The Scrollbar and Learner-control of Instructional Animations: Some Exploratory Studies

Two experiments involving the use of a scrollbar in an instructional setting were undertaken with a view to clarifying some of the conditions under which a scrollbar may prove to be an optimal means of interactivity. In the first experiment, the effectiveness of a "visually and semantically indexed scrollbar" for the assimilation of complex information was investigated. The second experiment studied the effect of using either "scrollbar-enabled" or "computer-controlled" animations on immediate recall of a procedural task. Despite the lack of significant quantitative differences between test conditions a number of conclusions regarding the use of the scrollbar in an educational setting became apparent. Future research may need to include the "pre-training" of participants on the effective use of a scrollbar, examine the role of learner prior knowledge, and consider participants with specific deficiencies in cognitive processing.

Introduction

The timeline scrollbar is a particularly flexible means of learner-control whose usefulness as a component in the design of educational multimedia appears to have been largely overlooked by the research community. The incorporation of a scrollbar allows segmentation, sequencing, speed and direction of the presentation to be determined by the learner, who can instantly modify these parameters to suit his/her level of expertise and specific learning objectives. Animated material can also effectively be "slowed down" to one image at a time in order to reveal fine-grain movements or facilitate the careful examination of inter-related phenomena. In point of fact, the flexibility afforded to the user by the scrollbar enables a level of learner-control that may call into question the significance of the ongoing debate between the relative superiority of stills and animations, particularly where complex information is involved.

Theorists and researchers in the field of multimedia learning have been at pains to understand and explain the counter-intuitive finding that stills are often as good as, if not better than, their dynamic counterparts (Tversky, Morrison et al. 2002). Whilst experimentalists have continued to produce conflicting results over the past decade or so (Höffler and Leutner 2007), theorists are generally in agreement that the inherent problem with animations is their transient nature. This transience often results in the learner finding themselves cognitively overwhelmed as they seek to process the current state of the animation whilst also having to integrate it with the previous and upcoming frames in working memory so as to adequately process the information (Kalyuga 2008), (Ayres and Paas 2007). The difficulty with this scenario is that learners have a severely limited "working memory capacity" that can act as a primary obstacle to learning in general, and particularly in relation to educational animations. The goal of learning, according to Cognitive Load Theory (Sweller 1999), is to free up these limited working memory resources in order to better facilitate the construction and automation of schemas ("defined as a cognitive construct that permits us to treat multiple elements as a single element" (Sweller 1999)) within long term memory. One mechanism for achieving this goal and overcoming the fleeting nature of animations is by controlling the speed and

sequencing of dynamic visualisations through a learner-control device such as the scrollbar. A theoretically driven three-tiered model, whereby the scrollbar played an "intermediary" role between static images and dynamic visualisations, has been outlined in a previous paper (Hatsidimitris and Wolfe 2010). However, quantitative and qualitative data needs to be procured so as to assist in determining and validating the optimal role of the scrollbar across various learning contexts.

Accordingly the present paper reports on two exploratory studies that investigate the effectiveness of the scrollbar with regard to reviewing complex information and also for the acquisition of a procedural task.

Experiment 1

A scrollbar was designed for an online resource entitled Physclips (Hatsidimitris and Wolfe 2009), that incorporates visual and semantic cues so as to enable the learner to accurately locate and subsequently review discrete portions of a lengthy presentation with a minimal amount of searching behavior (see Figure 1). In order to minimize any visual distraction created by this variation of the traditional scrollbar, the keywords and critical snapshots only appear when the learner engages the scrub bar to navigate through the presentation.

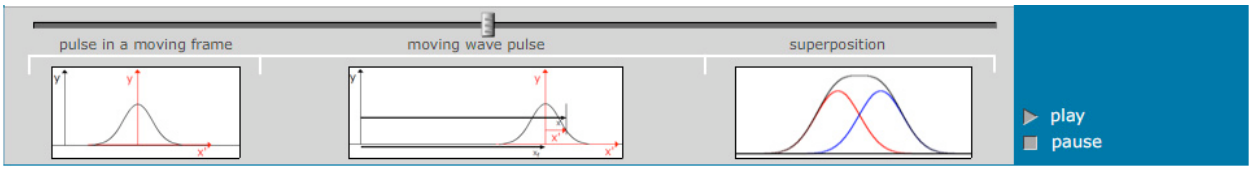

Figure 1. An enhanced scrollbar with visual and semantic cues.

