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Mobile Video Streaming Applications: A Systematic Review of Test Metrics in Usability Evaluation

Azham Hussain[1], Emmanuel O.C. Mkpojiogu[1] and Fazillah Mohmad Kamal[2]
[1]*School of Computing, Universiti Utara Malaysia, 06010 Sintok, Malaysia.*
[2]*School of Quantitative Science, Universiti Utara Malaysia, 06010 Sintok, Malaysia.*
azham.h@uum.edu.my

***Abstract*—In evaluating the usability of mobile video streaming applications, the performance of the applications comes into focus. This is because the performance of mobile streaming applications affects their usability. From this study, video streaming and video quality are identified as the two most evaluated elements in the usability test of mobile video streaming applications. These elements are affected by several related factors that are peculiar to the mobile platforms and domains. These in turn affect the usability of the applications. In mobile platforms, bandwidth is low and network connections are unstable; this is coupled with the limitations caused by the smallness of the screen sizes of the mobile devices. Furthermore, startup delays, jitter, latency and re-buffering are the determining factors for the performance of mobile video streaming. On the other hand, video quality is determined by frame rate, bit rate, and resolution. These factors present themselves due to the mobile context of mobile streaming applications. They combine to influence the performance of the applications as well as their usability. Therefore, in considering the usability of these set of applications, these factors (metrics) are important as they determine the performance of the applications and by and large also affect the usability of the applications. Other factors identified in the study that affect the usability of mobile streaming applications include: functionality, social context and user interface and appearance. On the whole, this paper presents the results of a systematic review of test metrics in the usability evaluation of mobile video streaming applications. The systematic review approach used include: defining the search strategy, selection of primary studies, the extraction of data, and the implementation of a synthesis strategy. Using this methodology, 238 studies were found; however, only 51 relevant studies were eventually selected for the review. The study reveals that time taken for video streaming and the video quality were the two most popular metrics used in the usability test and evaluation of mobile video streaming applications. Besides, most of the studies concentrated on the usability of mobile TV as users switch from traditional TV to mobile TV.**

***Index Terms*—Mobile Video Streaming Applications; Performance Evaluation; Systematic Review; Usability.**

I. INTRODUCTION

The video recording technology has been available for decades. People record videos, create movies, and publish them online so that the videos and movies can be shared to their online groups or even to the public. With the innovation of mobile technology, users use mobile to download videos from online sources, such as YouTube, Vimeo, LiveTV, and PPStream. Many mobile apps have been constructed to enable mobile users to stream videos online. When users use an application, they are always allowed to assess and give feedback on the application so that the application could be enhanced and improved to the next stage in meeting and satisfying the users' needs. Thus, usability studies have turned to be a very vital element in evaluating the application. Recently, with the emergence of various mobile apps, the role of usability studies extends the scope of studies to the evaluation of mobile apps as well [1], including the user interface, and performance. This scenario also goes for mobile video streaming apps as well. Researchers develop various video streaming apps and perform usability test for different groups of users under different conditions. However, there are no studies to consolidate the results of usability test for different mobile video streaming apps to produce a review on the metrics used in usability tests by the researchers. Studies in this domain are scarce and limited. This paper therefore seeks to systematically review the test metrics employed in usability evaluation with respects to mobile video streaming applications. The study will assist practitioners/ professionals as well as academics in knowing and understanding the commonly used test metrics in usability evaluation in the area of mobile video streaming applications. It will also enhance their practice and knowledge of usability evaluation in the mobile domain. Researchers will in addition grasp the existing gaps in the literatures so as to fill them. Even designers will find the results of the review interesting as it will foster their understanding of the functionalities that more frequently improve the satisfaction of users and customers

This paper is organized as follows: Section II describes the methodology and design for the systematic review, Section III discusses the details of the obtained results, and discusses the results, lastly, Section IV presents the conclusion from the review.

