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The influence of prior knowledge and viewing repertoire on learning from video

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Abstract Video is increasingly used as an instructional tool. It is therefore becoming more important to improve learning of students from video. We investigated whether student learning effects are influenced through an instruction about other viewing behaviours, and whether these learning effects depend on their prior knowledge. In a controlled environment, 115 students watched a number of instructional videos about the technical equipment needed in a course on digital photography. Every second student was instructed about other possible viewing behaviours. A pre-post-retention test was carried out to calculate learning effects. The differences with respect to the learning effects of students who received an awareness instruction on an alternative viewing strategy were not significantly different. The differences as observed in our earlier experiment however could not be reproduced. Students with a broad viewing repertoire showed higher learning effects than students with a narrow repertoire. Furthermore, students with a strategic viewing approach also showed higher learning effects. Certain conditions have to be met: the technical and didactical quality of the video must be good, the integration in a learning task must be apparent, students must be aware of their viewing behaviour, and teachers must be aware of their students' viewing behaviour in order to enrich the viewing repertoire of students when they have at least some basic knowledge e.g. after several lessons on the topics at hand. In future research, this study should be replicated using more complex video episodes than the

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instruction videos we used in our experiments that were only on the factual knowledge level of the taxonomy of Bloom. Moreover, replication of this study with a larger sample size could yield a significant improvement in learning effects. This is plausible because students need an amount of prior knowledge beyond a certain threshold value in order to be able to expand their knowledge network in their long term memory. Finally, additional media player functionality, facilitating effective student learning from video, can be described based on the results of this study.

Keywords Viewing repertoire · Learning styles · Streaming video · Adaptive systems · Log files · Metacognition

1 Introduction

Video is now frequently used as an instructional medium in education. It is therefore becoming more important to improve student learning processes in video instruction. Students are mainly coached to improve their learning skills from text. Video has not been a popular medium for learning to date. A media player control buttons (start and stop) give students only limited possibilities to interact with video.

The role of interactive features in learning from video versus print has been investigated by Merkt et al. (2011) who showed that the effectiveness of interactive videos was at least comparable to that of print, probably due to the opportunities provided for self-regulated learning.

The experiment described in this article is part of a larger study. This study investigates how to make learning management systems more adaptive at run-time, based on an analysis of the video viewing behaviours of students (Atif 2011). In the first part of this project, four *viewing scenarios* were identified based on anonymous data from log files on streaming media servers (De Boer and Tolboom 2008). One of the scenarios was *viewing by zapping* where a student appears to skim a video episode. According to earlier research (Blijleven 2005), a broken link between the learning task and the learning process could be the underlying reason.

In the second part of the study (De Boer 2010), learning processes and tasks and the possible link with learning styles were investigated further. This showed that student learning processes (constituting a learning task) could be monitored through the use of log files. However, there was no clear link between viewing scenarios of students and their learning style. Vermunt's distinction of learning styles (1992) includes not only a cognitive perspective, but also a self-regulating and motivational perspective. We proposed to extend the series of four viewing scenarios with a fifth one called *snorkelling scenario*. Students were looking for specific parts of the instruction videos, resulting in an other type of viewing scenario than the zapping scenario.

The third part of this study (De Boer et al. 2011) focussed on the cognitive perspective and investigated whether student viewing behaviour is determined by pervasive personality traits. The study noted that viewing behaviour with streaming video is not strongly correlated to more pervasive personal traits such as short-term memory capacity and learning styles. Students proved to be flexible in changing their viewing behaviour.

Our research group wanted to investigate the influence of prior knowledge on the learning effects of students with different viewing behaviours. In the current article we propose a new model which addresses both style-oriented and strategic-oriented elements in manifest viewing behaviours and distinguishes between narrow and broad viewing repertoires. This model is based on metacognition and recent theories about learning styles in educational research Peterson et al. (2009) and we have applied this model to a group of 115 students.

The remainder of this article is organised as follows. *Related Work* reviews the relevant literature on the use of multimedia and adaptive learning systems. In *Research Design and Research Questions* the methodology is presented. In *Results* the results of our experiment are presented. These results are discussed in *Discussion*.

