An Investigation of the Effects of Different Types of Activities during Pauses in a Segmented Instructional Animation

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ABSTRACT

Since the complex and transient information in instructional animations requires more cognitive resources, the segmenting principle has been proposed to reduce cognitive overload by providing smaller chunks with pauses between segments. This study examined the effects of different types of activities during pauses in a segmented animation. Four groups were asked to do different tasks in system-controlled pauses after each segment of an instructional animation: passive pauses (i.e., no-reflection vs. reflection), and active pauses (i.e., free-recall vs. short-answer). The results showed that active pause with free-recall group outperformed the two passive pause groups on both recall and transfer tests. However, no significant differences in mental effort for the instruction or the tests were found. The findings of this study provide valuable implications for effective ways of using pauses between segments in instructional animations.

Keyword

Segmenting principle, Instructional animation, Pauses in segments, Active pauses

Introduction

Instructional animations are dynamic visualizations that display a series of pictures for educational purposes. They are often used to illustrate dynamic changes within complex processes by depicting the motion or trajectory of processes (Betrancourt & Tversky, 2000; Hoffler & Leutner, 2007), such as the formation of lightning (Schmidt-Weigand & Scheiter, 2011), or the motions of electrons (Yang, Andre, & Greenbowe, 2003). Animations have been shown to be more effective than static graphics in helping learners build mental models of processes involving change over time (Hoffler & Leutner, 2007; Wouters, Paas, & van Merriënoer, 2008).

However, animations are not always superior to static graphics, because they may impose additional cognitive load (Hegarty, Kriz, & Cate, 2003; Mayer, Hegarty, Mayer, & Campbell, 2005; Phan, 2011; Spanjers, Wouters, van Gog, & van Merriënoer, 2011; Tversky, Morrison, & Betrancourt, 2002). For example, the information portrayed in complex or fast-paced animations is frequently too transient to enable essential cognitive processing (Mayer & Moreno, 2003). In other words, the transiency of information may not provide learners with sufficient time to process all of the elements in an animation (Hegarty et al., 2003). This may hinder learning by inducing high cognitive load (Ayres & Paas, 2007; Spanjers, van Gog, & van Merriënoer, 2010).

However, animations can be designed to reduce cognitive overload (Ayres & Paas, 2007) by visually cueing important information (e.g., de Koning, Tabbers, Rikers, & Paas, 2007), presenting related information before animations (e.g., Mayer, Mathias, & Wetzell, 2002), or dividing animations into segmented pieces (e.g., Mayer, 2009; Spanjers et al., 2010). The segmenting principle proposes that animations depicting complex tasks should be divided into smaller parts in order to be processed effectively (Clark & Mayer, 2011; Mayer, 2009). In instructional animation research, segmentation has typically been operationalized by inserting a pause between segments of an animation. Pauses have been shown to provide learners with sufficient time to process information presented in the previous segment. In addition, pauses between segments appear to serve as event boundaries to enhance understanding of procedural information (Spanjers et al., 2010).

More recently, Cheon, Crooks, and Chung (in press) found an embedded question condition to be superior to a pause condition. In their study, university students who received embedded retention questions related to the previous animation segment (i.e., active pause) outperformed students who received only a pause in the animation segments.
Even though instructional animations can facilitate learning by externalizing cognitive processes in specific areas, portrayals can increase learners' motivation (Phan, 2011). Under these conditions the transience of an instructional animation imposes excessive cognitive load on the information keeps coming while learners try to process previously presented information (Ayres & Paas, 2007; Lowe, 2004, p. 346). In other words, the detrimental effects of transiency in an animation are experienced as new frame at a time, and once the animation or video has advanced beyond a given frame, it is no longer available …“

As noted above, the limitations of instructional animations result from the transiency of information presented in animations. The effects of transiency on learning from an animation depend upon the amount, complexity, and speed of information presented in the animation. That is, the benefits of an animation may disappear as the amount, complexity, or speed of information exceeds the processing capacity of the learner (Hegarty et al., 2002; Hegarty et al., 2003; Mayer et al., 2005; Morrison & Tversky, 2001). This is primarily due to the fact that the learner “views one frame at a time, and once the animation or video has advanced beyond a given frame, it is no longer available …” (Hegarty, 2004, p. 346). In other words, the detrimental effects of transiency in an animation are experienced as new information keeps coming while learners try to process previously presented information (Ayres & Paas, 2007; Lowe, 2003). Under these conditions the transience of an instructional animation imposes excessive cognitive load on the learner (Spanjers, van Gog, Wouters & van Merriënboer, 2012; Tversky et al., 2002). The cognitive overload imposed by animations has been explained for the perspective of cognitive load theory.