In order to examine the impact of the scrollbar on student learning we examined learner-control of the multimedia presentation in three conditions: i.e. scrollbar with the critical snapshots and keywords, scrollbar without the critical snapshots and keywords and pause/play button only. All 3 groups had access to basic functionality in the form of play and pause buttons. The operation of the scrollbar was such that whenever the learner engages with the scrollbar by clicking on the scrub bar they are able to quickly navigate to any part of the presentation, which then resumes at normal speed when the learner un-clicks the scrub bar. The pause and play button allow the learner to pause the presentation entirely and re-start when appropriate.

Method

Participants and Materials

60 students from a first-year course in physics were offered a $20 book voucher for participating in the experiment. Participants were screened to ensure that they had no significant level of prior knowledge in the specific field being examined i.e. waves and sound. The integrated set of animations was taken from an online resource designed and produced by two of the authors. The subject matter was on the topic of travelling waves and the 4 sections that made up the chapter can be viewed at http://www.animations.physics.unsw.edu.au/waves-sound/travelling-waves/index.html.

Procedure

All students were randomly allocated to one of the three groups and seated at a computer with headphones so that they could study the narrated multimedia tutorials. All 3 groups were provided with instructions on how to navigate the material during the allotted 25 minutes for study. All groups were expected to spend the first 8 minutes simply listening to the material being presented for the first time after which they would navigate to the portions that they wished to review. A 10 minute paper-based posttest that included 14 multiple choice/short answer questions was

completed by all students following the study period in order to gauge their level of comprehension. Questions varied in difficulty and were representative of the diversity of the material in the presentation.

A paper-based questionnaire consisting of 2 questions on a 7-point Likert scale measuring the perceived cognitive load related to the learning and test performance stages was also completed by the students. No time limit was deemed necessary for this task.

Results

To evaluate the effectiveness of different types of interactivity on student comprehension with regard to a multimedia resource, a one-way between-groups analysis of variance was conducted. The ANOVA indicated no statistically significant differences in posttest performance and ratings of cognitive load between groups, F (2,57) = .294, MSe = (1.117,3.796), p = .746 for posttest results, F = 2.529, MSe = (3.8,1.503), p = .089 for ratings of cognitive load for the learning stage, F = .022, MSe = (.017,.77), p = .979 for ratings of cognitive load for the test.

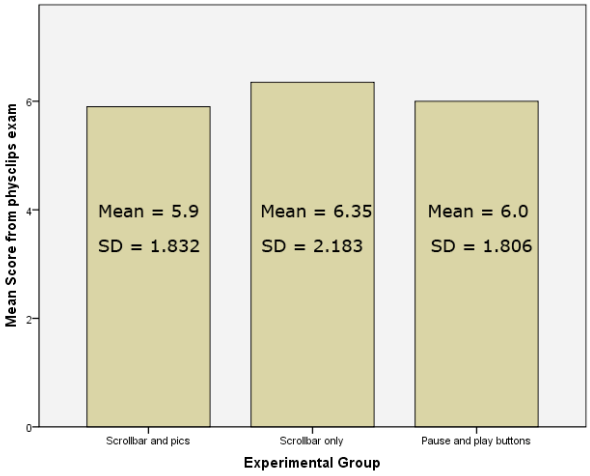

Figure 2. Graphical data for the three groups regarding their scores on the exam.

Discussion

There are several possible reasons for the lack of differences in this study. Firstly, the material was relatively homogenous in the sense that there were not particularly difficult portions whereby a student with scrollbar functionality could have had the advantage in more readily focusing his/her attention through re-playability. Secondly, there were no "fine-grain" details to be examined whereby the scrollbar user could have slowed down the animations to effectively examine the material in slow motion. Thirdly, the segmentation of various concepts within the material could have been identifiable from the change in the visual content of the material itself without recourse to the visual index, thus causing the critical snapshots to be partly redundant in this instance. Finally, there was sufficient allocated time for all groups to view several iterations of the narrated material, thus potentially mitigating possible differences between effects of different interfaces.

