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Assessing Learning Achievements when Reducing Mobile Video Quality

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Abstract: When using mobile phones for learning purpose, video content is considered to be the preferred type of multimedia content. However, the video file has a big size in comparison to text or audio and might lead to a high delivery cost when transmitted over a mobile network, a cost that not all users are willing to pay. Concerns regarding the monetary cost for accessing data content through mobile networks have been raised by various researchers. A solution that considers the user preference for trading off between video quality and price in order to reduce the content delivery cost is presented. This paper also evaluates the proposed solution and presents the results of an experimental study that assesses the video content adaptation impact on information assimilation. The results show that although video quality is reduced information assimilation is not negatively affected by the adaptation. This holds true regardless of the mobile device used in the study.

Keywords: Adaption/Adaptive eLearning, Personalization and Profiling, eLearning Systems/Technology/Tools/Platforms, Online Learning, Wireless/Pervasive Computing, Multimedia Information Systems
Categories: H.5.1, L.2.0, L.2.2, L.3.0, L.3.5, L.7.0

1 Introduction

Mobile phones' penetration and network coverage continue to increase, with mobile phones' penetration rate being currently of 96% globally [ITU 13], and 100% network coverage is expected to be achieved by 2015 [ITU 12]. These have made mobile phones an ideal platform to cater educational content anytime, anywhere. Given the individuality of the mobile learner, adaptation can be considered a pre-requisite in mobile learning systems [Marin 09]. The diversity of mobile phones also makes the adaptation a necessary, since content developed for one mobile device may not be functional for another device. From an educational point of view, it has been shown that adapted content is more effective [Specht 09], improving test results and learning goal achievement [Chen 08].

At the same time, video content is increasingly used in education. Different studies have investigated the potential of using video in education. It has been found that video enhances student interest [Dickinson 10], engagement [Neumann, 11], it has the potential to enhance student's performance [Fritsch 09], facilitate online learning [Weerakkody 14], can help students with high absenteeism [Dickinson 10],

and can be used to promote an inquisitive environment [Park 10]. Video is the most effective way of delivering the educational content to mobile phones [Macdonald 11], and it "is becoming casual and conversational", a "primary form of communication" between many young people [Bell 10].

Accessing the Internet on mobile phone is normally more expensive than accessing the same information via personal computers (PCs), and billing plans for mobile phones that allow unlimited Internet access without any restrictions are not common [Sen 13]. This problem is aggravated by the scarce resources of wireless networks as compared with wired ones, and the exponential increase of multimedia content over cellular networks [Trestian 12]. Concerns related to the cost of accessing the Internet from a mobile phone have been raised by various researchers from the mobile learning area and not only [Blackburn 14] [Gedik 12] [Mishra 12] [Shadle13].

Since the video file is larger in size than a text file it is prone to a higher price to be paid for its delivery over a cellular network. Moreover unlimited flat rate pricing for cellular networks is not the norm [Sen 13]. Currently most billing plans have "very strict quotas" [Raj 13]. Initially, mobile network operators offered flat rate plans but afterwards backed-up and capped the mobile data plans [Bode 12]. This trend continues even on higher bandwidth mobile networks such as 4G [Sohota12]. As the mobile data traffic increases dramatically [Rowell 14] capped billing plans are likely to persist, and affect the learners that use the Internet for accessing educational content.

It has been shown that not all learners are affected in the same way by the content delivery price with some being more affected than others [Molnar 10]. When learners were asked to choose between paying high prices for a high quality video or paying a lower price for a lower video quality, students' answers varied. Some of them where willing to pay for the high video quality, while others preferred to switch to a lower video quality in order to reduce the cost. Decreasing the quality of the video content has been shown to reduce the content size, and therefore it has a positive impact by reducing the delivery cost [Molnar 13b] [Oeldorf-Hirsch 12]. [Molnar 2015] have shown that the difference in the attitude of people when choosing a certain video quality over the price to be paid can be explained by people's attitude towards risk. The risk averse persons prefer to pay less for video content and to trade it off with video quality while risk seekers are more likely to prefer a high video quality. The study [Molnar 15] also presents a methodology that classifies people either in willing to pay for high video quality or not based on their age, gender and their attitude towards risk. It can be used by a video delivery mechanism that reduces the cost of delivery for the learners not willing to pay for the high quality video content.