To learn specific information, working memory needs to maintain and process the information by transferring the information to and retrieving it from long-term memory (Baddeley, 2007). However, working memory is limited in its capacity to simultaneously process a large amount of information (Baddeley, 2007; Barrouillet & Camos, 2007; Lusk et al., 2009; Mayer & Moreno, 2003). Cognitive overload takes place when the demands on working memory exceed its capacity (Baddeley, 1992). In other words, cognitive overload negates the learner’s ability to process critical information in working memory (Baddeley, 2007; Clark & Mayer, 2008; Phan, 2011). When the transience of the information in animations exceeds the learners' cognitive resources (Spanjers, van Gog, Wouters et al., 2012), cognitive overload will occur. Under these circumstances, instructional animations should be less effective than static graphics if the cognitive load associated with the static graphics goes beyond the learners’ capacity. Based on the assumption of limited cognitive capacity, cognitive load theory asserts that there are three different types of cognitive load: (a) intrinsic load, caused by the level of element interactivity in learning content, (b) extraneous load, caused by unnecessary cognitive processing, and (c) germane load, caused by cognitive processing that is essential for learning (Sweller, 2010; Sweller, van Merriënboer & Paas, 1998; van Merriënboer & Sweller, 2005). Cognitive benefits of static graphics may be more beneficial than animations because learners mentally animate the key steps presented in static graphics.

Instructional animation and cognitive load

Instructional animations have been found to provide both representational and aesthetic benefits. In terms of representational benefits, animations appear to facilitate the learners’ ability to transform the dynamic aspects of the animation into a robust mental model (Betancourt & Tversky, 2000; de Koning et al., 2007; Tversky et al., 2002; Phan, 2011; Wouters et al., 2008). This is likely because animations can depict continuous movement and trajectory as well as externalize abstract concepts, such as quantum mechanics and blood circulation. This visualization characteristic helps learners mentally simulate a process or procedure. Hoffler and Leutner’s meta-analysis (2007) showed that representational animations were superior to representational static pictures, whereas decorative animations were not. Animations appear to be especially beneficial for portraying procedural information that is difficult to describe in words (Wouters et al., 2008). The aesthetic benefits of animations pertain to helping learners to focus on the relevant parts of the animation because movement can hold learners’ attention. In addition, the authentic portrayals can increase learners’ motivation (Phan, 2011).

Even though instructional animations can facilitate learning by externalizing cognitive processes in specific areas, other studies have failed to find the superiority of the animation to static pictures. For example, Mayer et al. (2005) compared static illustration with printed text to narrated animation about four different topics (i.e., the process of lightning formation, how a toilet tank works, how ocean waves work, and how a car’s braking system works). They found that the paper groups outperformed the animation groups in four tests out of eight tests. In other studies, in a variety of learning domains, instructional animations did not yield better learning performance comparing static graphics in various learning domains (e.g., Byrne, Catrambone, & Stasko, 1999: computer algorithm; Hegarty et al., 2003: mechanical system; Hegarty, Narayanan, & Freitas, 2002: a flushing cistern; Morrison & Tversky, 2001: permissible social paths). Thus, Tversky et al. (2002) and Phan (2011) asserted that discrete steps with static graphics may be more beneficial than animations because learners mentally animate the key steps presented in static graphics.

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overload occurs with excessive intrinsic or extraneous load, and effective instruction can be developed by optimizing the three types of cognitive load.

Previous multimedia learning research argued that animations could pose extraneous cognitive load because the information does not stay long enough to be processed (e.g., de Koning et al., 2007; Wouters et al., 2008). However, the extraneous load caused by animations can be reduced by a meaningful instructional medium. The multimedia learning principle suggests a number of ways to reduce extraneous cognitive load, such as the modality principle, the contiguity principle, and the segmenting principle (Clark & Mayer, 2011). In addition, Wouters et al. (2008) proposed that learner pacing and segmentation of dynamic visualization (i.e., animations) would reduce extraneous cognitive load and free learners’ cognitive capacity for learning.

