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STILLS, ANIMATIONS AND THE SCROLLBAR AS COMPLEMENTARY MULTIMEDIA DESIGN TOOLS

Abstract: Researchers have been seeking the optimal design guidelines and learning conditions for the use of animated material. The current paper extends this search for a superior multimedia design by proposing a multi-tier structure that incorporates the particular strengths of stills and animations whilst also introducing a third intermediary component, i.e. the scrollbar. Such an "empirically-driven" design seems well suited to learning and rehearsing complex time-critical procedural tasks such as found in the field of sport, dancing, surgery and workplace environments wherein intricate human movement is involved. The three-tiered model is applied to a complex procedural task to illustrate the underlying rationale. An exemplar of best practice in the field of multimedia learning is evaluated in terms of providing complementary input from the viewpoint of an authentic learning scenario. It is recommended that multi-level animations can best accommodate the composite, and sometimes variable, nature of complex information structures.

Introduction

Over the past decade or so there has been a proliferation of educational animations, particularly on the internet, that range from basic linear movement to complex 3D systems. Many of these animated resources are misaligned with evidence-based guidelines in the field of multimedia learning in that their design fails to consider the working memory limitations of the end-user. Ultimately, they may be ineffective, or much less effective than the designer hoped. In fact, research has shown static graphics are often a better choice than their more "intuitively-appealing" animated counterparts (Tversky et al 2002). In more recent years the "stills versus animations" debate has increased considerably in breadth and complexity to encompass new theoretical frameworks (Schnotz and Lowe 2008), inter-disciplinary approaches (Ayres and Paas 2009), and a consideration of the larger learning environment in which dynamic visualisations are embedded (Hegarty and Kriz 2008). In this increasingly-diverse landscape it is important for instructional designers and content experts to play a more active role in the translation of research findings and theoretical constructs into meaningful and "classroom-oriented" multimedia procedures.

The author takes a designer-centred approach towards drawing on the research literature so as to substantiate the need for a "tiered-model" that incorporates the relative strengths of stills and animations together with the flexibility afforded to us by the use of a scrollbar. The resultant multi-stage multimedia resources are more attuned to the complexity, and/or variability, of difficult information structures.

Cognitive Load Theory and Animations

According to Sweller's (1999) cognitive load theory (CLT) a primary obstacle to learning is the limitation of working memory (WM) in terms of its capacity to process and recall information. The underlying goal of CLT is to free up WM resources in order to better facilitate the construction and automation of cognitive constructs called schemas within long term memory (LTM) and to this end a number of research-based guidelines have been formulated to assist designers and educators.

Mayer (2008) draws our attention to ten of these principles that are particularly relevant to the challenges of learning with animations. The modality principle states that animation and narration is better for purposes of learning than animation and on-screen text. This is by virtue of the fact that WM has both a visual and auditory channel (Baddeley 2000) and in effect the on-screen text can be "offloaded" from the visual channel to the auditory channel and thus capitalise on the learner's limited cognitive resources. Together with the pre-training principle (people learn better when the main concepts are introduced prior to the narrated animation) and the segmenting principle (self-paced segments are better than a continuous whole when learning with narrated animations) these three guidelines assist in what Mayer terms "managing essential overload". Excluding unnecessary elements (coherence principle) can reduce extraneous cognitive load and when onscreen text is omitted during a narrated animation then it results in more effective learning as stated by the redundancy principle. It is also important to ensure that related elements of an animation are co-located near corresponding text (spatial contiguity principle) and that similarly any narration should be presented synchronously with the corresponding animations (temporal contiguity principle). The learner's cognitive processing can be further facilitated by providing appropriate cues to guide their attention, such as highlighting and arrows (signalling principle). Another two principles relating to the style of the narration state that a conversational style (personalisation principle) using a standard-accented human voice (voice principle) are more likely to enhance learning. Despite the formulation of these design guidelines it is still a contentious issue as to whether the use of animations represents the most effective form of presenting the material.

Stills versus animations

Tversky et al (2002) reviewed a number of studies that examined the relative effectiveness of stills versus animations and found that static images often outperform animated versions in terms of student learning. Recently (Hoffler and Leutner 2007) conducted a meta-analysis of 26 studies and revealed that instructional animations appear to be more effective when highly realistic animations are being employed or when the acquisition of procedural-motor knowledge is required. There has also been persuasive argumentation that certain subject matter involving complex physical systems is more amenable to instruction through dynamic visualisation (Hegarty 2005). Even so, there is a growing consensus that animations pose a number of challenges for both the multimedia designer and the end-user.

