile devices into the TV experience from a control perspective, the typical usage being the manipulation of content displayed on the TV screen from the mobile device, and the access to functionalities on the phone that complements the TV experience.

Most recently, the extensive work by Cesar and his colleagues on the concept of secondary screen illustrates the diversity of possibilities offered by multi-device media environments [11]. To this purpose, the authors have developed a taxonomy describing user behaviors in such environment. The taxonomy includes content control (what and how to consume TV content), content authoring (manipulating the TV content) and content sharing (communicating with others). Relevant to the present study, this taxonomy includes "presentation continuity", which allows users to bring their media content along on their mobile device when leaving the room in which resides the fixed TV set. According to Cesar et al., this feature has been mainly investigated through a technological perspective, disregarding user studies.

2.2 Channel Switching Delay

It is commonly accepted that channel switching delay is a critical usability issue with mobile television. The time and cognitive resources allocated to watching television on the move are limited, and users do not like to wait for neither the service to load on their mobile device nor for the channel to switch when requested [12].

This issue has been tackled in the research literature mostly from a technical perspective so far. Clues concerning user's opinion on the topic are provided by studies not specifically targeted at the user experience with channel switching delays on mobile devices. Additionally, there seems to be very little consistence between general recommendations available, technical solutions proposed and user studies performed on existing mobile TV systems, as summarized in Table 1.

Even though the last study mentioned in Table 1 focuses on IPTV and not mobile television, Kooij et al. have conducted the closest study to the one reported in this paper. The authors followed the ITU recommendation concerning the estimation of end-to-end performance in IP networks formulated in [19], and conducted a comprehensive user study validating a model that links channel zapping time and perceived quality expressed as a Mean Opinion Score (MOS). The "zapping experiment" involved 21 test subjects who rated video clips (10 seconds, no audio, video resolution of 720×575) on a web-based interface displayed on a computer screen. When switching between the clips, the test subjects experienced delays of 0, 0.1, 0.2, 0.5, 1, 2 and

5 seconds. The results from the experiment indicate a threshold of 0.43 seconds as acceptable channel switching delay. [18]

Table 1. Maximum acceptable channel switching delay according to various studies

Source	Study type	Max. delay
Nielsen, 1994 [13]	Recommendation	< 1 second (interactive systems)
ITU, 2007 [14]	Recommendation	< 2 seconds (mobile TV)
Rezaei et al., 2007 [15]	Technical	0.9 to 1.6 seconds (DVB-H)
Hsu and Hefeeda, 2009 [16]	Technical	500 ms (DVB-H burst broadcasting only)
Knoche and McCarthy, 2005 [17]	User	5 to 15 seconds (SMDB)
Cui et al., 2007 [12]	User	Up to 10 seconds (SDMB)
Koij et al., 2006 [18]	User	0.43 second (IPTV)

For what concerns the potential factors that can influence the acceptability of channel switching time, Godana et al. investigated the effect of displaying random advertisement pictures during channel switching delay ranging between 0 and 5 seconds on an IPTV system [20]. According to this subjective experiment, displaying advertisement improves the reported Quality of Experience (QoE) for transition time longer than 0.65 seconds. However, showing advertisement only postpones the threshold at which users get annoyed. For short zapping times, the authors argue that a black screen generates better QoE.

In another experiment, De Watcher et al. proposed to display a low quality version of the channel to be displayed when switching channel on a fixed digital television [21]. The authors argue that not only the perceived effect of changing channel is reduced for the user, but the method also optimizes the transition delay itself. In fact, a technical evaluation of the approach showed that it was possible to reduce the channel switching delay from 1400ms to 78ms.

With this previous work in mind, the next section presents our approach in addressing the first of the two unresolved usability issues related to the successful integration of TV and mobile devices, namely the transfer of video content from a mobile phone to a TV set.

3 Acceptability of Transfer Methods from a Mobile Phone to a TV

It seems that despite the number of technical solutions investigated to enable presentation continuity in ubiquitous computing environments, no user studies have been conducted so far to validate the approach against potential end users.

In comparison, our approach tackles the problem from the users' perspective only, regardless of technical requirements or limitations. In this purpose, our contribution is twofold: we verify the interest in transferring video content from a mobile phone to a TV, and seek to identify the preferred method from a usability perspective.

3.1 Transfer Methods

Four pre-selected sets of actions for handing over content were evaluated in terms of usability. The proposed methods were all inspired by common interaction paradigms.

Tossing. This action encompasses a method with which the user literally "tosses" the content from a mobile device to a fixed one, conceptually similar to interacting with the Nintendo Wii. Previous research has shown that 'tossing' as means of interaction is fun to use, although a bit difficult to grasp [22].

Proximity. Here the user has to physically approach a fixed device with the mobile device in order to transfer the content. Previous research has shown that users in general are willing to use 'touching' as means of interaction with devices when such devices are nearby, when security issues exist or when ambiguity is a concern [23].