**Pauses between segments**

The segmenting principle states that “people learn better when a multimedia message is presented in user-paced segments rather than as a continuous unit” (Mayer, 2009, p. 175). The segmentation strategy was first explored in the context of reading. Several studies found that segmented text, grouped in meaningful units, was more beneficial for learning (i.e., recall and comprehension) than continuous text (Florax & Ploetzner, 2010; Gaddy, van den Broek, & Sung, 2001; Glynn, Britton, & Tillman, 1985; Hartley, 1986; Weiss, 1983). Spatially segmented text appeared to provide learners with the opportunity to stop the flow of information (Lusk et al., 2009) and to process the information more deeply. In a similar manner, multimedia researchers have examined the effectiveness of presenting dynamic instructional animations in smaller pieces (i.e., segments) rather than in a continuous format (Clark & Mayer, 2011; Mayer, 2009; Spanjers et al., 2010; Spanjers, van Gog., & van Merriënboer, 2012; Spanjers et al., 2011). Several studies have demonstrated the positive effects of segmentation in instructional animations (e.g., Hasler, Kersten, & Sweller, 2007; Mayer & Chandler, 2001; Moreno, 2007; Spanjers et al., 2011; van Gog & Paas, 2008).

In previous studies, the segmenting principle was applied as pauses between segments of the animation. The benefits of pauses have been explained from two viewpoints: (a) extra time, and (b) event boundaries. First, pauses are purported to reduce cognitive load by giving learners extra time to transfer information from the previous segment to long term memory and to prepare to process information in the next segment (Mayer & Moreno, 2003; Spanjers et al., 2010). Second, pauses are purported to provide temporal cues for chunking information. When continuous animations are divided into meaningful chunks, the segments provide natural boundaries between procedural events (Schwan, Garsoffky, & Hesse, 2000; Spanjers et al., 2012; Spanjers, Van Gog, Wouters et al., 2012).

Animation pauses have been investigated in previous studies within the context of either learner or system controlled pauses. In system-controlled pauses, computers control the time between segments. In learner-controlled pauses, learners control the time between segments. In studies employing learner-controlled pauses, Mayer and colleagues compared college students receiving either segmented or non-segmented animations about the formation of lightning and the functioning of electric motors. Their results showed that students studying the segmented versions outperformed those studying the non-segmented versions on transfer tests (Mayer & Chandler, 2001; Mayer, Dow, & Mayer, 2003). In another study, Hasler et al. (2007) compared two different learner-controlled conditions (i.e., pauses between segments vs. providing learners with stop and play buttons throughout the animation) to two continuous conditions (i.e., text and narration vs. narration only animations). They found that the two learner-controlled conditions outperformed two continuous conditions on the more difficult test items. They also found that the condition with learner-controlled pauses between segments was especially beneficial for novice learners (Moreno, 2007) and learners with low working memory capacity (Lusk et al., 2009). Spanjers et al. (2011, 2012) conducted two studies comparing system-controlled pauses to a continuous animation (i.e., no segmentation). The results of their first study showed that students studying animations with system-controlled pauses between segments learned more efficiently (i.e., invested less mental effort with no loss in performance) than students studying a continuous animation (i.e., no segmentation). Their second study showed that the segmentation group with system-paced pauses outperformed the continuous animation group on a posttest.

Spanjers et al. (2012) conducted another segmentation study designed to increase learner engagement by having learners create their own segments within a series of written worked examples. However, the results showed that asking learners to create their own segments required more mental effort (and reduced learning efficiency) than
presenting learners with predefined segment pauses. Learner created segmentation appears to require extensive cognitive resources that may overload the cognitive system. Even though their study did not use animation, the results can be explained by the guidelines for designing effective video-based model prosed by Wouters, Tabbers, and Paas (2007). Their guidelines suggest that pacing with predefined segments would be beneficial for learners with low prior knowledge, whereas creating segments would be suitable for learners with high prior knowledge. However, no studies have compared the two pace control options with pre-defined segments in an instructional animation.