Animations are transient by nature and thus tend to overwhelm the available cognitive resources of the user (Kalyuga 2008). Whilst working memory is attempting to process the current frame it must also maintain information from previous and upcoming frames. Dynamic visualisations of complex structures may involve several interacting elements displaying change over time and subsequently cause the user to split his visual attention between competing sources of information. These factors tend to contribute to a level of cognitive overload not often found in static representations. Nonetheless, animations have an advantage in that they can depict essential fine-grain movements and thus represent an efficient way of displaying an extended sequence of graphical images.

Stills, on the other hand, are static in nature and are thus able to be viewed concurrently, visually re-inspected a number of times and also tend to be more amenable to signalling devices such as labels, highlighting and arrows. There is also the suggestion that stills encourage the user to "mentally animate" from the given information, thereby inducing a more active level of cognitive processing than animations.

Given that both animations and stills have their respective strengths and weaknesses it is not surprising that cost-effective stills are sometimes preferable to resource-intensive animations. However the choice between one and the other format is not obligatory and there are recent studies investigating the use of both formats concurrently when dealing with complex information. Arguel and Jamet (2009) conducted studies in first aid procedures whereby video plus static pictures produced better results than either format alone. The rationale was that key snapshots presented during the video would effectively leave a trace for working memory and thus help overcome the difficulties associated with the inherent transience of animations. However, Betrancourt et al (2008) were unable to show a significant improvement when using the dual format of key-frame snapshots together with animated material.

Interactivity and levels of expertise

The boundary between animations and stills can be bridged by the introduction of interactivity to the learning design such that the level of motion or dynamism can be freely regulated through the use of a scrollbar. As with animations we find that learner-controlled interactivity must be employed judiciously if it is to be of benefit. When complex animations with a high level of user control are presented to novices they may find themselves focussing on perceptually salient characteristics of the animation rather than that which is thematically relevant (Lowe 2006). Overall, however, Ayres and Paas (2007) conclude from their review that learner-controlled animations result in more effective learning.

Designing a multi-stage animation

The need for a combined use of stills, animations and learner-controlled interactivity in a multimedia resource for the assimilation of complex information can be illustrated with a real-world example. The athletic triple jump will suffice as the subject matter but we could have chosen a dance routine, surgical procedure, the rapid assembly of intricate machinery or any number of tasks requiring complex human movement.

Stage 1: Stills

A good starting point is to incorporate Kalyuga's (2008) recommendation that learners may move from static to animated format as their level of expertise increases. We will work on the presumption that novices will form part of the learning cohort and thus commence with stills. When learners with expertise are involved they have the option to quickly scan the static material and move onto stage II if they consider it is appropriate.