To the best of our knowledge this is the first study that aims to personalise educational video delivered for a mobile phone based on people's risk attitude and the device characteristics in order to address the cost of delivery when the video is delivered over mobile networks. In order to assess the feasibility of the adaptation mechanism for educational purposes, this research assesses whether the learner's capacity to assess information is affected when lower video quality is provided at reduced delivery cost as opposed to the case when the learner receives higher video quality. The adaptation mechanism was tested on two different mobile phones with seven types of video content.

To do so, this paper is organised as follows. Section 2 presents related work on the cost of content delivery over mobile networks, and the usage of video in mobile learning. Section 3 briefly introduces the proposed video adaptation mechanism. Section 4 presents the results of the experimental study. Section 5 discusses the results and how they can be used in a broader context. Section 6 concludes the paper.

2 Related Work

The research presented in this paper, spans across the following areas: delivery cost of mobile learning content and video usage in mobile learning.

2.1 The Cost of Content Delivery in Mobile Learning

Concerns related to the monetary cost for accessing educational content through mobile networks have been raised by various researchers [Blackburn 14] [Gedik 12] [Mishra 12] [Shadle 13]. The delivery cost has been considered to be one of the most important problems hindering the widespread adoption of mobile learning [Dyson 09]. The fact that the downloaded mobile data is capped is also an issue impacting mobile data adoption among some learners [Koole 10] and the trend in capping mobile data is likely to persist due to the increase in mobile data traffic [Raj 13].

A study [James 11] performed on student perception and potential impact of mobile learning in Thailand concluded that there are still "crucial" technological constraints related to mobile learning. Various issues have been mentioned such as "huge" cost of always being connected to a mobile network [James 11] whereas [Maleko 12] reported that "cost of an internet connection was to some extent a hindrance" in usage of the mobile learning system.

There has been some previous research that aims to reduce the cost of delivery for mobile learning but it addresses mostly text type content. For video delivery, [Molnar 09] analyse the case when multiple networks are available on the mobile phone and offer different pricing options and quality of service. The propose solution selects the cheapest one for the learner as long as the delivery of content is supported by the quality of the service on that network. However, the cost is still an issue when only one network or similar priced networks are available for the learner. Previous work has shown that video adaptation can be used as a means of reducing delivery cost however, there was not a unanimous decision among people's preferences [Molnar 10]. Some people prefer a degraded quality just for paying less while other people prefer to pay for high quality regardless of the price [Molnar 10]. A multimedia adaptation mechanism can be implemented based on these results to reduce the video quality for the learners who wish to reduce their delivery cost. However, by degrading multimedia quality learner's ability to assimilate information could be affected, an aspect that this study addresses.

2.2 Usage of Video in Mobile Learning

Study habits are changing. Some students use video as an initial point of reference when they have questions related to a topic [Helft 09]. Video usage "is becoming

casual and conversational", a "primary form of communication" between many young people [Bell 10], being shown that students used mobile devices to watch YouTube videos [Kinash 12]. In education, video can be used among others to promote an enquiry environment [Park 10] to facilitate the comprehension of abstract concepts [Pereira 14], and to help students that were not able to attend the class [Dickinson 10].

Video has been used by mobile learning systems for different purposes such as: to enable access to education for a large number of students [Ullrich 10], to investigate different solutions for delivering mobile learning educational content [Macdonald 11], to adapt the content based on learning styles [Karadimce 13], and to investigate students preference for multimedia content [Uther 12].

Mobile Live Video Learning System, MLVLS [Ullrich 10] is presented as "the first learning system that streams video based lectures to mobile devices". The system was designed to work with Symbian OS smartphones. The video resolution of the broadcasted lectures was 320 x 240 pixels. Difficulties were noticed during the study due to the GPRS connection bandwidth that is low or unstable, leading to frame drops and distorted video and audio. The results of the evaluation have shown that students liked the introduction of the system.