**Passive pauses and active pauses**

Other strategies, besides segmentation, have been studied in conjunction with animations in order to increase their effectiveness. For example, Paas, Van Gerven, and Wouters (2007) showed a sequence of key frames from an animation directly after the animation. In another study, Mayer et al. (2003, Experiment 3) gave learners a question before showing an animation about the working of an electric motor and told them that they would have to answer the question after the animation. Both of these methods successfully enhanced student learning by actively engaging students with the information presented in the animation. Interestingly, however, few studies have attempted to engage students in active processing activities between segments of an animation (i.e., during the pause period). This is an important area of research since pauses between segments of an animation are only effective to the degree that learners actually use the time during pauses to process relevant information (Wouters et al., 2008), and some researchers have questioned whether learners use pause time effectively (Spanjers, van Gog, Wouters et al., 2012). Therefore, the primary purpose of this study was to explore the effectiveness of providing different types of student engagement during pauses in an animation.

The conventional pause between animation segments can be referred to as a **passive pause** because no instructional activity is presented during the pause. On the other hand, an **active pause** occurs when an instructional activity is presented during the pause (e.g., answering a question) (Cheon et al., in press). Presenting learners with an engaging instructional activity during a pause in an animation is likely to make the pause period more meaningful, since the activity should enhance the cognitive processing of information from the previous segment. For example, Cheon et al. (in press) presented embedded questions that required learners to retrieve information from the previous animation segment. In their study, the active pause group outperformed a passive pause group on recall and transfer tests; the authors concluded that this kind of active pauses promote germane cognitive load by enhancing schema construction. However, the positive effects of the active pause in their experiment might have been caused by the extra time spent by learners who responded to embedded questions because the pauses in their study were learner-controlled. Little is known about the direct effects of embedded questions during an animation pause. Even less is known about how different types of instructional activities during pauses affect learning performance. In addition, the effects of active pausing on cognitive load (Paas, Tuovinen, Tabbers, & Van Gerven, 2003) should be taken into consideration. The instructional activity presented during a pause may increase learners’ mental effort as they strive to understand the information depicted in the animation (Wouters et al., 2008). Alternatively, active pauses may decrease mental effort for a test because learners have already encoded and retrieved information by the pause activity.

The aim of the present study was to determine the relative advantage of active pauses over passive pauses on learning performance and mental effort in an instructional animation incorporating system-controlled pauses. Participants receiving passive pauses were instructed to either wait (i.e., no instruction to reflect) or to reflect on the information presented in the previous segment; participants receiving active pauses were asked to either write down everything they could remember from the previous segment (i.e., free recall) or answer short-answer test items during the pause period. The research questions were (a) How does pause type (active vs. passive) affect the learning performance of college students studying a segmented animation? and (b) How does pause type (active vs. passive) affect the mental effort of college students studying a segmented animation? It was hypothesized that active pauses would enhance learning outcomes (i.e., recall and transfer) more than passive pauses. Regarding mental effort, active pause groups were hypothesized to invest higher mental effort than the passive pause group during the instructional animation, but lower mental effort during the test phases.

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Methodology

Participants and design

Ninety-nine undergraduate students from a large Southwestern university participated in this study (Female: 50, Male: 49; Freshman: 35, Sophomore: 38, Junior: 19, Senior: 7). The participants were enrolled in an undergraduate course on computer literacy, and the course had an instructional research module designed to provide students with an opportunity to participate in a study related to instructional technology. Participants were randomly assigned to one of the four experimental conditions (i.e., two passive pause groups and two active pause groups): (a) passive pause, no-reflection, n = 29, (b) passive pause, reflection, n = 25, (c) active pause, free-recall, n = 24, and (d) active pause, short-answer, n = 21.

Materials

Instructional animation

The instructional animation consisted of a 160-second instructional animation about the formation of lightning (see Figure 1) created with Adobe Flash software. The animation was based on the animation used by Mayer and Moreno (1998) and consisted of 16 frames, each depicting a step in the process of lightening formation. The animation was divided into four 40-second segments (four steps per segment). The animation was accompanied by a narration identical to the text used by Mayer and Moreno (1998). The narration explained each of the steps in the formation of lightning.