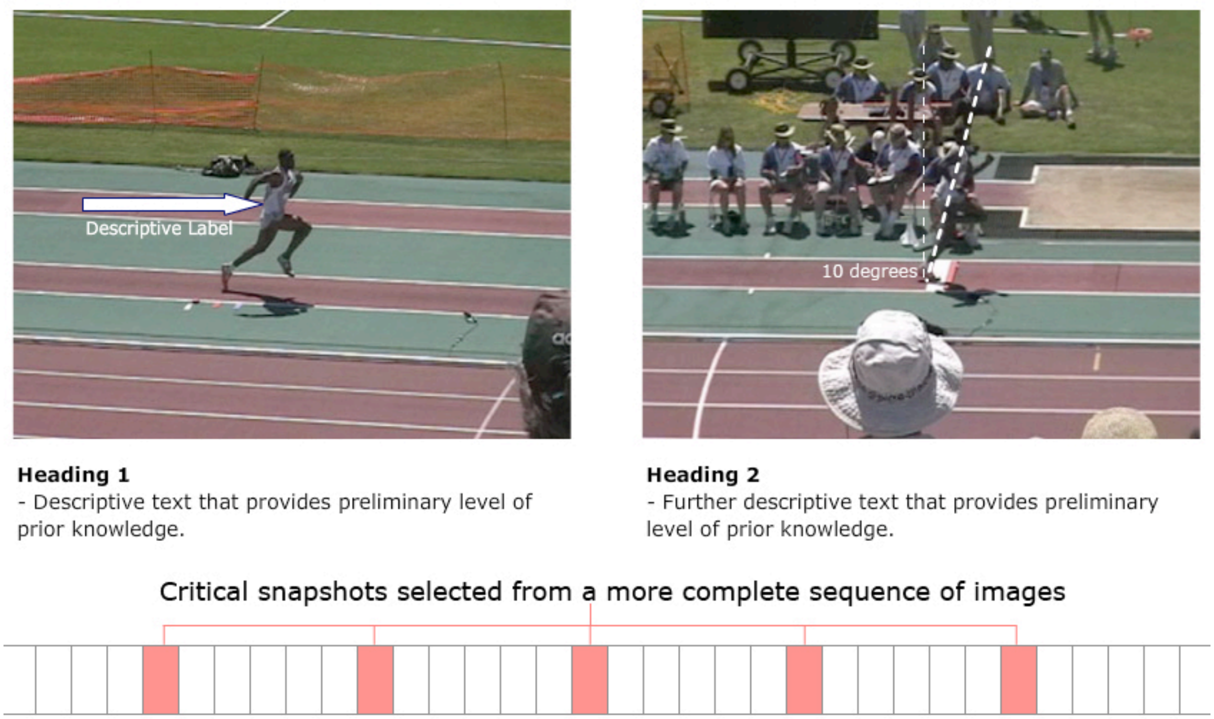


Figure 2 The use of critical stills with explanatory text and signaling forms stage 1 of the tiered animation.

Why begin with stills:

- **Segmentation and content representation**

Stills that focus on key points of the animation essentially segment the content and act as a visual form of content representation. This type of overview helps orientate the student and facilitates learning by minimising searching behaviour.

- **Signalling as a means of guiding attention**
  Stills at key points during a triple jump will provide an opportunity for the content expert to attune the learner to the thematically relevant aspects of the task through the incorporation of signalling devices such as arrows, labels and highlighting.

- **Pre-training and deeper understanding**
  Textual explanations can assist to explain underlying mechanisms and thus promote deeper understanding (Kriz and Hegarty 2007). The identification of key events within the procedural task acts as an essential form of pre-training.

- **Low cognitive load**
  Stills may be revisited and viewed concurrently thus ensuring the learner is not cognitively overwhelmed by the transience of animations.

Stage 2: The scrollbar

The learner is primarily concerned with copying or modelling the behaviour of the subject who is performing the triple jump. Consequently the fine details of the movement are of some interest to the student. Unlike with many physical or mechanical processes it would be difficult to mentally animate between the stills due to the unpredictable variance in the patterns of human movement. Consequently this second phase is a crucial element prior to viewing the task in real-time speed during the final stage.