[Hung 14] investigated the use of video prompts to promote student reflections. The students in the study were involved in outdoors learning activities. The prompts were delivered based on the context the students were in and the prompts were either video or text. The study showed that the use of video prompts provided better learning achievements than the text-based prompts.

[Macdonald 11] investigated the viability of using mobile learning for workplace learners. They conducted a pilot study that contained different media: text (as a PDF), video and audio. The content was both stored on the mobile phone, and part of it streamed over the Internet. The students were provided with a Nokia N96, and a Symbian S60 mobile phone, with a resolution of 240 x 320 pixels. The results of the study have shown that video was the most effective way of delivering content for mobile phones. At the opposite side were text files that were found cumbersome to use, and students reported eyestrains while reading.

Typically when video content is used in mobile learning projects a single version of the video is delivered to all the students and the version used will cover the main requirements for the given connection and devices the students have. Several studies have also looked into delivering adapted video content based on the learner's device battery consumption with the aim of increasing its lifetime [Jalal 14], based on the learner's cognitive styles with the aim of reducing the network strain [Karadimce 13] or adapted the educational content (either by adapting the content itself or by providing a different type of content) based on the learner context (e.g. device features, learners' preferred media type and learning location) [Garruzzo 2007a] [Garruzzo 2007b] [Rosaci 2010] [Zhao 11]. The research presented in this paper considers video content adapted based on the learner preferences and the cost of delivery. This type of content is larger than other types posing problems to the learners that have capped data plans and may lead to higher charges. The next section introduces the adaptation mechanism that aims to reduce the cost of video delivery considering a trade-off with video quality.

3 Cost Oriented Adaptive Multimedia Mechanism

This section provides a brief description of the video adaptation mechanism, COMEDY [Molnar 13a], which has been used for video adaptation during the study presented in this paper. This mechanism can be used to adapt the content of an online course when students that access the content have a capped billing plan. Figure 1 highlights a possible interaction with the online system that makes use of the adaptation mechanism. During the registration process the learner is asked to provide his age, gender and to answer a question assessing his risk attitude. The data is saved in a Learner Profile. When the learner requests a video clip, the data from the Learner Profile is used to compute his risk attitude. The risk attitude is further used by the system engine, which implements the adaptation mechanism, COMEDY, to provide the learner with adaptive video content. The System Engine implements COMEDY as an adaptation mechanism and a detailed description on how the mechanism selects the appropriate video quality is presented below, in Figure 2.

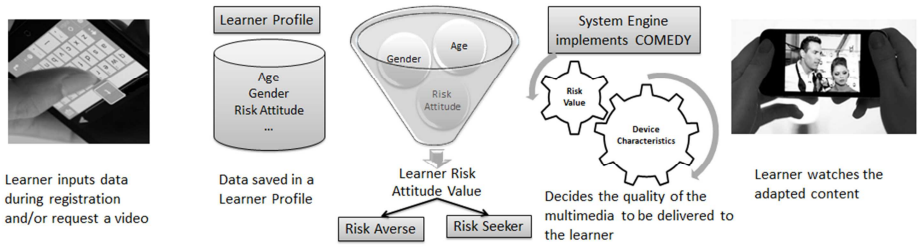

Figure 1: Adaptation mechanism scenario

The mechanism takes into account the mobile device's resolution (as described in Table 1) and learner's risk attitude (based on the formula below that considers the age, gender and learner answer to the general risk question), and adapts the video clip resolution and the bit rate value in order to reduce the video's delivery cost over the wireless network. Two types of learner risk attitude are considered: risk averse (a person not willing to assume risks under uncertain situations) and risk seeker (a person willing to take risk in uncertain situations). The learner risk attitude (RV_{Stable}) is computed based on the formulas below by considering her/his answer to the questionnaire answered during the registration and the data obtained from a sample of 22,000 participants (by using the SOEP dataset [SOEP 09]) to determine the weights and the probability for a learner of a certain gender and age to have a certain risk attitude ($RV_{AgeGender}$). More details are provided in [Molnar 15]

$$RV_{Stable} = w_1 * \mathrm{RV}_{GeneralRiskQuestion} + w_2 * RV_{AgeGender}, \text{ where}$$

$$w_1 + w_2 = 1, \text{ and}$$

$$\mathrm{RV}_{AgeGender} = \sum_{i=0}^{10} RiskValue_i * ProbabilityRiskValue_i$$