Likert-scale scores relating to the frequency and usefulness of the mode of navigation for each condition (collected in addition to the above dependent variables) suggested that the students attached more importance to the use of the scrollbar in the learning process than the pause/play group attached to their mode of navigation. As one student commented after the completing the experiment in the pause/play grouping "I couldn't access the material that I needed to because "it" (referring to the interface) wouldn't let me!" However, due to above reasons the subjective feeling that the scrollbar was helping them to study did not translate into better test scores.

Experiment 2

In designing the experimental tasks the author was mindful of the fact that providing a high level of learner-control can result in novices focusing on the "perceptually salient" aspects of animated presentations rather than that which is "thematically relevant" (Lowe 2003). Another finding relevant to the experimental design was that animations are superior to stills when complex procedural tasks are to be imitated (Wong, Marcus et al. 2009). In order to ensure the robustness of the design and to eliminate extraneous perceptual elements, an animation requiring the performance of a procedural task was formulated wherein the perceptually salient and thematically relevant aspects of the animation were equated i.e. all the perceived material was required in order to complete the procedural task. In such a scenario it was hypothesized that the scrollbar would assist the learner to encode the sequence of steps required to recall/perform the procedural task in a self-paced manner and that this would be a superior strategy to examining a computer-controlled animation playing repeatedly.

Participants, Method and Materials

Participants from Experiment 1 were then allocated to one of two experimental conditions on the basis of whether they had prior knowledge with a symbol based language such as Chinese or Japanese. Those students who had no prior knowledge were placed in the first group, herein referred to as the "Chinese Characters Group". All other students were placed in the "Mazes Group". Participants in both groups were randomly allocated to one of two conditions i.e. Learner-controlled animations with scrollbar or Computer-controlled animation with no interactivity.

Chinese Characters Group

24 students were randomly allocated to 2 groups of 12. Students were individually seated at a computer and presented with online instructions prior to the experimental task. In the scrollbar condition students were provided with an animation that illustrated scrollbar movement in a back and forth manner so as to exemplify how to control the pace and direction of the animation. The animation in the computer controlled group showed the character being drawn at a computer-controlled pace in the same manner as the upcoming task. Both groups were told they had 30 seconds in which to complete study of the stroke order of each character (as indicated by the decreasing height of a green bar), after which time they were instructed to reproduce the correct stroke order on the paper supplied. Each stroke was allocated one box and the strokes had to be drawn in a cumulative manner, i.e. the second box includes the first stroke and the second stroke, the third box contains the first three strokes and so forth. Participants in both groups were required to answer 4 questions on a 7-point Likert scale relating to the perceived difficulty of the material and the strategy adopted in acquiring the information i.e. what role did the interface play and did they adopt any particular recall strategy such as "chunking" strokes.

Mazes Group

36 students were allocated to two groups of 18. All students had some familiarity with symbol based languages and thus were not eligible to be included in the Chinese Characters Group. The allocated time to complete the task was twice as long, i.e. 60 seconds, as replicating a maze was considered to be of greater difficulty than the "more structured" Chinese Characters. Otherwise all other conditions were equivalent.

Scoring

Each subject was scored one point per correct stroke in sequence starting from the beginning of the task, and then when necessary also starting from the completion of the task and working backwards. Any sequence of two or more strokes that were isolated in the "middle" of the character was also scored as correct. Any strokes which were an obviously valid attempt but failed on one particular characteristic, e.g. the stroke was too long or slightly angled, was given a half point. To ensure the validity and reproducibility of the scoring method, two markers were employed and their scores were correlated.