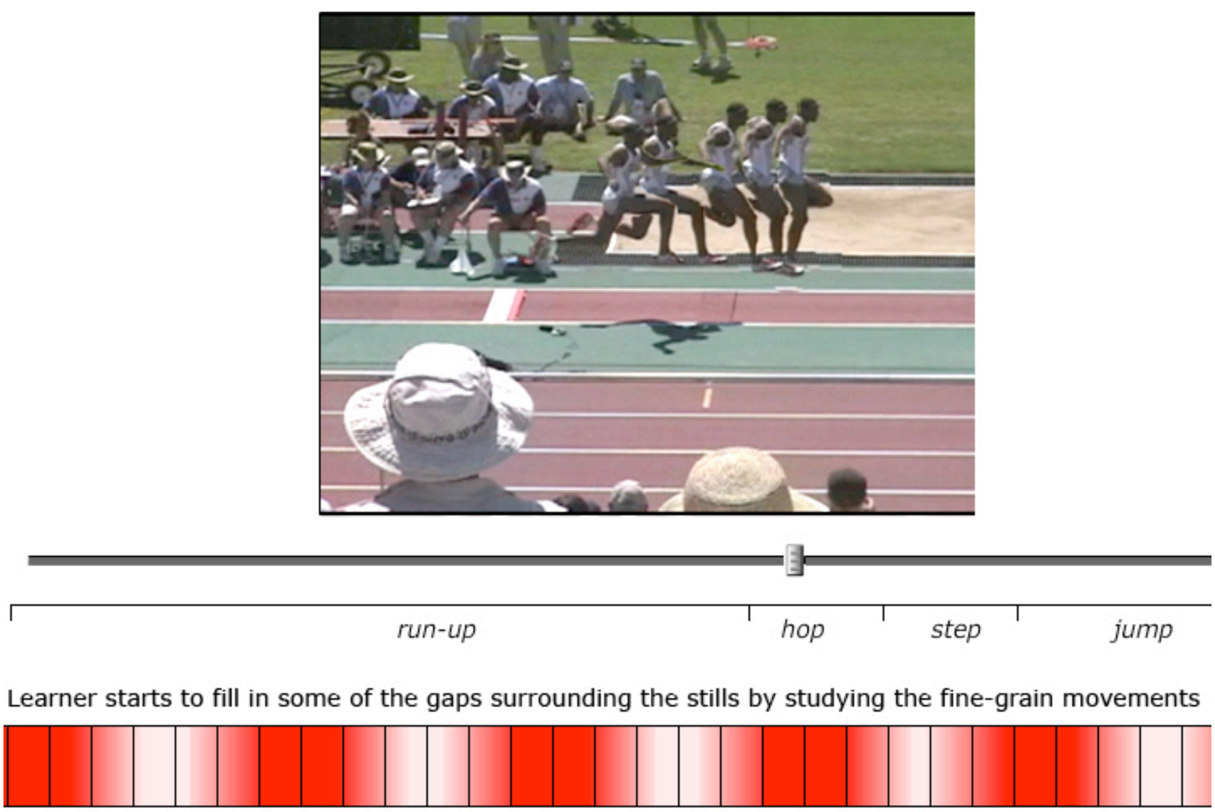


Figure 3 The scrollbar allows the user to examine fine-grain movements. Note that the multiple views of the triple jumper are there to accentuate the variation of his movement and do not appear in this manner when scrolling.

Why include scrolling:

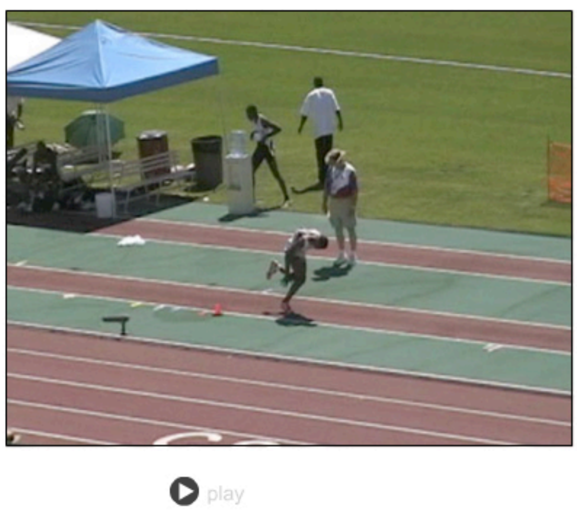
- **Self-paced examination of fine grain movements**
  Learner controlled interactivity allows the user to examine the details of the human movement in an iterative self-paced manner. Self-regulated scrolling facilitates schema construction.

- **Intermediary component**
  If we started with the scrollbar a novice would be unable to determine the critical points around which he should focus his attention. On the other hand, animation at full speed would not allow an appropriate examination of the fine details of human movement necessary to perform optimally in a triple jump.

- **Building information around critical steps**
  "From research on event cognition, it is known that people conceive of events such as assembling an object as discrete rather than continuous, and as hierarchical, organized at the higher level around objects or large parts and at the fine level around actions on the separate objects or object parts." (Zacks and Tversky 2003)

Stage 3: The animation

Now we are ready for the cognitively demanding task of viewing a complex animation. By this point we have some foundational understanding and have examined the procedural task carefully in a self-paced and informed manner.



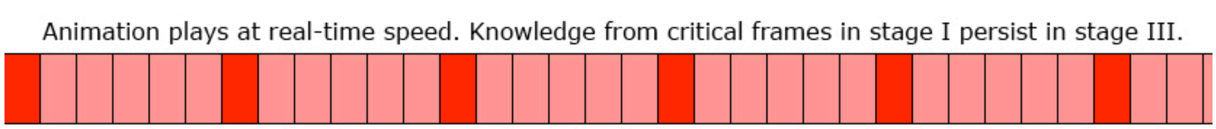


Figure 4 The real time video allows the learner to view the performance objective at speed

Do we still need the final animation?