II. SYSTEMATIC REVIEW

In this paper, the activities to be performed in the facilitation of the process of the systematic review are: the elaboration of the definition of a search strategy, the selection of primary studies, the extraction of data, and the implementation of a synthesis strategy

A. Search Strategy

In order to perform the search and selection of the usability test metrics for mobile video streaming apps, articles and

journals from different online databases were searched. Also, relevant data from the search results were extracted and finally, the collection of studies for review was listed. The search strategy is in this wise: 1) Search Terms: In this review, the search terms were chosen based on a scope narrowed to mobile video streaming apps. The search was done using the following search strings: **C1** ("User Experience" OR "User Review" OR "User Adoption" OR "Usability"), **C2** ("Mobile"), and **C3** ("Streaming" OR "Video Streaming"). So, the complete string used in the review was: **C1** AND **C2** AND **C3.** 2) Search Process: There were two phases in the search process, namely: the primary search and secondary search.

The primary search was performed using five online databases that contain articles and journals, conference proceedings and technical papers: IPA, Sci-Verse, Science Direct, ACM and IEEE Explore. Table 1 presents the total number of studies found, articles duplicated, and the articles eventually selected for the review per their respective databases of origin. Five (5) articles were selected from Sci-Verse database, 4 were selected from Science Direct, 22 were selected from ACM, and 20 were selected from IEEE Xplore databases. These make up the total of fifty-one (51) selected articles. No article was eventually selected from IPA database. During the secondary search, a thorough review was carried out on the references and citations obtained from the primary search. Table 2 shows a complete listing of all papers/ studies selected for the review. On the whole, there were fifty-one (51) papers selected for the review.

B. Study Selection

The scope of the review was defined to be the metrics used in usability test in mobile video streaming apps. Since the scope had been defined clearly before the search process was carried out, most of the articles and journals found were relevant to the review objective. However, there were many articles and journals excluded from the search process, based on the following criteria: 1) The study is only on mobile video apps development, 2) the study presents the usability test on mobile apps without touching on video streaming apps, 3) the study is not written in English, and 4) the study is a book.

Table 1
Total number of studies from databases of origin

Database	Found Articles	Duplicated Articles	Selected Articles
IPA	27	2	0
Sci-Verse	36	14	5
Science Direct	33	12	4
ACM	76	28	22
IEEE Xplore	66	16	20
Total	238	72	51

Table 2
Complete List of Selected Studies

Study ID	Author(s)	Year
S1 [2]	Yuwen at al.	2013
S2 [3]	Yajun et al.	2014
S3 [4]	Song et al.	2012
S4 [5]	Singh et al.	2012
S5 [6]	Singh et al.	2012
S6 [7]	Ramadan et al.	2008
S7 [8]	Kuwadekar et al.	2009
S8 [9]	Kovachev et al.	2013
S9 [10]	Jun et al.	2014
S10 [11]	Jahon et al.	2010
S11 [12]	Ickin et al.	2012
S12 [13]	Hussain et al.	2010
S13 [14]	Huifang et al.	2013
S14 [15]	Herman et al.	2011
S15 [16]	Ghadiyaram et al.	2014
S16 [17]	Díaz et al.	2010
S17 [18]	Devlic et al.	2012
S18 [19]	Chun-Han et al.	2014
S19 [20]	Changgiao et al.	2011
S20 [21]	Bo et al.	2013
S21 [22]	Smyth et al.	2010
S22 [23]	Abe et al.	2013
S23 [24]	Krishnan et al.	2012
S24 [25]	Kaasinen et al.	2009
S25 [26]	Shafiq et al.	2014
S26 [27]	Saleemi et al.	2008
S27 [28]	Wac et al.	2011
S28 [29]	Riede et al.	2007
S29 [30]	Cui et al.	2007
S30 [31]	Peltola et al.	2009
S31 [32]	Vidales et al.	2008
S32 [33]	Kaheel et al.	2009
S33 [34]	Liu et al.	2013
S34 [35]	Gro et al.	2009
S35 [36]	LaRosa et al.	2009
S36 [37]	Knoche et al.	2005
S37 [38]	O'Hara et al.	2007
S38 [39]	Davies et al.	2008
S39 [40]	Finamore et al.	2011
S40 [41]	Shen et al.	2013
S41 [42]	Wu et al.	2012
S42 [43]	Song et al.	2010
S43 [44]	Buchinger et al.	2009
S44 [45]	Maia et al.	2015
S45 [46]	Yoon et al.	2014
S46 [47]	Viswanathan et al.	2013
S47 [48]	Shiddiqi et al.	2010
S48 [49]	Yao et al.	2013
S49 [50]	Seo et al.	2014
S50 [51]	Xin-chen et al.	2010
S51 [52]	Evensen et al.	2014