2 Related work

2.1 Learning from video and adaptive learning systems

Merkt et al. (2011) investigated the role of interactive features in video learning as compared to learning with print. In contrast to prior studies, they found that the effectiveness of interactive video was at least as good as that of print, probably due to the opportunities for self-regulated information processing. Zahn et al. (2004) studied two apparently conflicting classes of design principles for instructional (hyper) videos. Their results indicated that both browsing and knowledge acquisition were not significantly influenced by the design parameters of the video. However, individual navigation behaviours were significantly correlated with knowledge acquisition.

According to Clark and Mayer (2008), multimedia offers several possibilities for knowledge acquisition. They discuss several proven guidelines such as the modality and contiguity principle. The modality principle states that text on screen should also be presented as narrative text. Verhoeven et al. (2009) argued that comprehension through multimedia involves the parallel processing of auditory and pictorial elements in working memory. This process of knowledge construction may depend on imposed cognitive load. Firstly, cognitive load is determined by prior knowledge. Secondly, it is determined by the load imposed by the processing of cognitive strategies and task demands.

As a basis for constructing more adaptive learning systems, the concepts of learning styles and learning strategies are often proposed. Tseng et al. (2008) have proposed an adaptive learning approach based upon two main sources of personalisation, i.e. learning behaviour and personal learning style. Abell (2006) described a model based upon learning styles and emerging digital media in order to individualise learning with the help of intelligent agents.

Schiaffino et al. (2008) identify two main research directions for constructing more adaptive learning systems: adaptive educational systems and intelligent tutor systems. The latter are characterised by continuous efforts to optimise both the system responsiveness and the meta-cognitive awareness of learners. Instead of allowing the learner to adapt the medium to his/her own learner traits, it provokes the learner to become more active and challenges his/her unbalanced mental trend or mental repertoire. Adaptive educational systems accommodate a variety of presentation styles and

navigation styles through the student's profile. Intelligent tutor systems recommend educational activities and deliver individual feedback according to the student's profile. The authors proposed an agent which may be considered as an intelligent tutor which unobtrusively observes the student's learning behaviour and builds the profile. A Bayesian network representation is explored in order to detect a student's learning style as a basis for more adaptive learning systems. During the course, this network is populated with information. Özpolat and Akar (2009) proposed an automated model in order to detect the learning style of a student. Both examples make use of the Felder & Silverman model to classify learning styles (Felder and Silverman 1988).

2.2 Learning styles and ongoing critique

Our experiments investigate how learning management systems may be made more adaptive at run-time, based on student viewing sequences. The design of adaptive learning environments on the basis of learning styles rests upon the idea that student learning styles are stable through time and across learning tasks. Huai (2000) tested this hypothesis and found evidence for this both in the literature and in experimental outcomes.

The use of learning styles has been questioned in that they are a simplification of many dimensions and cannot explain the essence of individual learning characteristics. Willingham (2009) disregards the existence of learning styles, differences across learners are however important. In fact, many differences across learners exceed the impact of personality traits. The most important differences are:

- The student's motivation to learn the subject in question
- The student's prior knowledge of the subject (novices need more structure and support)
- The extent to which the student has learned how to learn (independent learners will be much less demanding)

Becta (2005) summarised the fundamental difference between fixed *learning styles* and flexible *learning strategies* as follows: instead of adapting teaching and content to the learner, the learner needs to choose the approach that is most appropriate for the requirements of the task at hand. Becta also concluded that encouraging metacognition, i.e. being aware of one's own thought and learning processes, is perhaps the most important advantage that can be claimed for applying learning styles theory to learning and teaching.

Peterson et al. (2009) in a survey on learning styles showed a considerable degree of consistency among researchers with respect to the potential impact of learning styles. They for instance point out the use of awareness by students and teachers of learning styles.

The first part (De Boer and Tolboom 2008) of the present study did not show any relationship between manifest sequential preferences and underlying personality traits. The experiment in the second part of our study (De Boer 2010), demonstrated that student learning processes within a learning task could be monitored through the use of log files. However, there was no clear link between viewing scenarios of students and their learning style. The link between short-term memory and learning styles according

to Huai could not be reproduced (De Boer et al. 2011). There were no significant correlations between preferred viewing styles and personal traits, such as learning styles and short-term memory capacity. Some students switched their viewing style to suit their cognitive need. However, this did not lower their test score.