The mechanism that determines learner's risk attitude and the video quality to be delivered is illustrated in Figure 2. The mechanism first computes the learner's risk attitude, *learnerRiskAttitude*, based on information saved in the Learner Profile and classifies the learner as either risk averse or risk seeker. Then, based on the learner's mobile device features the suitable video resolution is determined, *recommendedVideoResolution*. Due to the diversity of mobile phones resolutions that exist on the market [Molnar 2013a] the resolutions have been classified into five resolution classes (Table 1). By considering this classification a learner with a given device resolution receives a video content that has the recommended resolution for the class it belongs to. Based on the *recommendedVideoResolution* and the learner's risk attitude, *learnerRiskAttitude*, the mechanism determines the recommended bit rate value for the video content, *recommendedVideoBitrate*. For each resolution class, recommended value for the maximum and minimum required bit rates have been established based on various adaptive video-streaming providers and standards as described in [Molnar 2013a] (see Table 1). The low bit rate value is the recommended video bitrate for learners classified as a risk seeker (column 3 from Table 1) whereas the high value issued for the ones classified as risk averse (column 4 from Table 1). If the video content that the learner has requested has a resolution or a bit rate value higher than the recommended one, it will be transcoded to the recommended value and then delivered to the learner.

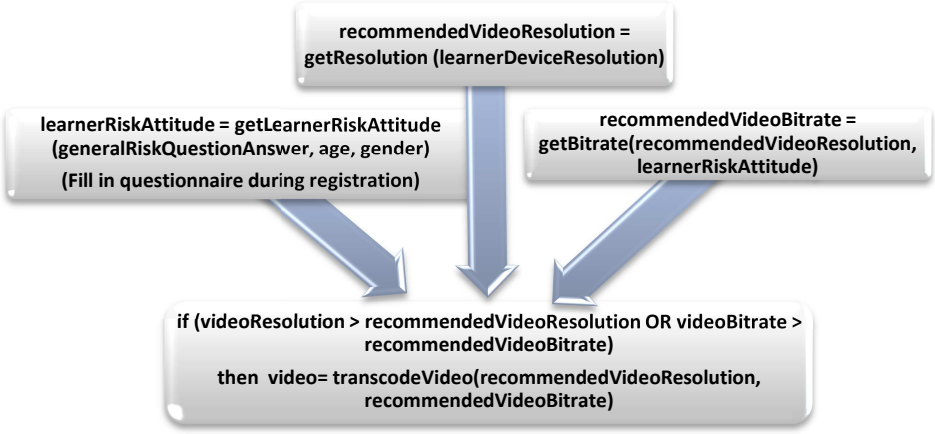

Figure 2: Determining the suitable video quality to be delivered

Resolution	Shorthand	Low Threshold Bit Rate Values	High Threshold Bit Rate Values
800 x 1280	1080p	2 Mbps	3 Mbps
720 x 1080; 640 x 960	720p	1.5 Mbps	1.8 Mbps
480 x 640; 480 x 800; 480 x 854	480p	0.6 Mbps	1 Mbps
360 x 640; 360 x 480; 320 x 480; 320 x 320	360p	350 kbps	550 kbps
240 x 400; 240 x 320; 176 x 220; 120 x 160; 128 x 128; 96 x 128	240p	150 kbps	250 kbps

Table 1: Resolution classes and recommended bitrate values

4 Experimental Study

The aim of the study is to assess whether video clips of lower quality impact on learner capability to assimilate information provided in the video clip. A mobile learning system should support the learning and the learner should be able to acquire the correct information provided in the video. The learning achievement is defined as the quantity of knowledge the learner has accumulated. Learner assessment can be formative, summative or criterion referenced. The formative assessment is defined as evaluating the student knowledge, capabilities, etc. without passing a formal grade. The summative assessment is defined as the evaluation in which the learner is graded, at a certain point in time. The criterion referenced assessment is defined as evaluating the learner against a set of benchmarks.