- **Real time speed of human movement.**
  The relative importance of viewing the video at original speed depends on whether performance of the procedural task is time-critical. A dance routine would have a specific rhythm and seeing the execution of the task at normal speed would be beneficial. Assembling machinery could be less time dependant in that

the exact rhythm would not be critical to performing the task and as such the first two stages may be adequate.

- **Performance objective**
  The video at original speed constitutes a representation of the objective to be attained. It could also have been shown at the beginning of the presentation as a form of representing the learning objective for which the learning scenario was designed.

- **Empirical Evidence**
  Hoffler and Leutner's (2007) meta-analysis suggests that highly realistic animated material (e.g. video) and animations rquiring the acquisition of procedural-motor tasks are the type of dynamic visualisations that are likely to be more effective than their static counterparts.

The example of an athletic event served to illustrate the need for several stages of presentation in order to guide the novice from a fundamental knowledge through a stage of visual rehearsal and finally to viewing the film clip which would otherwise have imparted little in terms of meaningful learning.

However, not all learning involves this form of time-critical human movement and we need to also consider complex subject matter that is more conceptual in nature.

Designing for conceptually complex subject matter

Hegarty (2005) suggests that understanding complex physical systems involves three types of knowledge. The *configuration* , i.e. an understanding of the parts that form the spatial layout, can be represented as a static model whereas the *behaviour* refers to how the parts move and interact with each other. The *function* of the machine, or what the machine was designed to do, involves the interplay of configuration and behaviour to achieve the machine's goal.

A parallel can be drawn with the framework for a tiered animation.

1. Stills: The *configuration* is best understood with stills and text as it is a static model.
2. Scrollbar: If the system is high in "element interactivity" (Pollock et al 2002) a scrollbar may assist in examining the *behaviour* between the various parts that make up the whole.
3. Animation/Video: The *function* of the machine is most closely represented when operating at the speed for which it was designed.

Kriz and Hegarty's (2007) experimental methodology examined comprehension of a complex mechanical system amongst groups using stills, learner-controlled animations and computer controlled animation. The complexity of the subject matter and the consequent low level of comprehension exhibited by all of the subjects suggests that the learning design may have been optimised through the use of a "multi-stage" animation. Kriz and Hegarty concluded that "it is important to study the effectiveness of animations in more iterative learning situations that are more characteristic of real-world learning situations".

Physclips: An exemplar of multi-level multimedia resources

Introduction

It is possible to examine the research literature and, by incorporating the cognitive design principles and recommendations stemming from the experimental outcomes, to approximate an optimal multimedia design. However much of this empirical evidence is based on controlled experiments that consider cognitive processing at the "micro" level where one or more design parameters can be conveniently manipulated. A complementary approach might be to consider an exemplar of best practice that provides multimedia procedures in an authentic learning scenario. Situated between a community of users and a complex body of research, exemplars of best practice can help provide valuable insight into the creation of learning resources. One such case is Physclips, an ongoing project that is the outcome of an intuitively oriented content expert collaborating with an educational-multimedia designer. The recipient of a prestigious international accolade i.e. the physics division of the 2007 Pirelli Prizes for Science Communication, Physclips attracts over 2000 unique visitors per day. Users regularly incorporate the downloadable re-usable learning objects into blogs, powerpoint presentations, lectures, school projects and so forth.

Overview of Physclips (http://www.animations.physics.unsw.edu.au)

Physclips is a set of integrated resources that work at three levels and was created for learning introductory physics. Topics are initially introduced in narrated multimedia presentations that incorporate animations, video clips, images and associated equations or textual material. These narrated modules incorporate contextually embedded hyperlinks to support pages that provide deeper explanations or analysis. In the most recent additions, each chapter has a laboratory section that provides hands on activities utilising common, inexpensive components. By re-visiting the same animations whilst embedded in the various modes of narrated presentation, detailed textual analysis and hands-on laboratories the learner is able to develop a high level of expertise in relation to the animated material.