This student flexibility in adapting viewing behaviour is in line with the missing correlation between pervasive personality traits and learning styles, as demonstrated earlier. The term *viewing strategy* was proposed by De Boer et al. (2011) instead of *viewing style*, in order to account for the flexible, conscious, and strategic change in student viewing behaviour.

2.3 Metacognition and awareness

Efklides (2006) defined awareness and metacognition as a level of thinking which involves active control over the process of thinking used in learning situations. He divided metacognition into three components:

- Metacognitive *knowledge* (monitoring learning behaviour) is defined as what individuals know about themselves and others as cognitive processors;
- Metacognitive *experiences* (monitoring learning behaviour) are defined as those experiences which relate to the current, on-going cognitive endeavour;
- Metacognitive *regulation* (controlling learning behaviour) is defined as the regulation of cognition and learning experiences through a set of activities which help people control their learning endeavour.

Examples of metacognitive skills are: planning how to approach a learning task, monitoring understanding, and evaluating progress at the end of a learning task. Students who are able to use a wide range of metacognitive skills score higher in exams and complete learning tasks more efficiently (Efklides 2006).

De Boer et al. (2011) used the term ‘viewing strategy’ for a student showing signs of strategic viewing behaviour. A student with a typical strategic viewing behaviour stated in an interview: ‘*I first watch the movie, and then I try to guess which questions will be asked, and then I watch those specific fragments again.*’ This viewing behaviour is strategic in the sense that the student consciously plans at the beginning of a viewing session to list the fragments to be watched again at the end of the video. He also monitors his learning behaviour (metacognition). We have added this strategic viewing behaviour to our four earlier defined viewing styles: Zapping, Linear, Maintenance Rehearsal, and Elaboration (De Boer et al. 2011) (see Table 1).

Students can exhibit additional strategic viewing behaviours, but the one described above was predominant in our experimental setting using relatively short videos. In the interviews held after the sessions, students often mentioned a strategy to master a software program using a long video tutorial. They stopped the video periodically to exercise the skills demonstrated in the video and continue watching the video after practising with the software.

Kozhevnikov (2007) explored cognitive style research methods in order to examine superordinate cognitive styles (meta styles). She defined the extent to which individuals exhibit flexibility and self-monitoring in their choice of styles. The *one-trick viewers*

Table 1 Viewing styles and viewing behaviour De Boer (2011)

Viewing style	Viewing behaviour
Linear	a student watches a video in one pass (uninterruptedly) from beginning to end
Elaboration	a student watches a video a second time after the first complete viewing
Maintenance Rehearsal	a student watches parts of a video repeatedly
Zapping	a student skims the instructional video watching relatively short segments
Strategic	a student watches a video in one pass (uninterruptedly) from beginning to end, and then watches one or more specific segments again

have a narrow viewing repertoire and the *multi-trick* and *strategic viewers* have a broader viewing repertoire.

Cook (1991) examined learning style awareness among a group of 78 college students in order to determine the extent to which learning style awareness is independent of teaching styles, and whether these students would benefit from such an awareness in terms of academic achievement. Cook found a significant difference in academic achievement in favour of the learning style awareness group.

The concept of learning style awareness has been adopted in our earlier experiment (De Boer et al. 2011) in order to enhance learning effects. We checked whether learner awareness of their viewing style contributed to learning effects. No strong correlation between viewing styles and pervasive personal traits was perceived. Some students switched their viewing style based upon their cognitive need without lowering their test score. The ability of the student to adapt their viewing behaviour may have led to this correlation being observed. Students scored 20 % higher on the test scores after using an awareness instruction.

2.4 Research design and research questions

We increased the number of students participating in this study compared to our previous study (De Boer et al. 2011) in order to investigate whether students could indeed achieve higher learning effects using an awareness instruction. Furthermore, we investigated the effect of the prior knowledge level on these outcomes, as proposed by De Boer et al. (2011). Based on the research of Salomon (1984), we expected that students with a high level of prior knowledge would achieve higher learning effects. Finally, we checked whether students with a strategic or multi-trick viewing behaviour had higher learning effects than students with a one-trick viewing behaviour.

