EFFECTS OF MULTIMEDIA ON MOTIVATION, LEARNING AND PERFORMANCE: 
THE ROLE OF PRIOR KNOWLEDGE AND TASK CONSTRAINTS 

DISSERTATION 

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ABSTRACT

This study examines the effects of instructional presentation methods and different types of tasks on learning processes and outcomes from cognitive load and learner control perspectives. Situated in software training, a between-individual, 2 (Tutorial Type: Static images with print text or animated pictures with narration) x 3 (Task Type: Rote or Explore or Explore with Tips) experimental design is used. Prior experience is examined as the key covariate in the analyses.

The primary findings of this study suggest that using animated pictures with narration to present instructional content can reduce learners’ cognitive load while improving their retention test performance. The animated version of the tutorial helped enhance self-efficacy more than the text version. Moreover, the two versions of tutorial did not differ significantly on affordances and usability measures, countering the usability concerns in the conventional view of animated and audio-visual presentation. Results also indicate that giving learner more control over their learning processes may not translate into the feeling of being in control. Furthermore, this study found the Explore with Tips task with more learner control led to lower retention test scores. Flow and intrinsic motivation were examined as a potential explanatory mechanism. The overall lack of motivational variance across experimental groups is discussed.
Dedicated to my family
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The dissertation experience is like running the longest marathon. Yet it is the most rewarding experience I have had in my life. For me, it was an inevitably lonely process. Thanks to the solitude, I found out more about myself and got to understand human nature in yet another "extreme" context. Fortunately, I was able to finish this tough journey with all the guidance and support from the people listed below.

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This dissertation marks the end of my graduate studentship and the exciting start of learning in the wild.
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CHAPTER 1

INTRODUCTION

Multimedia instruction such as training videos and narrated animations are used pervasively in software training. Despite their popularity and speculated advantages over leaner media such as text and static images, the mixed findings from empirical research have stimulated discussions and debates. This study is an attempt to tackle unresolved questions about presentation media and prior knowledge level in the context of software training. Static images with text and animated pictures with narration are two frequently used instruction presentation methods in software training. In recent years, training videos and podcasts have gained increasing popularity, while the traditional text-and-image format is still the default option for classroom instruction and many software online help systems. This study examines the effectiveness of these types of instructional presentation for novice and experienced learners in different training tasks.

Empirical research has provided support for the superiority of multimodal presentation in domains such as complex systems user interfaces (Sarter, 2006) and instructional design that conforms to the modality principle in E-learning (Clark & Mayer, 2003). The underlying design rationale for many of the successful applications of multimodal presentation is humans have separate channels for visual/pictorial and
auditory/verbal information processing (Baddeley, 1986; Paivio, 1986). One solution to the limited capacity of each channel is the distribution of tasks and information across various sensory channels according to the multiple-resource theory (Wickens, 1984). Therefore presenting graphic information with spoken explanations, for example, would be more effective than presenting both graphics and corresponding explanatory text on screen concurrently, as the latter will likely overload the visual channel with both sources of information competing for the limited visual attention. Indeed, multimedia learning research has produced consistent evidence for the benefits of using the auditory channel to present textual explanation that accompanies visual information in multimedia lessons (Mousavi, Low, & Sweller, 1995; Mayer & Moreno, 1998; Moreno & Mayer, 1999; O’Neil, Mayer, Herl, Niemi, Olin, & Thurman, 2000). However, from the usability and affordances perspective, instructional videos and narrated animations can have both advantages and disadvantages compared to visual and static presentations. For example, due to the fleeting nature of spoken text and animated pictures, searching for information may be difficult, while onscreen text affords better preview and browsing. Furthermore, using the video or animation playback controls and progress bars may not be as easy as navigating a static text-image document.

The vastly richer information afforded by animated pictures by showing intermediate steps between key frames can reduce the mental effort required to fill in the gaps between frames that would otherwise be necessary when processing static, discrete images. However, this affordance of process visualization can be double-edged as well, as some researchers argue that having to fill in the gaps between key frames encourages
learners to engage in active processing of the learning material, which should lead to better information retention and deeper understanding. Summarizing the above findings and speculations, two competing hypotheses have been proposed regarding the effectiveness of static and animated media in learning (Mayer, Hagerty, Mayer, and Campbell, 2005). This study tests the dynamic media hypothesis in favor of animated pictures with narration or videos over text and pictures in a software training context.