A summative assessment allows easier comparison of subjects' performance and provides reliable data [Shute 10]. Therefore, this method is suitable to be used in an experimental study, where the aim is to assess/compare students' performance. The summative assessment can be performed as a course grade, pre/post test scores, and standardised scores. In general, a test may contain the following types of test items: true-false, forced-choice, multiple-choice, essay and/or gap-filling. The most used form of assessment is a pre/post-test, where students' knowledge is evaluated before the educational content is introduced and a post-test is performed after the study to analyse the effect on the results. The study presented in this paper uses forced-choice and true-false items when assessing the participant's knowledge.

4.1 Set-Up and Procedure

A total of 76 participants took part in this study. These were students or members of the staffs from the two Irish universities who volunteer to participate in the study. Among these 26% were females and 74% were males with ages between 19 to 57 years old. The participants' risk attitude was assessed by using the method described in [Molnar 15] classifying 36% of the participants as risk averse and 64% as risk seekers. This information was obtained from a questionnaire the participants were asked to fill in at the beginning of the study.

The participants were provided with two smartphones: a Google Nexus and a Samsung Europa. Android smartphones were selected due to the fact that Android Operating System (OS) is the most common OS currently on the market [Mahapatra 13]. Regarding the smartphone's manufacturer, Samsung and Google were selected, since Samsung is the most used manufacturer considering the overall mobile subscriptions, and Google has the most smartphone subscribers [comScore 11]. The two smartphones have the two most common resolutions for mobile phones 480 x 800 pixels and 240 x 320 pixels.

To evaluate whether the adapted video clip impacts on the learner's capacity to assimilate information provided in the video clip we selected seven educational video clips covering a large variety of video type content: a slideshow, a screencast, a presentation (two persons speaking with the help of some slides), a lab demo, an interview, a documentary and an animation clip. All the video clips that were used during the evaluation were downloaded from the iTunes U[niversity]. The clips belong to the following categories from iTunes U[niversity]: business, learning resources, environmental, science, ecology, astronomy, and one belongs to the unknown category. The encoding format of the video clips is MEPG-4 ACV/H.264. The video clips were transcoded to 480p and 240p. For each resolution class two versions of the same video clip were created with bit rate values as indicated in Table 1. The video clips were embedded in a web page when presented to the participants, each clip on a separate web-page.

The experimental study took place into a controlled environment: the participants did not have the possibility of interacting with other participants (it was a single participant in the room where the evaluation took place), and the settings did not allow noise and interruptions. The study lasted on average 40 minutes. The participants were asked first to fill in a questionnaire. The questionnaire contained demographic data and questions used to determine the learner risk attitude [Molnar 15]. Based on this data they were divided into one of the two groups: risk averse (that got the lower video quality selected according to the video quality recommendations for mobile devices and were the experimental group for the study) or risk seeker (that got the higher video quality selected according to the video quality recommendations for mobile devices and were the control group for the study). After that the participants were also asked to do a pre-test in order to evaluate their knowledge level on different areas covered by the video clips. The results of the pre-test and post-test were used to assess the learning achievements.

After completing the questionnaire a written description of the experiment was given to the participants. A training session was also conducted before starting the actual experiment in order to avoid biases due to misunderstanding. The results of the training session were not taken into account in the analysis. Up to this point, the tasks were the same for the participants regardless of their group. Next, the division in the two groups accounted for the video version they have received. The participants watched the first version of the video clips, belonging to the 240p class, on the Samsung Europa smartphone, and the second version of the video clips, belonging to the 480p class, on the Google Nexus smartphone. After watching each clip they answered a question related to the information presented in the clip. These questions assessed participants' ability from the video clips and they were part of the post-test.