In the first part of the next model we propose to classify the use of our viewing behaviours, based on Efklides' conclusions about learning behaviour.

- A student may exhibit only one specific viewing behaviour (e.g. either linear or elaboration) and not a *strategic* viewing behaviour (*one-trick viewers*)
- A student may exhibit several viewing behaviours (e.g. linear and elaboration) but not a *strategic* viewing behaviour (*multi-trick viewers*)
- A student may exhibit specific viewing behaviours (e.g. linear and maintenance rehearsal) as part of a *strategic* viewing behaviour (*strategic viewers*)

The operational research questions for the underlying experiment were:

1. *What is the difference in learning effects between students with and without an awareness instruction on an alternative viewing behaviour?*

The number of students was increased during the experiment in order to investigate in more depth whether students can indeed achieve higher learning effects. An awareness instruction on an alternative viewing behaviour was given to every second student. It was expected that students who received this awareness instruction would attain higher learning effects.

2. *What is the effect of the students' prior knowledge level on the learning effects?*

We investigated the possible influence of prior knowledge on the students' learning. The pre-test score is a proxy for this prior knowledge level.

3. *What is the difference in retention decay between students with and without an awareness instruction on an alternative viewing behaviour?*

Between three and 4 weeks after the post-test, a retention test was held in order to see how far the post-test effect became extinct, and whether the intervention (awareness) factor had any influence on this.

4. *Do multi-trick and strategic viewers achieve higher learning effects than one-trick viewers?*

The viewing behaviours of students were scored with the metacognitive model described earlier, and the learning effects of students with a multi-trick and strategic viewing behaviour were investigated and compared with one-trick viewers.

In this experiment, 115 bachelor students from the Hanze University of Applied Sciences followed a 9 weeks course about photography in four periods: three periods of the academic year 2010–2011 and one in the academic year 2009–2010 (see Table 2).

In one of the weeks of this course the students learned about portrait photography in a photo studio, and how to use equipment for the digital darkroom and photo studio such as a flashlight and a light meter. We developed five instructional videos about the use of this equipment and made them available for the students in the web-based learning environment (see Table 3). The instruction videos we used in our experiments were only on the factual knowledge level of the taxonomy of Bloom (Bloom et al. 1956). The number of questions is the same as the number of information elements in the video.

The following three steps were undertaken during this experiment:

Table 2 The four periods and the number of students that followed the course about photography

Period	No. of students
March 2010–April 2010	19
September 2010–November 2010	38
December 2010–February 2011	28
March 2011–April 2011	30
Total	115

Table 3 The instructional videos used, the topics covered and the number of multiple-choice questions

Instruction video no.	Topic covered	Length (m:ss)	No. of questions
1	Short introduction to flashlight equipment	0:53	4
2	Flashlight equipment	0:53	4
3	Flashlight meter	1:12	4
4	Linking the flash equipment with the digital reflex camera	1:35	4
5	RAW format and photo editing software	3:30	12

- 1 The students were instructed about the instructional design: the learning tasks and the multiple-choice tests.
- 2 The students performed the learning tasks with the support of the five instructional videos.
- 3 The students were assessed by five online multiple-choice tests with respect to the topics covered in the videos.

Every student was interviewed between the fourth and the fifth instructional video. Every *second* student during this first interview was assigned to receive an awareness instruction about their viewing behaviour: (s)he was made aware of the existence of alternative viewing behaviours. After (s)he had completed the learning task every student was interviewed again on typical features of their viewing behaviour, and in order to measure the learning effects.

The learning task was recorded in a usability lab (see Fig. 1 below) with an eye tracker. Eye tracking is normally applied for tracing the user's eye movement e.g. during reading. In recent studies, eye tracking has also been used to study cognitive processes in multimedia learning environments (Gog et al. 2009). In the experiment, the eye tracker was used as part of the so-called retrospective think-aloud method

Fig. 1 The usability lab used in the experiment

(Guan et al. 2006). Applying this method, students are interviewed directly after the learning task using the video recording functionality of the eye tracker. This recording includes a screen capture, eye movements, and mouse movements, the surroundings with a webcam, and surrounding sound with a microphone. The student and researcher together view the recording immediately after the experiment. The student is therefore able to recognise his learning process and answer questions in a more objective way.