Differences between the conditions involved the type of activity required of students during the four pauses in the animation. The animation, including pauses, was system-controlled, and total time to complete the animation was 320 seconds (i.e., 40 seconds per segment and 10 seconds per pause). During pauses, the passive pause, no-reflection group was presented with a blank screen with the follow message typed in the middle of the screen: “Please wait. You will be moving to the next animation in 40 seconds.” The passive pause, reflection group was presented with the following message encouraging self-reflection on the material they had just studied: “Please try to remember what you saw in the previous animation. You have 40 seconds.” The active pause, free-recall group was presented with the following message: “Please type as much of the information from the previous section that you can remember. You have 40 seconds.” The active pause, short-answer group was presented with the following message followed by two short-answer questions pertaining to the previous segment, “Please answer the following questions. You have 40 seconds.”

![Figure 1. A screenshot of instructional animation](image-url)
Prior knowledge test

Prior meteorology knowledge was collected from the participants using items developed by Mayer and Moreno (1998) and consisted of a seven-item meteorology-knowledge checklist (e.g., “I know what a cold front is ___,” “I know what a low pressure system is ___”) and a self-rating that asked participants to rate their knowledge of meteorology on a 5-point scale (1 = very little; 5 = very much).

Learning performance tests

Learning performance was measured with two tests (i.e., recall test and transfer test). The recall test instructed the participants to type everything they could remember from the instructional animation they had just studied. Following Mayer and Moreno (1998), free recall performance was scored by awarding participants one point for each of the 19 idea units contained in the instructional text, resulting in a total of 19 points possible. The transfer test, also developed by Mayer and Moreno (1998), consisted of four open-ended questions that required participants to transfer their knowledge of the instructional animation to correctly answer the questions (e.g., “What could you do to decrease the intensity of lightning?”). The transfer test was scored by awarding from zero to 3 points per item, resulting in a total of 12 points possible.

Mental effort rating

A mental effort rating scale was used to measure mental effort invested in both the instruction and the test phases. The nine-point rating scale was developed by Paas (1992) and consisted of the following statement: “Please indicate how much mental effort you invested in this test ranging from 1 (Extremely low) to 9 (Extremely high).” This subjective self-rating measure is non-intrusive and has proven to be a reliable indication of the mental effort experienced by participants (Paas et al., 2003).

Procedure

The study was conducted in a computer lab with 15 to 20 participants in each experimental session. A research proctor began the study by instructing the participants to turn on their computer monitors and silently read the instructions pertaining to their randomly assigned condition. The participants were also informed that they would be given a series of brief assessments after their study of the material; however, they were not informed about the nature of the assessments. They were next asked to complete the participant questionnaire including demographic information and prior knowledge. The participants then studied their assigned instructional animation. Since the animation including pauses was system-controlled, all groups completed the animation at the same time. After studying the instructional animation, the participants completed the recall test and then the transfer test.

Results

Regarding prior knowledge of the learning material, there were no significant differences among groups in either of the prior knowledge measurements (Seven-item meteorology-knowledge checklist, $F(3, 98) = 1.616, p = .191$; self-rating question $F(3, 98) = 1.257, p = .294$).

The research questions in this study were investigated through one-way ANOVAs. The analyses showed that test scores were influenced by the types of pauses (research question #1). However, mental effort scores were not significantly different (research question #2). The means for each measure by group are presented in Table 1.

Regarding recall test scores, the results revealed significant differences among the groups, $F(3, 98) = 4.861, \eta^2 = .365, p = .003$. Post-hoc comparisons indicated that the mean scores for the active pause, free-recall group ($M = 10.54, SD = 3.13$) was significantly higher than both passive conditions: no reflection ($M = 7.31, SD = 3.24$) and reflection ($M = 8.08, SD = 3.51$). However, the active pause, short-answer group ($M = 8.86, SD = 2.65$) was not significantly different from any of the other groups.
Table 1. Means and standard deviations for recall, transfer, and mental effort by treatment group