To assess the statistical significance of the learning achievements, an adaptation of the Student t-test, Welch's t test [Welch, 17] has been used in this study. This test can be used when the assumption of equal variances cannot necessarily be made and it also works well with samples of unequal size, as the samples used in this study are. A Confidence Interval (C.I.) of 95% was adopted for statistical significance. The data was analysed using R (http://www.r-project.org), release 1.12.1.

4.2 Results

4.2.1 Pre-test

A pre-test analysis was performed to assess whether the participants could have known the answers for the post-test questions before watching the educational clip. Figure 3 presents the percentage of people who answered correctly the questions based on the risk category they are in, and the type of video. It can be seen that the participants had previous knowledge only on the content presented in the animation clip, and much less knowledge regarding the content presented in the other clips.

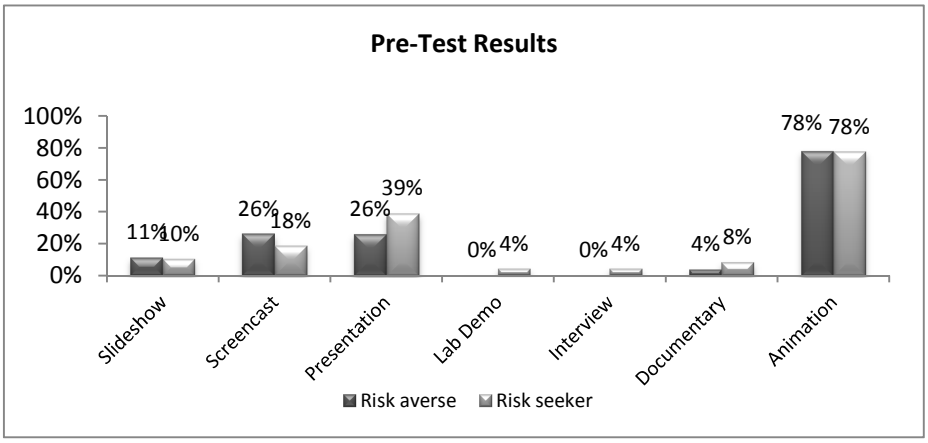

Figure 3: Pre-test results

In order to determine if the risk averse and risk seeker groups have the same prior knowledge, regardless of the material presented in each clip, a Welch t test was performed on the answers provided by the two groups. Since the material presented in each clip, is from different areas, it was decided the test to be performed for each clip. A 95% Confidence Interval (CI) was considered for statistical significance. The results show that there is no significant difference between the two groups (see Table 2). Since the two groups do not vary significantly in their knowledge, only the post-test results will be used further on in the analysis.

Video Clip Category	t value	p value
Slideshow	0.1201	0.9049
Screencast	0.7373	0.4645
Presentation	1.1571	0.2520
Lab Demo	1.4292	0.1594
Interview	-1.4292	0.1594
Documentary	-0.8234	0.4131
Animation	0.2213	0.8257

Table 2: Welch t test results for the pre-test

4.2.2 Learning Achievements when using Samsung Europe

The participants that have used the Samsung Europe device have received video clips encoded at a resolution of 240 x 320 pixels, the device resolution. The risk averse participants got the video clips encoded with a bit rate value of 150 kbps and the risk seeker participants got video clips encoded at 250 kbps (see Table 1). After watching a video clip the participants were asked to answer a question assessing the information presented in the content. Table 3 presents the percentage of participants who answered correctly, based on the video category and the group they are in. All the participants answered the questions correctly for the interview and documentary category, regardless of the group they belong to. Correct answers were also given for the low quality of the screencast and presentation clips. Although there is a difference in the percentage of correct answers for the two groups, the difference is low. The lowest number of correct responses was obtained for slideshow, for both groups.