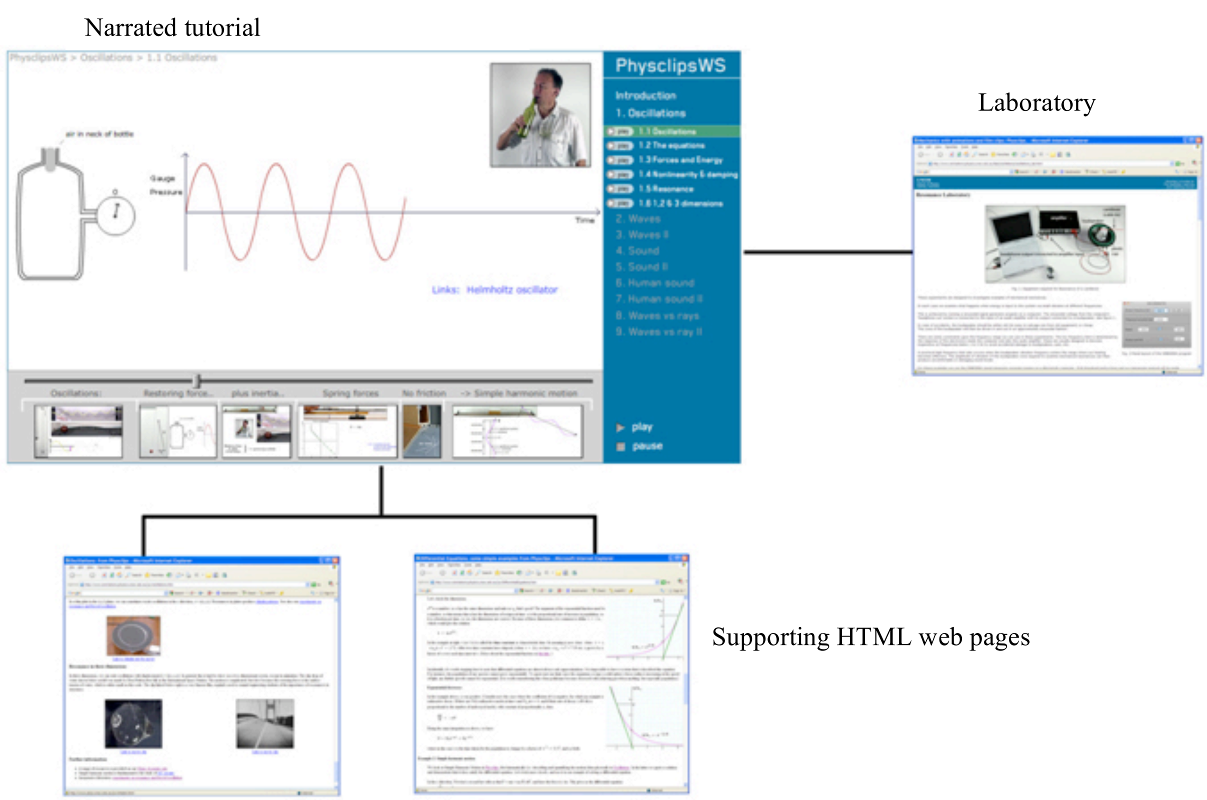
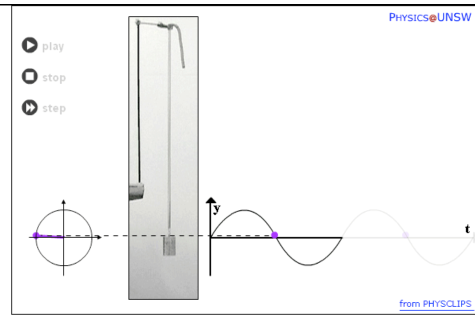