<table>
<thead>
<tr>
<th>Dependent Variables</th>
<th>Passive pause, no-reflection ( n = 29 )</th>
<th>Passive pause, reflection ( n = 25 )</th>
<th>Active pause, free-recall ( n = 24 )</th>
<th>Active pause, short-answer ( n = 21 )</th>
<th>( p )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recall test scores</td>
<td>( M = 7.31 ) (SD = 3.24)</td>
<td>( M = 8.08 ) (SD = 3.51)</td>
<td>( M = 10.54 ) (SD = 3.13)</td>
<td>( M = 8.86 ) (SD = 2.65)</td>
<td>.003*</td>
</tr>
<tr>
<td>Transfer test scores</td>
<td>( M = 3.93 ) (SD = 2.25)</td>
<td>( M = 4.52 ) (SD = 2.14)</td>
<td>( M = 5.58 ) (SD = 1.31)</td>
<td>( M = 4.90 ) (SD = 1.61)</td>
<td>.019*</td>
</tr>
<tr>
<td>Mental effort for instruction</td>
<td>( M = 5.79 ) (SD = 1.42)</td>
<td>( M = 5.64 ) (SD = 1.63)</td>
<td>( M = 6.21 ) (SD = 1.50)</td>
<td>( M = 6.00 ) (SD = 1.70)</td>
<td>.604</td>
</tr>
<tr>
<td>Mental effort for recall test</td>
<td>( M = 6.59 ) (SD = 1.30)</td>
<td>( M = 6.00 ) (SD = 1.47)</td>
<td>( M = 6.50 ) (SD = 1.14)</td>
<td>( M = 6.67 ) (SD = 1.32)</td>
<td>.285</td>
</tr>
<tr>
<td>Mental effort for transfer test</td>
<td>( M = 6.38 ) (SD = 1.18)</td>
<td>( M = 5.68 ) (SD = 1.28)</td>
<td>( M = 6.08 ) (SD = 1.44)</td>
<td>( M = 6.52 ) (SD = 1.47)</td>
<td>.138</td>
</tr>
</tbody>
</table>

There was also a significant transfer effect, \( F(3, 98) = 3.459, \eta^2 = .314, p = .019. \) Post-hoc comparisons indicated that the transfer test scores in the active pause, free-recall group (\( M = 5.58, SD = 1.31 \)) were significantly higher than the scores in the passive pause, no reflection group (\( M = 3.93, SD = 2.25 \)). There were no significant differences among the other groups.

There was no effect for mental effort for instruction, \( F(3, 98) = .620, p = .604 \), recall test, \( F(3, 98) = 1.281, p = .285 \), and transfer test, \( F(3, 98) = 1.884, p = .138 \). Taken together, these results suggest that the active pause, free-recall condition positively affected learning over the passive pause groups without increasing the mental effort of the participants.

Discussion and conclusion

This study investigated whether active pauses in an instructional animation would increase learning outcomes and mental effort more than passive pauses. The results partially supported this hypothesis in that the only one active pause group (i.e., free-recall condition) outperformed both passive pause groups (i.e., no-reflection and reflection) on a free recall test and a transfer test. Although the effect of the active pause, short-answer condition was not significant, the means for both recall and transfer were higher than the two passive pause groups (i.e., no reflection and reflection). However, neither mental effort in the instruction nor the tests was influenced by active pauses. In the following paragraphs we present implications relating to the advancement of the literature on the segmenting principle and the practice of instructional design.