A large volume of research indicates that some successful instructional strategy and interface design for novice users or learners may not work as effectively for experienced learners with greater prior knowledge (Kalyuga, 2005). Researchers have replicated this phenomenon, also known as “expertise reversal effect,” in empirical studies of computer-based science instructions (Lee, Plass, & Homer, 2006; Reisslein, Atkinson, Seeling, & Reisslein, 2006). In the context of software training with audio-visual animated presentation or static presentation using text and images, a potential expertise reversal effect may be observed and explained by the differential amount of information presented in different modes and modalities. Animations may appear more interesting, motivating, and perhaps even easier to the novice learner due to its novelty, enabling and facilitating effects (Schnotz & Rasch, 2005). However, the inherent linearity of a video tutorial may seem to be an inefficient way of gaining knowledge for experts or the more experienced user. Hence the preview and skimming that text and images afford may become more important for instructional efficiency for advanced learners. At the same time, for a more experienced learner, however, a clip of animation introducing a
novel feature of the software may still be more appealing and efficient than static content introducing the same feature.

Following this line of reasoning, other possible explanations exist for the differential effectiveness of these presentation modes in different situations. Can they serve the same learners at different times, for different purposes? In knowledge and skill acquisition, when a learner has control over how much and what they learn, which applies to many e-learning and software training situations, learner motivation becomes a key component to design for in instruction. Learner motivation also has an important role in how much learners are willing to explore and practice. Both presentation media type and the nature of the learning task can influence learners’ level of intrinsic motivation.

Therefore, it is important to examine how different presentation methods and perceived learner control can affect different learning tasks. It has been found that exploration and discovery-based learning environment that allows the learner more control over their learning experience is more intrinsically motivating (Martens, Gulikers and Bastiaens, 2004). However, research also shows that exploration-based training may be ineffective due to the fact that learners fail to systematically explore the learning subject (Wiedenbeck, Zavala & Nawyn, 2000) or simply spend less time on task when they are given such control (Flowerday and Schraw, 2003). Explanations offered by researchers include inadequate knowledge to set goals or adopt the right learning strategies. Therefore, performance and exploration may not always co-vary in the same direction. Moreover, giving learner the control over how and what to learn may lead to cognitive overload as too many instructional choices can overwhelm a novice learner.
without any prior knowledge in the task domain (Neiderhauser, Reynolds, Salmen and Skolmoski, 2000). In this case, allowing the learner to explore can have detrimental effects on learning outcomes through cognitive load. Under extreme conditions, the learner may be too cognitively overloaded to be motivated to learn.

Learner preferences of tutorial type and learning styles are also factors contributing to learning outcomes, particularly in software training scenarios that offers instructional material in different modalities or allows various degrees of exploration. Research examining learning styles in multimedia learning is limited and has produced mixed findings regarding the moderating role of learning styles. Some studies found that learning is enhanced when multimedia instructional content is used for high visual-orientation students (Smith & Woody, 2000) and when training method is matched to learning styles (Liegle & Janicki, 2006; Simon, 2000), while others found learning style unrelated to learning outcomes or instructional methods (Harris, Dwyer, & Leeming, 2003). This study is designed to find out not only the effects of different presentation methods in different task environments, but also whether and how individual preferences and learning styles interact with the instructional presentation and task environments.