Figure 6: A schematic overview of resources accompanying each topic in Physclips

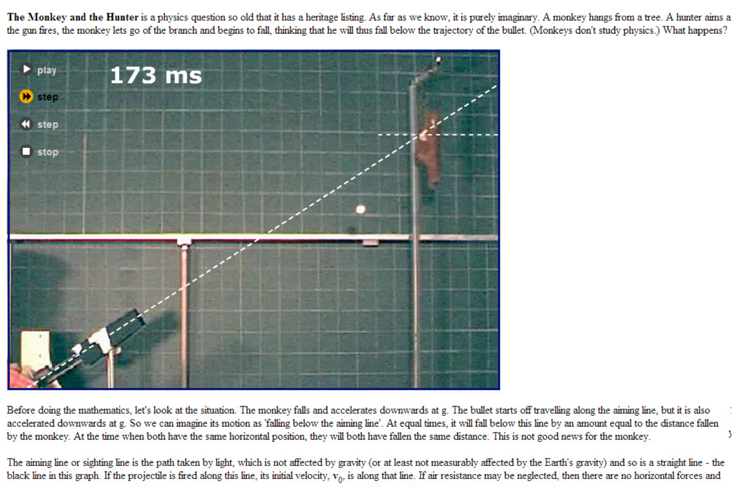
Intuition and teacher experience – The role of the content expert

Content experts can utilise their expertise in the field to determine the combination of stills, videos and/or overlaid animations that are most appropriate for the specific phenomena under study. Physicists are required to observe the relevant physical elements in a real world situation and to model them in terms of physical laws. Here, the flexibility of multimedia allows for a film clip to be accompanied by an animation that explicitly reveals to the novice the abstractions that an expert might automatically associate with the physical phenomena.

Table 1. The format of the animation reflects the information complexity and the learning objective.

A video of a spring pendulum is accompanied by an integrated overlay of a sine wave in order to make explicit the corresponding relationship between the abstracted waveform and the operation of the pendulum.	

Hegarty and Kriz (2008) suggest that the effectiveness of animations as a pedagogical tool is dependent on how they are embedded within the broader learning environment. In this regard they also point to the use of text to provide ancillary information for the purposes of deeper understanding where complex physical systems or invisible forces are involved. Physclips provides this level of textual explanation in web pages that support the introductory presentation of the material during the narrated sequence of integrated animations.



The Monkey and the Hunter is a physics question so old that it has a heritage listing. As far as we know, it is purely imaginary. A monkey hangs from a tree. A hunter aims a the gun fires, the monkey lets go of the branch and begins to fall, thinking that he will thus fall below the trajectory of the bullet. (Monkeys don't study physics.) What happens?

Before doing the mathematics, let's look at the situation. The monkey falls and accelerates downwards at g. The bullet starts off travelling along the aiming line, but it is also accelerated downwards at g. So we can imagine its motion as 'falling below the aiming line'. At equal times, it will fall below this line by an amount equal to the distance fallen by the monkey. At the time when both have the same horizontal position, they will both have fallen the same distance. This is not good news for the monkey.

The aiming line or sighting line is the path taken by light, which is not affected by gravity (or at least not measurably affected by the Earth's gravity) and so is a straight line - the black line in this graph. If the projectile is fired along this line, its initial velocity, v_0, is along that line. If air resistance may be neglected, then there are no horizontal forces and so the horizontal component of velocity, v_x, is constant. The vertical component, on the other hand, is steadily decreased by the acceleration due to gravity. The resulting

*Fig.*7 illustration of an interactive animation embedded within a more extensive textual explanation.

Physclips and current trends in research: Input from the multimedia designer.

Physclips accords well with all ten cognitive design guidelines relating to the challenges of animations as forwarded by Mayer (2008). Arguel and Jamet's (2009) study discussed earlier, whereby video plus static pictures in the form of critical snapshots produced better results than either format alone, suggests that critical snapshots can serve as "trace elements" when dealing with lengthier animated material. Physclips has adapted this finding by incorporating labelled keyframes as a type of content representation under the scrollbar. This is particularly useful when dealing with a sequence of cognitively-demanding animations.

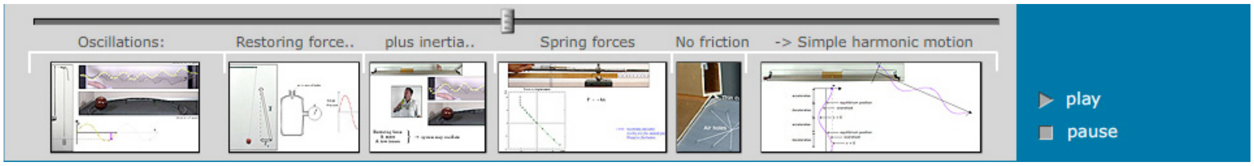


Figure 8: A visually-enhanced scrollbar is used to facilitate searching across a sequence of animations

The visually enhanced scrollbars utilises both textual and graphical cues to assist the user to recall the material, locate specific sections and form a skeletal overview of how the key concepts relate to one another. The purpose of the scrollbar is primarily navigational, and used in conjunction with the supporting thumbnails, helps to minimise searching behavior. It can of course be used for examining fine details where necessary in a similar manner to stage II of the tiered animation described earlier.