The positive effects of the active pause, free-recall condition (i.e., free recall test: \( p = .003 \), transfer test: \( p = .019 \)) can be explained as resulting from an emphasis on germane cognitive load as opposed to extraneous cognitive load. Based on the limitations of working memory when processing large amounts of information (Baddeley, 2007), the segmenting principle asserts that presenting a continuous animation in small chunks can reduce learners’ cognitive load (Mayer & Moreno, 2003; Moreno & Mayer, 2007). Thus, learners can process previously presented information during pauses between segments. The positive effect of pauses has been found in the previous studies, but the effect is clearly dependent upon the metacognitive skill and/or motivation of the learners, as they may not use the pause time effectively (Spanjers, van Gog, Wouters et al., 2012). The conventional pause was called as a passive pause in this study because there is no required task for learners. On the other hand, an active pause was proposed using embedded assessments between segments. We hypothesized that while the passive pause condition may reduce extraneous cognitive load, the active pause conditions should promote generative cognitive load by facilitating schema construction. The findings are consistent with the results obtained by Cheon et al. (in press) and more clearly illustrate the effects of an active pause condition. The previous study found that a short-answer question group
outperformed a no-reflection pause group, but these results might have been caused by the additional time spent by the active pause group. Therefore, the present study controlled the pause time to investigate whether learning performance differences were caused solely by the additional time afforded by the embedded questions. The results of the current study show that the active pause likely facilitates germane cognitive load by requiring learners to actively process material from the prior segment. Interestingly, it was the group asked to free recall rather than respond to short-answer questions that was responsible for the learning differences. We conjecture that because the short-answer questions covered only two steps, out of four steps, in each segment they may have focused on only half of the material in each segment. Also, learners may not have had enough time to fully take advantage of the stimulus, because they had to read and understand two questions first in order to type their responses. Thus, with a system-controlled pace, we contend that free recall during pauses is superior to short answer.

Contrary to our expectations, the current study did not find a mental effort effect. For the instruction with animation, we hypothesized that mental effort in the active pause groups would be higher than the other groups because both passive and active pauses already reduce extraneous cognitive load, but the questions in the active pause groups required more mental effort to answer the questions. This assumption was partially supported in that the mental effort ratings in both active pause groups were higher than the passive pause groups, but not statistically significant. Mental effort ratings during the tests were even less disparate, even though we predicted that mental effort would decrease in active pause groups since they could easily retrieve information from their long-term memory. We speculate that the inconsistent mental effort level may be caused by the complexity of the learning contents. The lower mean scores across the tests is an indication that the tests were complicated in general.

From a practical point of view, this study provides instructional designers with practical implications regarding a potential role of active pauses between segments in instructional animations. The general goal for instructional design is to minimize extraneous load and maximize germane load to a level that remains within working memory limits (Wouters et al., 2007). The current findings expand the knowledge base established from previous studies, such as the effects of asking questions before an animation (Mayer et al., 2003), or showing key frames after the whole animation (Paas et al., 2007). In line with Spanjers, van Gog, Wouters et al.’s study (2012) in which additional time after each segment was more beneficial than additional time after whole animation, active pauses (e.g., free recall test) may be more useful for learners to process transient information. However, the active pauses should not be too complex to interrupt the flow of learning from the animation.

Our results and interpretations also yield a number of suggestions for further research. First, the questions used in the active pause conditions prompt the retrieval of information from the previous segment. However, a prompt to predict the next step could be used in active pauses. For example, Hegarty et al. (2003) asked learners to predict the behavior of a machine from a static diagram in order to enhance mental animation. The prediction activity may trigger cognitive processes to select and organize information from the previous segment in order to expect the next event. Moreover, learners’ prior knowledge can be another consideration of using active pauses. Depending on the level of prior knowledge, the active pause may affect learning differently. Further studies could examine the differences between reflection and prediction prompts during pauses in terms of prior knowledge. Second, this study predefined the length of the segments, but further studies may explore the effect of active pause depending on the length of the segments. Third, the topic of the instructional animation used in this study was meteorology. It seems that this subject was somewhat difficult for the participants. Future studies may use a different topic to examine the effects of active pauses with animations. Last, the primary benefit of using segmented animation is to reduce extraneous cognitive load. On the other hand, this study proposes another potential role of pause that is to increase germane cognitive load. The mental effort level gauges the overall load, but it would be useful to have an instrument that measure different types of cognitive load (Mayer & Moreno, 2003; Spanjers, van Gog, Wouters et al., 2012).

Instructional animations can be a promising tool to deliver complex and procedural information, but the transient nature of animated information may strain learners’ cognitive system and hinder their learning. In other words, instructional animations may require significant cognitive resources that exceed the limitations of the learners’ working memory. Thus, instructional designers should design multimedia instruction in a way that minimizes unnecessary cognitive load (Mayer & Moreno, 2003). The segmenting principle is proposed to be one of the ways to optimize instructional animations. Our approach of using active pauses between segments is based on the idea that learner’s cognitive processing could be stimulated during pauses. The potential role of active pauses can add more value to the segmenting principle when using animated instruction.
References