A Welch t test with a 95% confidence interval was performed for each video clip. For the following video clips no significant difference was obtained: slideshow, screencast, presentation, lab demo, and animation (see Table 3). The Welch t test was not performed for interview and documentary since all the participants answered correctly all the questions regarding these two video clips. Therefore, for the 240p device class, the reduction of the video quality for the risk averse participants did not affect in a statistically significant manner their capacity to assimilate information, comparing with the risk seeker participant, who got a higher video quality. Moreover Cohen effect size (d) and Pearson correlation (r) were all smaller than 0.01 showing a small effect size between the two groups [Cohen 88].

Video Clip Category	Correct Answers: Low Quality	Correct Answers: High Quality	t value	p value
Slideshow	78%	82%	-0.39	0.6982
Screencast	100%	98%	1	0.3223
Presentation	100%	94%	1.7693	0.0832
Lab Demo	96%	98%	-0.3932	0.6961
Interview	100%	100%	n/a	n/a
Documentary	100%	100%	n/a	n/a
Animation	93%	94%	-0.2075	0.8365

Table 3: The percentage of participants that provided correct answers and Welch t test results for the 240p class

4.2.3 Learning Achievements when using Google Nexus

After using the Samsung Europe device, the subjects were asked to use the second device, Google Nexus, with a resolution of 480 x 800 pixels and to visualise video clips similar to the ones presented on the first device, but having a different educational content. The second set of video clips, presented to the participants, was encoded at a resolution of 480 x 800 pixels. A video bit rate value of 0.6 Mbps was used for the video for the risk averse participants and a video bit rate value of 1 Mbps for risk seekers. Table 4 presents the percentage of questions answered correctly by the participants based on their risk attitude and the video clip type. The questions addressed information presented in the images of the video clip, as the image was the only one degraded during the adaptation.

Similar to the tests for the 240p category, a Welch t test with a 95% confidence interval was performed on the results for each video clip (see Table 4). The only exception was the documentary category, for which, the participants answered all the questions correctly regardless of the category. For slideshow, presentation, lab demo, interview, and animation, the test did not show significant differences between the two groups. For the video clip from the screencast category, the Welch t test shows that the differences between the groups are statistically significant. However, as it can be seen from Table 4 the risk averse participants performed better in the post-test. Therefore we can conclude that the reduction of the video quality for the risk averse category did not negatively affect their capacity to assimilate information, comparing with the risk seeker category. Cohen effect size (d) and Pearson correlation (r) were all smaller than 0.01 showing a small effect size between the two groups [Cohen 88].

Video Clip Category	Correct Answers: Low Quality	Correct Answers: High Quality	t value	p value
Slideshow	82%	94%	-1.4815	0.1469
Screencast	100%	88%	2.588	0.0127
Presentation	93%	98%	-0.971	0.3383
Lab Demo	88%	90%	0.1201	0.9049
Interview	56%	45%	0.8805	0.3825
Documentary	100%	100%	0.8234	0.4131
Animation	96%	92%	-1.4815	0.1469

Table 4: The percentage of participants that provided correct answers and Welch t test results for the 480p class

5 Discussion

This article presented an experimental study that investigated if the knowledge acquisition from low quality video clips is affected when COMEDY, is employed as a video adaptation mechanism. The aim of the mechanism is to reduce the video delivery cost over the mobile networks that make use of capped billing plans. The monetary savings when employing this mechanism have been assessed in [Molnar 2013b]. Learning achievement has been measured in term of correct answers to questions on the educational content presented in the video clips. The results of the post-test show improvements in learning gains compared to the pre-test results. All participants regardless of the group and the video class answered questions related to the documentary clip correctly. All participants answered correctly the question for the interview type clip for the 240p class device regardless of the group they belonged to. For the remaining clips Welch's t test was performed to see if there is a significant difference between the two groups. The test shows no significant difference between the two groups. The same results were obtained for the 480p category, except for the video clip from the screencast category. In this case statistically significant difference was obtained. It can be noted that the risk averse group answered more questions correctly. Therefore, we can conclude that in this case, the proposed video adaptation mechanism does not negatively affect the knowledge acquisition from the video clip.