Results

To assess the relationship between the two independently marked scores, a bivariate Pearson's product-moment correlation (*r)* was calculated. The correlation between the two markers was positive and strong i.e. (r) = .975 (Chinese Characters) and .943 (Mazes) significant at the 0.01 level (two-tailed). An independent samples *t* test was used to compare the effect of using a scrollbar to the use of computer-controlled animations in the immediate recall of the procedural task. The *t* test between the two conditions was not significant for both the Chinese Characters Group $t(22) = 1.268$, $p = .218$ and the Mazes Group $t(32) = -.233$, $p = .818$.

The Shapiro-Wilk Statistic was significant for a number of the recall tasks for specific combinations of conditions and characters/mazes, indicating that the results did not always reflect a normal distribution and thus compromising the robustness of the *t* test results (particularly given the relatively small sample size). Scores from the Likert-scale questionnaire revealed no significant differences between the two conditions in either of the two groupings.

Discussion

The lack of a superior performance in the immediate recall task by the participants in the scrollbar condition may have resulted from a number of factors that were not accounted for the in the experimental design but became evident to the author who witnessed the experiment.

Firstly, the participants resorted to mimicking the writing of the strokes with their hand as they viewed the animations. This was more prominent in the groups without the scrollbar as their writing hand remained entirely free to capitalize on this strategy whilst the other participants were required to use the mouse in order to engage with the scrollbar and thereby manipulate the animation. Participants in the scrollbar group also had to make decisions regarding pace, segmentation and iterations with respect to how the stroke order was examined. The cognitive resources expended to interact with the scrollbar may have mitigated any benefit gained from segmentation and self-pacing of the animation.

Secondly, the general lack of symmetry in the distribution of the scores reflected the fact that there was a diversity of learning strategies amongst the participants. Whilst some students were able to effectively divide the task into self-paced segments for rehearsal with the aid of the scrollbar, many others engaged less productive strategies. At least one student attempted to remember the completed state of the maze and then transpose this pattern onto the score sheet with a view to working "backwards" to the initial state of the animation. The first stage of his strategy proved overly demanding for his limited working memory capacity and as a result he scored poorly. One student adopted a more successful strategy in that she divided the task into segments, pausing after each segment to disengage momentarily with the mouse and scrollbar so as to allow herself an opportunity to mimic the writing actions associated with that particular cluster of strokes. Given the severe time constraints inherent in the experimental design it seems that a significant number of seconds were spent by the scrollbar groups in attending to and overseeing the manipulation of the animation. In this context it is interesting to note that the scrollbar groups nevertheless performed as well as the groups whose cognitive resources were entirely devoted to information assimilation, thus suggesting that the scrollbar has "efficiency" characteristics worthy of further investigation.

Finally, the Chinese Characters and the mazes both effectively left a "trace" in so far as the completed characters and mazes represented the summation of information that transpired during the animation. As a result the "transient characteristics" of the animation, which the scrollbar was designed to overcome, may not have featured as a critical obstacle to learning performance.

Conclusion

The scrollbar, whilst enabling the learner to exercise a high level of learner-control, requires a certain amount of attentiveness and decision-making on the part of the user. Subject matter that is either highly variable in its

difficulty, incorporates detail that could be better examined in “slow motion” or where the segmentation is not obvious from the visual aspects of the presentation itself may be most likely to benefit from a visually enhanced scrollbar. A seemingly straightforward procedural task measuring immediate recall appears to have been approached by the participants through a wide variety of learning strategies. Many of these approaches were not in line with the participants working memory capacity and thus the scores were widely, and asymmetrically, distributed. The conditions under which the scrollbar is of optimal benefit remains unclear, however the findings indicate that its incorporation in the learning environment may benefit through the provision of guidance as to how its functionality may be optimized for meaningful learning within the limits of human cognitive architecture. Further studies are required to clarify the conditions, and the learner population, whereby the inherent flexibility of the scrollbar is most beneficial to the learner. Future research should examine the effect of learner guidance (e.g., in the form of pre-training) as to how the scrollbar can facilitate the type of mental processes that could reduce potential working memory overload and thereby enhance meaningful learning. In the context of a digital information age wherein e-books, educational videos and instructional animations are likely to further proliferate it seems prudent to be forward thinking in designing multimedia resources that are both transparent in their content and facilitative of a self-paced iterative approach to learning.

Acknowledgements

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