We recorded and used eye movements in the interviews, but ignored quantitative data (e.g. position on screen, distance from screen) in our further analysis. However, we did use the video recordings afterwards to study the strategic viewing behaviour of the student, and the position of the fixation points on the screen. We noticed for example that towards the end of the video some students checked the progress bar of the media player.

In order to measure learning effects a pre-post test was designed. Due to the small number of items in each test, a regular pre-post test could not be used. In order to measure post-test scores, we used the regular score of the multiple-choice test after the last instruction video. The pre-test score was determined by asking the students during the last interview which multiple-choice questions they could have answered without watching the corresponding instructional video.

The (*absolute*) *learning effect* is defined as the post-test score minus the pre-test score. In order to distinguish between students with the same absolute learning effects, we also related the absolute learning effect to the maximum possible learning effect of a student in the test (see Fig. 2). This maximum possible learning effect is the maximum possible score of a test minus the pre-test score of a student, i.e. the maximum that a student could learn in that situation.

We define the *relative learning effect* as the quotient of the absolute learning effect (post-test score minus pre-test score) and the maximum possible learning effect (max score minus pre-test score).

For instance: if a student has a pre-test score of 40 and a post-test score of 80 (maximum score of the test is 120) his absolute learning effect is 40 ($80 - 40$) and his relative learning effect is 0.50 ($(80 - 40) / (120 - 40)$), i.e. this specific student learned 50 % of

Fig. 2 The absolute learning effect and maximum learning effect

what (s)he could have learned. For another student, with a pre-test score of 80 and a post-test score of 120 (maximum 120) the absolute learning effect is *also* 40 (120–80) but the relative learning effect is now 1.00 (120–80/120–80), i.e. that student learned 100 % of what (s)he could have learned.

These two examples show that two students, with the *same* absolute learning effect, can have *different* relative learning effects. The *relative* learning effect also aligns with the awareness instruction where a student has to enhance their learning effects to his/her best. We will use both measures in our further analysis to get a more complete picture of the learning effects of a student.

After three to 4 weeks a retention test was taken – this was the same test as the post test. The retention test was not conducted in the same controlled situation as the post test. The test was taken in class and via email due to organisational circumstances. The *absolute retention decay* is calculated as the post-test score minus the retention score. For instance, if a student had a post-test score of 90 and a retention score of 60, his/her absolute retention decay is 30. This absolute retention decay has also been rescaled to a relative measure. We define the *relative retention decay* as the quotient of the absolute retention decay and the post-test score. For instance, if a student had a post-test score of 90 and a retention score of 60, his/her relative retention decay is 0.50. We will use both measures in our further analysis to get a more complete picture of the retention decays of a student.

3 Results

In total 115 students participated in an elective course about photography between March 2010 and April 2011 (see Table 2). The students differed with respect to the major of their bachelor study. In our dataset 19 students from our earlier experiment were included (De Boer et al. 2011). ANOVA was used in order to test the differential learning effects between the four periods and revealed no significant differences between these four periods.¹

In the interviews held afterwards, the students were asked to rate both the technical and the didactical quality of the instructional videos. On a scale from 1 to 10, the technical quality was rated with a 7.9 and the didactical with a 7.6. Thus the overall quality of the videos can be assessed as good, and thus the quality of the videos is unlikely to be a cause for any additional interruptions of the video by the student (e.g. a student couldn't hear a specific fragment due to poor audio quality and therefore rewinds the video).

The first research question was: *What is the difference in learning effects between students with and without an awareness instruction on an alternative viewing behaviour?*

Exploratory data analysis (Tukey 1977) revealed that there were three types of student:

- 4 The first type of student (*good student*) is defined as: (s)he achieves a very high score on our multiple-choice tests and uses a one-trick viewing behaviour. Because

¹ $F(3, 111)=0.50, p=0.68$

her/his score is already high, there is no need to change their *one-trick* viewing behaviour to a more elaborate viewing behaviour e.g. *multi-trick* or *strategic* viewing behaviour.

- 5 The second type of student (*weak student*) is defined as: (s)he achieves a very low score on our multiple-choice tests and is using *multi-trick* and/or *strategic* viewing behaviour. Her/his score is already low while using more elaborate viewing behaviour.
- 6 The other students (*students with improvement potential*) belong to the third type.