There are several implications of this research. Although this research addresses learners in particular it could be extended to general consumers of mobile video content, as most often the video content delivers certain information.. For the learners, the outcome of this research could be beneficial, as they can obtain content that is adapted based on their needs: the risk averse type learners receive video content that involves low delivery cost and the risk seeker type learners receive a higher quality than the one provided to the risk averse. The advantage of this mechanism is that video quality is reduced just for the learners who prefer reduced quality for paying less, while the ones who prefer to pay for the high quality will still obtain a high quality. Content providers and mobile network operators could benefit as well from the results of this research. From the content providers' point of view, offering adapted content can lead to more satisfied learners as they are provided with content

based on their needs. It can also lead to the ability of the learner/user to consume more of the content provided and hence increase the revenues. The proposed mechanism also reduces the bandwidth consumption and help preventing traffic overload to the server or proxy. A big problem that mobile network operators face is congestion. The proposed adaptation mechanism can help in reducing the bandwidth consumption, hence diminishing the congestion problem. Alternatively the mechanism can be used to better manage network resources and to accommodate more users.

As all research studies, this study has several limitations. First, this study is an experimental study and has the drawbacks associated with it (i.e. the study is performed in a controlled environment that does not take into account all the contextual factors which may affect mobile learners). This set-up allowed us to control certain parameters and as a result to draw more accurate conclusions but as a side effect, it may not fully represent the multitude of factors that may affect a user learning on a mobile device. Second, this study considered only the scenario where the learner uses a mobile device for educational purposes but other means of learning may be available (e.g. laptop). We did not analyse the learner experience when using a desktop computer as opposed to a mobile phone, mostly because the content accessed from a laptop or PC is accessed via a broadband (e.g. Wi-Fi) connection that is not always capped or when capped, the threshold data the user needs to reach is high. Fourth, we have focused only on video content as this is the content that consumes considerably more bandwidth than other types of content (i.e. audio, image, text). Fourth, affecting the video quality could lead to user dissatisfaction. While a low quality could lead to a worse user experience, there are mixed results in the literature regarding the importance of high quality video to be delivered to the students. Some studies report the importance for students to have high definition video when it is used in educational contexts [Weerakkody 14]. Other studies report on users not always selecting the best video quality when given the opportunity to do so [Ghinea 06], [Molnar 10]. Measuring the perceptual video quality is considered "notoriously difficult" [Ghinea 06] and gently affecting the quality does not always have an effect on the perceived video quality [Chen 06]. In this study we assume that if the learner is using the mobile device for learning purposes and he has a capped billing plan there may be learners who are not willing to pay the full price for the video quality (e.g. consuming the data in the bundle or paying extra for exceeding data) but also learners who may prefer a reduced price. Under these circumstances the last category may be willing to accept a lower video quality [Molnar 10] [Molnar 15]. However a learner who prefers a lower quality to save money may prefer a higher video quality if s/he does not have the cost constraints [Molnar 10] [Molnar 15]. Therefore, the adaptation mechanism proposed in this article will not necessarily provide an optimal user experience for the learners who have unlimited access to the data but has the potential to improve user experience for those who do have it. Future studies will be needed to assess whether this mechanism could be suitable also for laptops and PCs when the learner's Internet connection is capped.

6 Conclusions

The aim of this research was to assess whether adapting the video content with the aim to reduce the cost of the delivery negatively affects the learning achievement for the learners receiving lower quality video content. Learning achievement has been measured as correct answers to the questions related to the educational content presented in the seven types of video clips. Two devices were used in the evaluation: Samsung Europa (resolution: 240 x 320 pixels) and Google Nexus (resolution: 480 x 840 pixels). An experimental study was performed with 76 participants and the results have shown that regardless of the device used, the mechanism does not negatively affect the knowledge acquisition from the video clip. As such this results provide positive evidence regarding the potential of using a similar adaptation mechanism when the learner is accessing video content under the restrictions imposed by a capped billing plan.

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