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# Acceptable Channel Switching Delays for Mobile TV

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## ABSTRACT

This paper presents a user study investigating the acceptability of channel switching delays on mobile television systems. The authors first review the previous work in the area, then propose a study design and present results from its implementation, focusing on the overall acceptability threshold as well as three potential effect factors: the transition type, the test environment and the audiovisual content. The results show that delays longer than 5.7 seconds annoyed test participants, and that the transition type had a significant impact on the rating of channel switching delays. However, neither the test environment nor the audiovisual content influenced the ratings significantly. Finally, a discussion of these results and directions for future research are proposed.

## Categories and Subject Descriptors

H.5.2. Information interfaces and presentation: User interfaces – *Evaluation/methodology*.

## General Terms

Measurement, Performance, Experimentation, Human Factors, Verification.

## Keywords

Mobile TV, channel-switching delay, user studies, simulated environment.

## 1. INTRODUCTION

Traditional analog television allowed switching channels almost instantaneously. Quite surprisingly from a user perspective, despite the great improvement in terms of video quality, digital IPTV technology suffers from a noticeable latency when changing channel, due to various technological constraints [13].

For what concerns mobile TV, a lot of focus has been placed on various usability matters [1]. However an open issue still exists regarding channel switching delays. Providing low response times comparable to those known from analog TV is important, but the definition of ‘low’ remains unclear. The time and cognitive resources allocated to watching television on the move are limited and differ from those available when watching fixed television, i.e. on a stationary set at home. Furthermore, users do not like to wait for neither the service to load on their mobile device nor for the channel to switch when requested [2].

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In this paper we therefore address the unresolved usability issue of acceptable TV channel switching delays on mobile phones.

## 1.1 Outline

In the next section, we provide an overview of previous research within TV channel switching delays. We then detail our study design, methodology and results for our conducted experiment, before discussing the results and applied methodologies. Finally, a general conclusion summarizes the findings and discussions, and opens for potential future work.

## 2. PREVIOUS WORK

A general human-computer interaction rule concerning response times is that a system should respond to a user input in less than 1 second in order to provide a continuous experience with the system without losing his/her flow of thought [10] (p.135-137).

Waiting times are a common metric to assess service-quality of mobile applications. For instance, the studies described in [11] investigated the change in user satisfaction as a function of the waiting time when performing various tasks on a mobile phone (loading a web-page, placing a phone call, sending an email and downloading content), and under various conditions of place of use and degree of relaxation.

Concerning mobile TV, the issue of channel switching delay has been tackled in the research literature mostly from a technical perspective so far. For instance Rezaei et al. investigated optimal channel switching delays for broadcast television over DVB-H, focusing on the decoder refresh delay and the buffering delay as main responsible factors for the overall channel changing time [12]. This study shows that minimal channel switching delays with DVB-H mobile TV can be expected between 0.9 and 1.6 second. A study by Hsu et al. shows that the burst broadcasting scheme used in DVB-H can be optimized to not only guarantee maximum channel switching delays of 500 milliseconds but also minimize the energy consumption of the mobile device [4].

Contrasting with the technology oriented discussions, user studies are lacking in the area, and most clues are provided by studies not specifically targeted at the user experience with channel switching delays on mobile devices. When designing their requirements for mobile TV, Knoche and McCarthy reported an early study of the streaming based MobiTV service in the USA showing that switching channels on handheld terminals occurred within 5 to 15 seconds [7]. The authors fear that the high contrast between switching delays on a mobile TV service compared to those on a fixed TV set may be a barrier for adoption. In 2006, a study of S-DMB mobile TV usage in South Korea reported that at the time it was common to experience delays of up to 10 seconds when switching channels on a mobile phone [2]. Despite this early work in the area, more recent and detailed studies of the acceptability of channel switching delay seem unavailable.

When it comes to IPTV systems, the ITU recommends channel switching delay to be below 2 seconds to guarantee a satisfactory Quality of Experience (QoE) [5]. Even though many studies in technology optimization have been conducted for desktop PC-based IPTV services, the results of these studies do however not apply to the mobile world due to constraints related to processing power. Nevertheless, these studies provide the closest reference to our concern available in the literature. Kooij et al. followed the ITU recommendation concerning the estimation of end-to-end performance in IP networks formulated in [6], and conducted a comprehensive user study validating a model that links channel switching delay and perceived quality expressed as a Mean Opinion Score (MOS) [8]. In both studies, the selected range of transition delays experienced by the test subjects is based on a logarithmic interpolation between predetermined minimum (0.1 seconds) and maximum (5.0 seconds) values of delay durations, selected according to observations about quality perception [10].

The experiment reported in [8] involved 21 test subjects who rated very short 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 video clips, the test subjects experienced delays of 0, 0.1, 0.2, 0.5, 1, 2 and 5 seconds. The results from the experiment match the proposed model and indicate a threshold of 0.43 seconds as acceptable channel switching delay.