Browsing. Here the user actively searches for equipment capable of taking over the presentation of content from a mobile device. Once located, the user selects a device and the handover is initiated. Previous research has shown that browsing may be seen as a very technical way of interacting with devices and that users therefore tend to avoid it when possible, unless the device in question is outside touching or pointing range [23].

Pointing. With this action (inspired by Point-and-Connect [24]), the user simply points at the device that is to take over the playback of the video from the mobile phone of the user. When pointed to a compatible device, its name appears on the mobile for the user to click on in order to initiate the transfer of content.

3.2 Setup

The content transfer experiment was conducted as a Wizard-of-Oz setup for which a web-based prototype (see Fig. 1) was developed, allowing video content to be 'transferred' between a mobile phone and a large flat screen TV connected to a computer, based on the actions of the test participant.

The user, only seeing the mobile phone and the flat screen TV, is lead to believe that (s)he actually controls on which device the video content is displayed. The user is also unaware that a wizard is observing his/her actions via live video recordings of the test scene and thereby determining on which device to show the video feed.

All participants are first introduced to a typical scenario in which they are to transfer content from their mobile phone to the TV screen. The facilitator instructs them to select, in turn, each of the four transfer methods on the home screen of the mobile phone application, and then to actually perform the transfer. The order in which the methods are evaluated is randomized for each user in order to minimize potential learning/biasing effects. Participants should comment on each of the four concepts immediately after experiencing it. Finally, after having tried the four concepts, they should indicate and justify their preferred method.

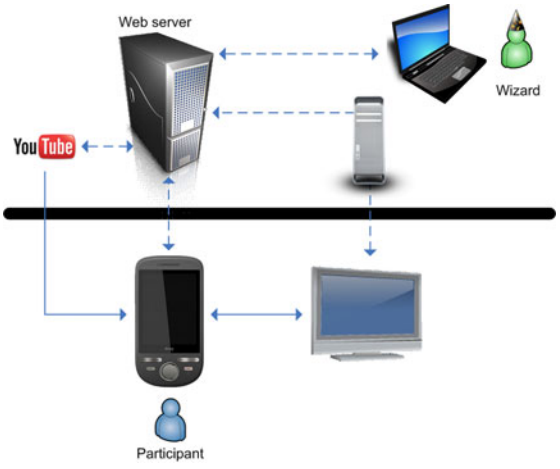

Fig. 1. Technical setup of the content transfer experiment

3.3 Results

Each participant was asked to specify a preference among the four concepts for initiating a transfer from the mobile phone to the TV. The results are shown in Fig. 2.

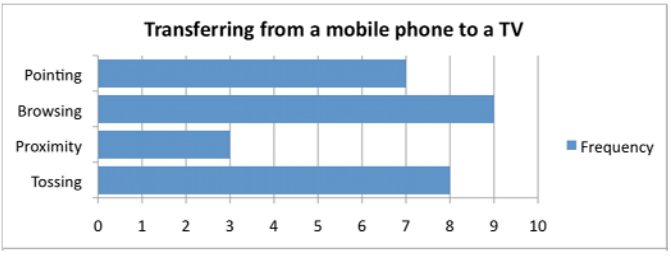

Fig. 2. Preferences when transferring content from a mobile phone to a TV

Based on these findings no significant conclusion can be drawn, although there appears to be a general dislike against the 'proximity' concept. This gives good reason to investigate closer the comments stated by the participants during the experiment. Based on these comments, the participants have been clustered into different groups indicating if they are predominantly positive or negative in their statements about each concept. From the comments collected, it can be inferred that tossing is a popular concept due to the fun of using it. Browsing and pointing are popular due to their resemblance to well-known interaction paradigms (respectively searching for devices under MS Windows and using a remote control). However proximity is not a popular concept, as it requires the user to move around physically which was perceived inconsistent with the context of watching TV.

4 Acceptability of Channel Switching Delay on a Mobile Device

To investigate the acceptability threshold of transition delay when switching between TV channels on a mobile device, video clips pre-padded with a 'transition' were used and compiled into playlists. This approach allows for full control of the delay durations without depending on network conditions and other such environmental factors. An iPod Touch was used to play the video clips and a custom-made web interface displayed on a laptop computer served to assess the transition delays.

The acceptability experiment consisted in assessing the statement "The duration of the transition was acceptable" on a 6-point Likert scale ranging from "Agree very strongly" to "Disagree very strongly". We deliberately chose a forced-choice response scale to reduce the central tendency bias. A range of transition delays (0-10 seconds) was selected based on observations of systems available today: fixed digital televisions offering short channel switching times (approximately 2 seconds) and DVB-H capable mobile phones with which longer delays are usually experienced (approximately 6-8 seconds).