The first type of student has a high cognitive score and low metacognitive score. The second type of student has a low cognitive score and a high metacognitive score. The rest of the students belong to the third type.

The criteria for identification of Type 1 students was: their post-test score was ≥ 110 , and their viewing behaviour was one-trick viewing in the first four (of five) videos ($N=9$). The criteria for identification of Type 2 students was: their post-test score was ≤ 80 , and their viewing behaviour was either multi-trick viewing or strategic viewing ($N=3$). Students who did not meet the criteria for either Type 1 or Type 2 were labelled as Type 3 students. We restricted the analysis below to the Type 3 on these Type 3 students of ($N=102$).

The differences in relative² and absolute³ learning effects between both groups show no significant differences (see Table 4). The differences in learning effects shown as a result in our earlier experiment (De Boer et al. 2011) could not be reproduced on the same scale. As proposed by De Boer et al., we will also investigate the effect of prior knowledge level.

The second research question is: *What is the effect of student prior knowledge level on the learning effects?*

We investigated the effect of prior knowledge level on learning. The pre-test score is a proxy for the level of prior knowledge. The students were divided into four groups: very low (0–30), low (40–60), middle (70–90), and high pre-test scores (100–120). We investigated both the *absolute* learning effect (see Table 5) and the *relative* learning effect (see Table 5).

When comparing students with and without awareness instruction, we note no significant differences independent of the level of the prior knowledge (Table 5). We disregarded the results of students with *high* prior knowledge because of their low number ($N=2$, according to Table 5). The largest difference in learning effects for students with medium level prior knowledge was still not significant.⁴

The third research question is: *What is the difference in retention decay between students with and without an awareness instruction on an alternative viewing behaviour?*

Between three and 4 weeks after the post-test, a retention test was set in order to see whether knowledge level had decayed and whether prior knowledge level, and whether the intervention (awareness instruction) had any influence on this. The test was sent via

² $t(92.3)=0.98, p=0.33$

³ $t(95.6)=0.12, p=0.91$

⁴ $t(24)=1.20, p=0.09$

Table 4 Learning effects: The relative learning effect (absolute learning effect divided by the maximum learning effect)

	No.	Absolute learning effect (mean)	Std. deviation	Relative learning effect (mean)	Std. deviation
Awareness instruction	52	47.1	20.0	70.7 %	18.1
No awareness instruction	50	46.6	23.9	66.6 %	23.4
Total	102	46.8	21.9	68.6 %	20.7

email to those who were not present. The differences between retention learning decays - taken either in class or sent by e-mail - were not significant.

The relative retention decay of the no-awareness intervention group shows no differences. The influence of prior knowledge on retention decays was also investigated (see Table 6).

The relative retention decay of students from the awareness intervention group and *very low* knowledge level group appears lower than the relative retention decay of students from the non-awareness intervention group (see Table 7). The relative retention decay of students from the awareness group and *low* knowledge level group seems higher than the relative retention decay of students from the non-awareness group. The relative retention decay of students from the awareness intervention group and *medium* knowledge level group seems higher than the relative retention decay of students from the no-awareness intervention group.

The differences in relative retention decay of students from the awareness intervention group and the non-awareness groups were not significant and independent of the level of prior knowledge (see Table 7).⁵ We disregarded the results of students with *high* prior knowledge because of their low number ($N=2$, according to Table 7).

We conclude that the retention decay appears higher for students who received an awareness instruction about alternative viewing behaviour, than for students with *very low* prior knowledge level. The retention decay appears lower for students with *low* and *medium* prior knowledge level.

The last research question is: *Do strategic viewers achieve higher learning effects than non-strategic viewers?*

The viewing behaviour of the students was also scored with the metacognitive model described earlier, and compared with their learning effects. We used the entire group as earlier and did not compare the intervention group, because in the intervention group there was only one student remaining with one-trick viewing behaviour.

The difference in relative learning effects between students with one-trick and multi-trick viewing behaviour is significant⁶ (see Table 8). The difference between multi-trick and strategic viewers is small.

Students with a strategic and multi-trick viewing behaviour score higher relative learning effects than students with a one-trick viewing behaviour. Furthermore, the percentage of strategic viewers is high (over 60 %).