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 [3]. The results from the subjective experiment reported show that displaying advertisement improves the reported QoE for transition time longer than 0.65 seconds. However, showing advertisement only postpones the threshold at which users get annoyed. For short switching delays, the authors argue that a black screen generates better QoE, and for long delays, animated advertisement might improve the QoE compared to fixed advertisement.

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 [15]. This way, 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 time from 1400 ms to 78 ms.

Summarizing this previous work, we can conclude the following:

- Few user studies have focused on the issue of acceptable channel switching delays for mobile TV
- Guidelines exist for dealing with this issue on fixed systems, but today's mobile TV technology cannot comply with them
- Improvements of mobile TV technology have been proposed but have not been implemented in market-ready products
- Various factors may influence the acceptability threshold of channel switching delays on mobile systems

### 3. USER STUDY DESIGN

To investigate the acceptability threshold of transition delay when switching between TV channels on a mobile device, video clips at a resolution of 640×480 pre-padded with a 'transition' were used and compiled into playlists. The reason for choosing this approach

instead of e.g. a real DVB-H setup is that it allows for full control of the delay durations without depending on network conditions and other such environmental factors. The participants manually traversed the video clips using an iPod Touch. A custom-made web interface displayed on a laptop computer enabled participants to assess transition delays right after experiencing them. This aims at reducing any inaccuracy associated with recall-based assessment.

The acceptability experiment consisted in assessing the statement "The duration of the transition was acceptable" on a 6-point Likert scale ranging from 1-"Agree very strongly" to 6-"Disagree very strongly". A forced-choice response scale was deliberately chosen to reduce the central tendency bias.

A linear range of transition delays 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 (6-8 seconds).

The 40 participants who took part in the experiment were recruited among staff and students from the university. They were mostly males: 34 against 6 females. The participants were 30 years old on average, and highly IT literate.

In addition to identifying the threshold of perceived acceptability of the transition delays, the authors investigated the three following factors that may affect the rating of delays.

**The transition type** Two types of transition were used between the video clips. One type consists of displaying an animated icon on a blank screen while the other consists of a deteriorated version of the video clip (blurred video track together with unaltered audio track). The former represents the de facto standard loading symbol of today (as used by e.g. YouTube) while the latter simulates transition conditions that are good enough to deliver information in low quality only. This allows us to investigate whether quality or continuity is of primary concern to users when evaluating transition delays.

**The test environment** Two environments were used as a setup for the experiment: Firstly a quiet room without any visual or auditory disturbances allowing the participants to focus solely on the test. Secondly, a usability lab setup simulating an exterior environment while maintaining the benefit of controlled parameters. In the latter setup, participants seat in a dark tent, facing a video projection of a scenario relevant for the evaluation. In this case, the scenario selected was a 12 minutes bus ride filmed from a 1<sup>st</sup> person view aiming at exposing the participants to a social atmosphere during the test.

**The audiovisual content** Eighty-one video clips were recorded randomly from 43 Danish cable television channels during two sessions: one mid-morning and one mid-afternoon another day. Forty playlists (one per participant) were then created by randomly selecting 33 different clips. The playlists generated reflect a natural browsing session throughout 33 different channels. Although strictly speaking, each channel may appear twice in a given playlist as they were recorded twice, the content differs sufficiently to pass as a different channel.

## 4. RESULTS

### 4.1 Acceptability Threshold

The approach used to calculate the acceptability threshold consists in averaging the personal acceptability threshold of all

participants. The participants experienced delay durations three times each, in order to ensure data consistency. The median of the three responses is computed for each delay duration, which produces an array of 11 marks from 1-6 as depicted in Table 1. The personal acceptability threshold is then determined by the last acceptable value (1, 2 or 3 – with a white background) when reading the array from left to right. This approach favors lower delay durations to be considered as the threshold in cases where an acceptable mark is given to a delay that is longer than the one of the first unacceptable duration (as for instance the rating of the five seconds-long delay in participant 8’s case illustrated in Table 1). We argue that a delay that has been rated as unacceptable should be given a higher priority, even though longer delays may have been rated as acceptable. The reason for this is that 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 it.

**Table 1. Examples of medians and acceptability thresholds.**

Participant ID	Delay duration (seconds)										Personal acceptability threshold	
	0	1	2	3	4	5	6	7	8	9		10
2	1	1	2	3	3	3	4	4	4	4	4	6
8	1	2	2	3	4	3	4	4	5	5	5	3

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**.

## 4.2 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. The hypotheses associated with these three factors are as follows.

*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.*

To investigate hypotheses H1 and H2, one can perform analyses of variance (ANOVA) of the distribution of ratings according to the two factors of interest among clips that have been experienced under the same condition of delay duration and with the two values of each factor. In other words, the effect of the transition type is investigated for each clip experienced with deteriorated content and an animated icon at the same delay duration, and the effect of the test environment is investigated for each clip experienced in the lab and the tent at the same delay duration. However, the randomization of video clips used to create the playlists prevents from studying the effect of both factors simultaneously and their potential interaction. The effect of each factor is thus computed independently from the effect of the other factor.