In addition to identifying the threshold of perceived acceptability of the transition delays, we investigated three factors that may influence the perceived acceptability.

4.1 Possible Impacting Factors

Transition Type. Two types of transition were used between the video clips. One type consists in playing the clip of which the video is blurred while the other consists in displaying an animated icon on a blank screen. The former simulates transition conditions that allow delivering content in low quality only, while the latter simply informs the user that something is happening on the device.

Test Environment. Two environments were used as a setup for the experiment: a quiet room where nothing happened besides the test and a usability lab setup that simulated an exterior environment without actually going out in the field. In this case, the scenario for the simulation was a bus trip: the participants were sitting in a dark area, facing a video projection of a 12 minutes bus ride filmed from a 1st person view.

Video Content. Eighty-six video clips were recorded randomly from 43 Danish cable television channels during two sessions on different days. Forty playlists were then created by randomly selecting 33 different clips from the 86 available. The playlists reflect a natural browsing session throughout 33 different channels.

4.2 Results

Acceptability Threshold. Each participant experienced delay durations three times each in order to ensure data consistency. The median of the three responses is computed for each delay duration, producing an array of ratings per participant for all delay durations. Individual thresholds are then determined by the last acceptable rating when reading the array from short to long durations. This approach favors lower delay durations if an acceptable mark is given to a delay longer than the one of the

first unacceptable duration. We argue that a delay rated as unacceptable should be given a higher priority, because the experiment aims at identifying the threshold at which people start getting annoyed by the delay rather than the threshold at which they stop getting annoyed by such delay. Once the personal threshold has been calculated for all participants, averaging them provides a general acceptability threshold. The first conclusion from this study is thus that the participants felt annoyed by delay durations longer than 5.7 seconds.

Effect of Factors. We then investigated the effect of the transition type, test environment and audiovisual content of the video clips on the rating of individual transition delays, according to the following hypotheses.

H1: The ratings of transition delays vary significantly depending on the type of transition used between video clips.

H2: The ratings of transition delays vary significantly depending on the test environment in which the video clips are played.

H3: The ratings of transition delays vary significantly between video clips according to their audiovisual content.

For what concerns the transition type, the one-way analysis of variance (ANOVA) performed shows that similar transition delays visualized as an animated icon were rated as more acceptable with a high level of significance ($p = 7e\text{-}4$). With regards to the test environment, the one-way ANOVA performed shows no significant level of variance between the simulated environment and the quiet room setups.

To investigate the impact of the content on the perceived acceptability of delay durations, the clips have been categorized using a collapsed version of the LSCOM-Lite content classification scheme [25] focusing on the program categories "news" or "entertainment", the scene types "indoor" or "outdoor" and the display of a group of "people" or a single "person". No significant effect of any of these categories was found by the ANOVA performed, which seems to indicate that the type of content does not influence the perception of transition delays.

Table 2 concludes on the three hypotheses concerning the effect of the transition type, test environment and content type on the rating of transition delays.

Table 2. Effect of three factors on the perceived acceptability of transition delays

Hypothesis	Conclusion and comments
H1	Accepted with high significance (transition delays are rated as more acceptable when illustrated with an animated waiting icon than with deteriorated content).
H2	Rejected, only a tendency: transition delays are rated as more acceptable in the lab than in the tent.
H3	Rejected, transition delays are not rated differently according to the video clip audiovisual content.

5 Conclusions and Potential Future Work

In this paper we have investigated usability issues related to ubiquitous media environments. Especially, we have focused on transferring video content from a mobile phone to a TV and on acceptable channel switching delays on a mobile device.

Among the four concepts for initiating a transfer of content from a mobile phone to a TV no significant preference has been found. The lack of conclusive result in terms of preferred method and the somewhat contradictory comments can be interpreted in two ways when it comes to inform potential designers of a market-ready application. Firstly, the pros and cons of each method may equal out among participants, who individually may value different features. In that case, the application should offer end users the possibility to choose among various transfer methods. A second solution would be to encompass all positive features found in the methods evaluated in this study: remoteness (transfer content from afar), directedness (target one specific device), memory (remember devices) and enjoyability (fun to use).

The second experiment reported in this paper shows that delays of up to 5.7 seconds are considered acceptable when switching between two TV channels on a mobile device. The type of content played did not significantly impact this result. For such delay duration, displaying a blank screen with an animated icon was perceived significantly more acceptable than displaying a blurred version of the video feed. The fact that the environment did not impact the results indicates that researchers may conduct such study in a standard usability laboratory without setting up a test environment with a high level of realism.

A real implementation of the content transfer methods would possibly uncover additional usability aspects caused by technical constraints. Additionally, examining participants' reactions when experiencing the four transfer methods could provide further insights on the preference they reported verbally. A behavioral classification scheme could be established in order to do so.

Investigating other scenarios, such as jumping directly to a known channel or skipping over several channels at once, could extend the delay study.

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