Finally, the retention decays were investigated.

⁵ Very low: $t(15.7)=1.17$, $p=0.26$; Low: $t(39.0)=-1.04$, $p=0.30$; Medium: $t(20.6)=-1.12$, $p=0.28$

⁶ $t(23.7)=-2.86$, $p=0.009$

Table 5 Relative learning effects: The students were divided into four groups: very low (0–30), low (40–60), medium (70–90), and high pre-test scores (100–120)

Pre-test group	Awareness instruction			No awareness instruction		
	Relative learning effect (mean)	No.	Std. deviation	Relative learning effect (mean)	No.	Std. deviation
Very low (0–30)	74.3 %	11	12.1	76.2 %	12	14.9
Low (40–60)	70.3 %	26	15.8	70.5 %	23	11.3
Medium (70–90)	63.7 %	13	23.4	49.6 %	13	35.4
High (100–120)	100.0 %	2	0.0	75.0 %	2	35.4
Total	70.7 %	52	18.1	66.6 %	50	23.4

We conclude that the difference in both retention decays between multi-trick and strategic viewers is small. The students with a one-trick viewing behaviour have the lowest scores (see Table 9).

During the interviews held as part of a retrospective think-aloud method, ten ‘strategic viewers’ described their viewing behaviour almost exactly as defined in our metacognitive model. Furthermore, five of the multi-trick viewers also said that they would have viewed the material in a strategic way if the buffering – and therefore pausing - of the videos did not occur. Six students stated that they would have used strategic behaviour had the videos been longer. Finally, five students described some techniques which helped them when viewing video in a strategic way e.g. they used the cursor as a marking point on the progress bar to help them to remember which segments to watch again. Two students indicated that the quality of videos was already quite good, saying they experienced no need to watch segments again.

4 Discussion

The learning effects of 115 students have been investigated. The study extrapolates from an earlier experiment of 19 students (De Boer et al. 2011). The results have been collected during four different periods. As expected, the effect of period did not have any influence on the difference in learning effects.

The differences with respect to the learning effects of students who received an awareness instruction on an alternative viewing strategy were not significantly different. The differences as observed in our earlier experiment (De Boer et al. 2011) however could not be reproduced. The largest difference in learning effects

Table 6 Retention decay: The relative retention decay (absolute retention decay divided by the post-test score)

	No.	Relative retention decay (mean)	Std. deviation
Awareness instruction	41	10.9 %	17.5
No awareness instruction	45	14.3 %	18.2
Total	86	12.6 %	17.8

Table 7 Relative retention decay: The relative retention decay is the absolute retention decay divided by the post-test score. The students were divided into four groups: very low (0–30), low (40–60), middle (70–90), and high pre-test scores (100–120)

Pre-test group	Awareness instruction			No awareness instruction		
	Relative retention decay (mean)	No.	Std. deviation	Relative retention decay (mean)	No.	Std. deviation
Very low (0–30)	24.0 %	7	13.7	13.8 %	11	22.8
Low (40–60)	9.1 %	22	19.6	14.9 %	19	16.3
Medium (70–90)	5.6 %	10	12.8	13.1 %	13	19.3
High (100–120)	12.5 %	2	5.9	13.3 %	2	7.0
Total	10.9 %	41	17.5	14.0 %	45	18.2

for students with medium level prior knowledge was still not significant. However, the p-value of 0.09 suggests that with a larger sample size a significant improvement in learning effects could be achieved. This is plausible because students need an amount of prior knowledge beyond a certain threshold value in order to be able to expand their knowledge network in their long term memory. This also accounts for the students with high level prior knowledge but the number of these students was too low in our sample. Our results did not match those of Cook (1991). She gave students tips about their learning behaviour based on their learning styles, and found significantly higher learning effects. In our experiment, we did not use study tips based on the student's learning style, but we used suggestions about their viewing behaviour based on our metacognitive model. The retention decays were also included in the analyses. Our hypothesis was that students with lower prior subject knowledge are less capable of enhancing their metacognitive skills while learning from video.