Concerning the transition type, the one-way ANOVA performed shows that similar transition delays visualized as an animated icon were rated as more acceptable with a high level of significance

( $p = 7e-4$ ). 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, an ANOVA has been performed on the ratings of all clips used in the participants’ playlist. It shows low significance in the variance of the clips rating ( $p = 0.019$ ). The following paragraphs extend this analysis in order to properly conclude on the effect of the video content on the acceptability of transition delays.

The clips have been categorized using a collapsed version of the LSCOM-Lite content classification scheme [9], focusing on the program categories “news” (political, financial and weather related) or “entertainment” (including sport and advertisement), the scene types “indoor” or “outdoor” and the display of a group of “people” or a single “person”.

Since the audiovisual content only affects transitions during which the content is observable (in this case the deteriorated content version), the animated icon counterpart is used as a control for the rating. The difference in ratings for a given clip experienced at the same transition delay was then used as an indicator of the effect of the content on the rating.

However, no significant effect of any of the content categories used was found by the analysis of variance performed, which seems to indicate that the audiovisual content does not influence the rating of transition delays, and that the preliminary results presented above may be due to other factors.

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

In this section we discuss four issues that may further explain the outcome of the conducted experiment.

### 5.1 Consistency With Previous Research

The result of 5.7 seconds as acceptability threshold for transition delays seems inconsistent with the guidelines and the previous results presented in Section 2, in which much shorter delay durations are discussed. However it should be kept in mind that the guidelines in [10] apply to interactive computer systems in general and seems to overlook environmental factors such as ambient noise or distributed cognitive load inherent to mobile systems, while [5] focuses on IPTV systems (fixed).

### 5.2 Time Validity

The validity of these results in time is debatable, as one might argue that mobile TV technology will rapidly improve and most likely reduce current constraints and thus lower delays to a level

that complies with the guidelines for offering acceptable QoE. However, advertisers or researchers could exploit the fact that people are tolerant to some delays. For instance, displaying advertisement, as investigated in [3] seems to result in an unaltered QoE up to a certain duration. Another way of taking advantage of people's tolerance to delays would be to use this time to involve users in a "game with a purpose" (as defined in [14]), which could help e.g. tagging or rating audiovisual content.

### 5.3 Range Selection

In the work conducted in [5] and [8], the selected range of transition delays experienced by the test subjects is based on a logarithmic interpolation between predetermined values of delay durations. In the study presented in this paper, the choice of using a linear range of transition delays was motivated by observations of systems available today, ranging from low delays (2 seconds or less) in fixed TV systems to high delays (up to 6-8 seconds) in mobile TV systems.

Interestingly, in both cases the response of participants follows the distribution of the chosen delay range: a logarithmic range of delays generates a logarithmic response, while a linear range generates a linear response. This observation leads to questioning the choice of the range as a critical aspect of the test design, and calls for future work in the area. Indeed it seems rather difficult to argue for either of the scales with current experimental data.

### 5.4 Impacting Factors

The experiment shows that participants accept longer delays when exposed to an animated icon than to a deteriorated version of the audiovisual content, and therefore prioritize content quality over experience continuity. This result contrasts with the authors' prior assumption and the positive comments from test participants towards the latter visualization option. A potential explanation for this is the frustration that may occur when one can see only partially what happens on the screen, and hence the delay is perceived as more irritable. The presence of audio might add to the frustration for clips that rely on both audio and video for being understood.

The fact that the test environment does not significantly affect the ratings of transition delays is unexpected. However, this finding indicates that researchers can study delay transitions in a standard usability lab instead of simulating realistic test conditions.

The lack of significant impact of the audiovisual content on the acceptability threshold might be due to the short duration during which the content is important for the rating. Longer extracts might show variation in the perception of delays, as participants would get more involved into the topic of the clip.

## 6. CONCLUSION AND FUTURE WORK

In this paper we have described a user study assessing acceptable channel switching delays on a mobile device. The experiment reported in this paper shows that among young highly IT literate users delays of up to 5.7 seconds are considered acceptable when switching between two TV channels on a mobile device. Using an animated icon as a transition appeared significantly more acceptable than playing a deteriorated version of the content. However, neither the test environment nor audiovisual content had a significant impact on the perceived acceptability of transition delays.

Studying additional scenarios, for instance increasing the realism of the browsing session by involving content of interest for the

participant, or jumping directly to a channel number could extend the delay study presented in this paper. Additionally, the choice of playing a low quality video when changing channel could be compared to displaying advertisements or playing games as an alternative during channel switching time. Finally, another content classification scheme could be used to investigate the impact of more specific audiovisual features, such as scene dynamics or color palette, on the rating of channel switching delays.

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