Physclips and scaffolded animations

The study of physics is particularly challenging due to much of its subject matter being either high in element interactivity, counter-intuitive in nature or dependant on the learner having a high level of spatial ability. Consequently it can be considered as ideal domain-specific knowledge for testing the effectiveness of different multimedia design strategies. In the example below (from an associated set of resources) we see how stills can introduce various aspects of a more complex animation through accompanying text. The complex animation on the right could also have been presented sequentially such that "Jasper's version" was shown first and then "Zoe's version" was revealed during stage II in a manner akin to the "isolated-interacting elements" approach (Pollock et al 2002). In a similar manner to the "empirically-driven" model, we find that the availability of the scrollbar allows the user to examine the behaviour of the various elements and the interaction between them.

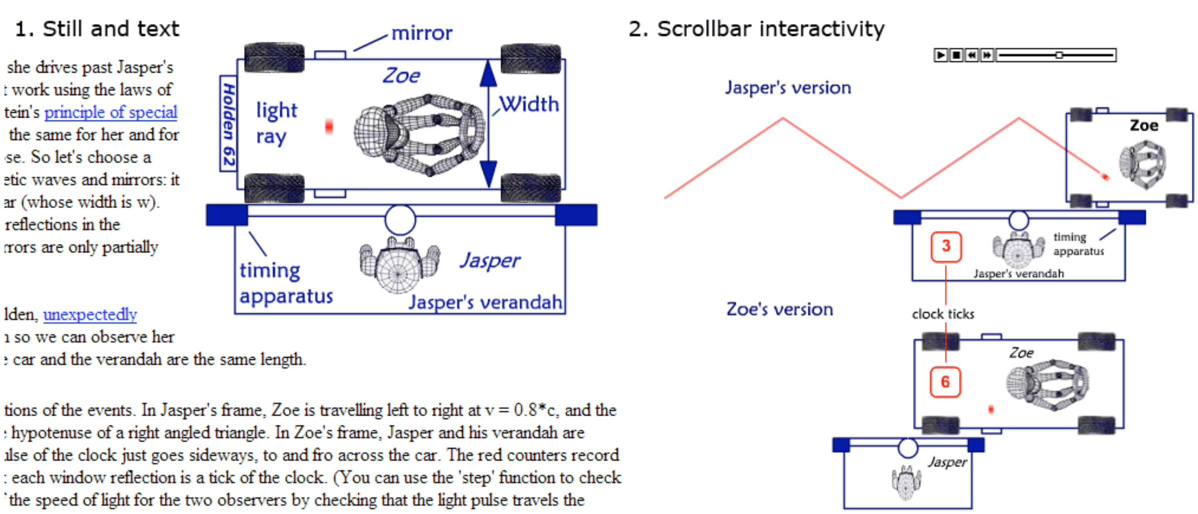


Figure 9: Conceptually challenging subject matter can also be scaffolded from stills to animations in a similar manner as when dealing with complex procedural tasks.

Conclusion

There are no hard and fast rules when designing for the assimilation of complex information structures or time-critical procedural tasks. An awareness of the need to allow for various levels of expertise whilst also remaining cognisant of the relative strengths and weaknesses of employing stills, animations and learner-interactivity will allow the designer/educator to make informed decisions as to the optimal multimedia design with regards to the subject matter at hand. Some types of information appear to be more easily accommodated by certain levels of dynamism and interactivity. Complex time critical tasks requiring mimicry of fine grain movements may commence with critical snapshots and move through scrollbar interactivity to the real-time animation. Conceptually challenging material may, for example, require sequencing of specific elements as part of an intermediary stage in a multi-tiered animation. An intimate knowledge of the domain specific knowledge, or a close collaboration with a content expert, will further assist in tailoring the multimedia design to the particularities of the specific subject matter. As a complementary approach, case studies may afford us insight into innovative multimedia design techniques and therein also serve as a starting point for dialogue between practitioners, researchers and theoreticians.

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