The learning effects of students were also investigated on the basis of our metacognition model. It was found that the multi-trick and strategic viewers achieve higher learning effects than the one-trick viewers. We would have expected that the learning effects of the strategic viewers would be higher than of the multi-trick viewers. Some students indicated in interviews that they changed their viewing behaviour from strategic to multi-trick due to interaction complexity - buffering for instance was sometimes a nuisance when searching for a specific element in the video. In our experiment, both types of viewing behaviour appeared at times to have similar learning effects. We configured the streaming video server in such a way that buffering at the local client was not possible - we did this in order to monitor the clicking behaviour in the log files on the server. Under normal conditions, we would not recommend using these settings.

We calculated the prior knowledge (pre-test score) by asking the students directly after the final multiple choice test which questions they could have answered without watching the corresponding instructional video. In order to measure the post-test score, we used the regular score of the multiple-choice test. The questions about pre-test scores were answered well by students. Students were well able to reconstruct their prior knowledge after the test.

Table 8 Metacognitive model: Viewing Behaviour and Relative Learning effects

Viewing behaviour (metacognitive)	No.	Relative learning effect (mean)	Std. deviation
One-trick viewers	16	53.1 %	24.7
Multi-trick viewers	23	73.2 %	16.1
Strategic viewers	63	71.0 %	19.9
Total	102	68.7 %	20.9

The differences in retention decays between one-trick, multi-trick, and strategic viewers were small. Students with a broad viewing repertoire (multi-trick) showed higher learning effects than students with a narrow repertoire (one-trick). Furthermore, students with a strategic viewing approach also showed higher learning effects. The retention test was not conducted in the same controlled situation as the post test. The test was taken in class and via email for absent students. If we were to repeating our experiment, we would keep the circumstances for the post and retention test the same both in the usability lab and in class. In our experiment the differences were small between the lab and class situations.

A large proportion of the students in the experimental group exhibited the strategic viewing behaviour. After watching the video in one pass, they watched specific parts of the video again. Some of them used the cursor as a marking point on the progress bar to help them remembering the segments to watch again. In general, video players should offer more options for helping students in their search for the content they want to watch again. This could be done by instructors linking the starting points of the segments of a video with the progress bar. Furthermore, the segments could also be presented at the end of the video to give them an opportunity to watch specific segments again. Such a list could also be presented at the start of a video to give an overview of the contents (Ausubel 1960). Finally, external links to other videos could be embedded within the video in order to help the student with learning from video (Zahn et al. 2004).

Students who demonstrated the multi-trick viewing behaviour exhibited more interaction with the media player than those with one-trick viewing behaviour. These multi-trick viewers presumably to use the strategic tools less because switching their viewing behaviour can be done with the regular buttons (rewind or play) of the media player. On the other hand, some of these students indicated that due to buffering of streaming video they gave up the strategic viewing behaviours.

In order to improve learning from video it is also sometimes necessary to improve the quality of the video itself when appropriate. Some students indicated that they

Table 9 Metacognitive model: Viewing behaviour and retention decay. The relative retention decay (absolute retention decay divided by the post-test score)

Viewing behaviour (metacognitive)	No.	Relative retention decay (mean)	Std. deviation
One-trick viewers	14	15.1 %	21.6
Multi-trick viewers	21	9.4 %	20.3
Strategic viewers	51	13.1 %	15.8
Total	86	12.6 %	17.8

would have shown other viewing behaviours than one-pass viewing behaviour if the videos were of a lower quality. Thus the viewing behaviour of all students may be considered as an indication of the quality of the instructional videos.

For future research, we recommend to develop and implement a didactically-enhanced media player. This way, students can be supported in developing their strategic viewing behaviour. Furthermore, research is needed to apply our guidelines to another set of videos which are not as “smooth” as the ones we used. In this way students’ interactions with the videos would be more natural. Strategic viewing can sometimes be the only option left for students when confronted with demanding videos.

We conclude that video is a modality that can offer added value to the didactical process, as was stated by Hattie (2009). Certain conditions have to be met: the technical and didactical quality of the video must be good, the integration in a learning task must be apparent, students must be aware of their viewing behaviour, and teachers must be aware of their students’ viewing behaviour in order to enrich the viewing repertoire of students when they have at least some basic knowledge e.g. after several lessons on the topics at hand.

If these conditions are met, as in the described research setting, learning effects from instructional videos could be increased by 20 %.

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