III. RESULTS AND DISCUSSION

The results obtained from the reviewed articles were classified based on the categories of metrics used in the usability test of mobile video streaming apps, the detailed metrics, number of studies and the percentage of studies. The classification was illustrated in Table 3.

Table 3
Classification of studies based on the metrics used in the usability test

Metric Category	Metrics	Number of studies	Percentage
Streaming Performance	Startup time	5	9.80%
	Packet loss	5	9.80%
	Streaming time	15	29.41%
Functionality		9	17.65%
Interface	Appearance	5	9.80%
	Interactivity	10	19.61%
Social context		15	29.41%
Video quality		23	45.10%
Others	Device	7	13.73%
	Stalling	3	5.88%
	Power consumption	5	9.80%

According the Table 3, streaming performance (49.01%) (Comprising of startup time, 9.80%, packet loss, 9.80%, and streaming time, 29.41%) was the most evaluated element in the usability test for mobile video streaming apps; this is followed by video quality (45.10%). Interface (29.41%) (Composed of appearance, 9.80%, interactivity, 19.61%) and social context (29.41%) were also used in mobile video streaming usability test. Next, in the order of usage are functionality (17.65%), device (13.73%), power consumption (9.80%), and stalling (5.88%). The following sections discusses the metrics used based on the highest total number of studies.

A. Streaming Performance

Video streaming apps involves downloading the video content from remote servers and playing it on a local platform. In desktop application, users usually use broadband connection which provide high bandwidth and a good download rate which allows desktop applications to play high quality video without problem. However, things do not go so smooth when it moves to mobile platform. In mobile platform, the bandwidth is low and the network connection is not stable. If it is not well managed, the video presented will be jittering, pausing to re-buffer frequently. In this review, there were 14 studies that took streaming performance as an aspect to evaluate; and to be enhanced to improve usability of mobile video streaming applications. From these works reviewed, there were a few aspects that researchers evaluated on, to determine the streaming performance provided by a mobile video streaming app, they include: 1) Startup delay: How long does a user has to wait for a video to start playing? In technical term, it describe how long does the app take to download a playable length of video. 2) Jittering: How frequent does jitter happen along the playback of a video? 3) Latency: How long does it take for the data to transfer from remote server to local mobile devices? 4) Re-buffer frequency: How frequent does the video pauses for re-buffer? 5) Re-buffer duration: How long does it take for each re-buffer to complete and resume playback? Based on Table 3, many researchers took streaming time as the main metrics to evaluate the usability of the mobile apps, which showed that streaming performance is the most concerned issue from the perspective of researchers. Some works [5, 21] proposed methods to implement awareness in mobile apps to monitor the performance and lower the video quality when the streaming performance is getting lower than expectation.

B. Video Quality

Video is the main aspect to look at when it comes to video streaming. This does not differ in the case of mobile streaming. Users use video streaming mobile app to consume video of their interest. It cannot be denied that video itself is the key for users to assess or rate the usability of a mobile video streaming app. In this review, there were 23 studies that emphasized video quality as a key aspect in the assessment of the usability of a mobile video streaming app. When users consume the video, it will be meaningless if the video is corrupted, blurred, or not visible. Hence, the mobile video streaming apps need to provide video with clear and satisfying video quality to achieve higher usability. This however is a challenging task because there are many limitations and challenges in mobile platform such as device screen size, fluctuating network connection and limited bandwidth. Generally, there are a few characteristics that affect the video quality that was gathered from the studies and research works reviewed: 1) Frame rate: The number of frame to present in 1 second of video. The higher the frame rate is, the more fluent the video will be. However, the size of the video file will increase as well. 2) Resolution: The dimension (width and height) of the video. The higher the resolution is, the more detail the video will be. However, the size of the video file will increase as well. 3) Bit rate: The size of data to represent a frame after codec compression. The higher the bit rate is, the clearer the video will be. However, the size of the video file will increase as well. Several works [9, 14] have been carried out by researchers to find a solution to obtain optimized video quality in mobile platform streaming through the features itemized above.

C. User Interface and Appearance

User interface design is a vital factor in application development. It touches not only the appearance design, but also setting up the navigation flow, and incorporating functionality into various forms of interactive elements to be used by users. Hence, user interface is an important factor in the assessment of the usability of an application. Of course, mobile video streaming apps are not exempted from this. Among the studies that were reviewed, there were 9 works that talks about user interface factors in assessing the usability of a mobile video streaming app. Some studies [25, 44] suggested that developers should not simply migrate their web video streaming application into mobile platform without any changes. In fact, the developers and designers should re-design the application to fit into the mobile platform. For example, the mobile devices such as smart phones are generally small in screen size. To optimize the screen, the video should be shown full screen without any other elements such as description, links, and advertisements around the video. For more on the usability of mobile devices, see [53-61].

D. Functionality

In video streaming apps, the performance of streaming video and the video quality offered are vital factors for usability. However, apps have to offer other functionality for the users to access the video provided, before the users can consume and interact with them. Without this functionality, the users cannot find the video they are interested in, hence, degrading the usability of the apps. Among the studies reviewed, there are works on the importance of functionality in enhancing and evaluating usability of mobile video streaming apps. Below is some of the example of the functionality that was extracted from the research works: Browsing video, Searching, Pause the video, and Seeking (jumping to a certain scene, or particular seconds in the video). Song et al. [4] has pointed out that the functionality should also include interactive functions such as content selection, rating, quality selection, as well as content availability.

E. Social Context

An application should have a context it aims to serve at. Although it is generally named as "mobile video streaming app", but the context may be different for each app. For example, there might be news video streaming app, TV

watching app, documentary viewing app and etc. Besides that, it also includes the factor of social context that surrounds the app and the users. In this review, 15 studies highlight social context as an aspect to evaluate a mobile video streaming app. From these studies, a few aspects regarding the context can be highlighted: 1) Purpose: Whether the app meets its purpose. It evaluates the app's capability to fulfill the purposive expectation from users. 2) Content Type: Whether the app is able to provide various types of content that suits the users' interest, as well as for different situations. For example, user might be interested to watch some relaxing music video during tea break after working, or may prefer to watch TV series when lying on his/her bed. 3) Content Duration: Whether the app is able to provide video of various durations. For example, users might want to watch a short clip when he is waiting for buses or might want to watch a longer clip when he is trying to get relaxed after taking shower.

There were other researchers that carried out usability test based on some minor aspects, such as devices used, stalling rate, and power consumption during video streaming. Although there were no significant data shown in the review, those elements could be the factors that impact the usability of the mobile apps.

IV. CONCLUSION

This paper presents the results of a systematic review on the metrics of usability test in video streaming using mobile apps. In the study, 238 studies were found, but only 51 were eventually chosen for the review. The study shows that time taken for video streaming and the video quality were the two most popular metrics used in the usability test for mobile video streaming apps. Besides, most of the studies concentrated on the usability of mobile TV as users are switching from traditional TV to mobile TV. The review on the mobile video streaming apps revealed that streaming performance and video quality were the most concerned factors in developing a usable mobile video streaming app. From the articles, users who participated in the usability test indicated that they will abandon the mobile app if the video took a long time to stream the videos. Secondly, if the images in video had low resolutions, and low bit rate, the users may lose their interest in watching the videos. Hence, those were the two main metrics to be used in testing or evaluating the usability of mobile video streaming apps as captured in the systematic review.

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