To address the objectives of this project, a between-individual, 2 (Tutorial Type: Static images with print text or animated pictures with narration) x 3 (Task Type: Rote or Explore or Explore with Tips) factorial design is proposed. The role of prior experience is examined as the key covariate. This study is an attempt to replicate the expertise reversal effect that was found in Kalyuga, Chandler, and Sweller’s study (2000) with two different instructional presentation methods – animated pictures with narration, and static
images with text – and to further clarify the strengths of each type of instruction

presentation method for different types of tasks. Task types are manipulated in this study
such that participants perform either a rote task in which they follow a worked-out
example, or an exploratory task with or without extra instruction content to create an
image using tools and features introduced in the tutorial.
CHAPTER 2

LITERATURE REVIEW

The Mode and Modality Question in Multimedia Learning

Recent computing and multimedia technologies enable more presentation formats and modality options, as evidenced in the increasing use of both audio and visual channels in static and animated presentations. When designing instruction for a certain group of learners in a certain task domain, should we choose static media including images and text, or animated pictures with narrated text? Would the advantages of animations and the additional audio channel pay off the production costs, bandwidth requirements for delivery, and demand for the learners’ cognitive resources? What would be the tradeoffs due to this choice?

Cognitive Theory of Multimedia Learning and Its Three Underlying Assumptions

Multimedia learning refers to the knowledge construction process where learners build mental representations from both words in the form of spoken or printed text, and pictures such as graphic illustrations, photos, animation or video (Mayer, 2005). The Multimedia principle (Mayer, 1997) asserts that People learn more deeply from words
and pictures than from words alone, which is also the rationale for multimedia learning. Three important assumptions set the theoretical foundation for the cognitive theory of multimedia learning: Dual processing channels, limited capacity, and active processing (Mayer, 2005).

Dual-channel processing assumes that humans have two separate information processing channels for visual and auditory representations of stimulus material. This concept of dual-channel processing is closely associated with Paivio’s dual-coding theory (1986) and Baddeley’s model of working memory (1986, 1999) in cognitive psychology. There are two approaches to conceptualizing the differences between the two channels based on presentation modes and sensory modalities respectively. Consistent with Paivio’s distinction between verbal and nonverbal systems, the presentation-mode approach focuses on whether the represented material is verbal (such as printed or spoken words) or nonverbal (such as background sounds and animated pictures). In contrast, the sensory-modality approach follows Baddeley’s distinction between the visuo-spatial sketchpad and the phonological or articulatory loop and differentiate between the visual channel that processes visually represented material and the auditory channel that processes auditorily represented material. Cognitive theory of multimedia learning adopts both approaches when examining how learning material is processed. For example, narrated text is processed in the verbal channel of the presentation-mode approach and auditory channel in the sensory-modality approach.

The limited cognitive capacity assumption follows that humans can only process limited amount of information in each channel at one time, that is, the working memory
has a limited capacity. For example, if a graphic illustration or animated pictures of how to use a word processing program is shown, the learner can only hold a portion of the presented information such as creating a document, changing font sizes and saving a document rather than an exact copy of all the processes in working memory. In this case, the limits of the nonverbal and visual channels determine that only a few images can be processed at one time. Similarly, if a narration is presented to a learner, only a few words can be held in working memory at any one time. These constraints on the processing capacity force the learners to decide between several sources of information, which one to pay attention to, and to what degree the selected information should be connected with each other as well as with existing knowledge. In contrast, human long-term memory has a large to virtually unlimited capacity.

The last assumption of the cognitive theory of multimedia learning is that humans are active cognitive processors when they construct coherent mental representations of their experiences. Processes involved include paying attention to, organization and integration of selected incoming information with other knowledge (Figure 2.1). Two important implications can be derived from this assumption for multimedia design: 1) the presented material should have a coherent structure and 2) the message should provide guidance to the learner for how to build the structure. If one of them is missed, it would be either impossible or cognitively overwhelming for the learner to build a coherent mental representation.
Cognitive Load Theory

Working memory limitations present a major constraint in learning. Instructional designs that primarily aim at the accumulation of knowledge in long-term memory through schema construction and automation and take into account the working memory characteristics are more likely to be effective and efficient than those that do not (Sweller, 2005).


Intrinsic cognitive load is the result of the natural complexity of the information that must be processed. It is determined by levels of element interactivity. When individual elements of material can be understood without understanding all elements, element interactivity is considered to be low and working memory load is also low. In contrast, the elements that constitute the learning material may interact in the sense that one cannot meaningfully learn one element without simultaneously learning many other elements. The complexity of these interactions increases as the number of elements increases, leading to a higher level of cognitive load.


elements. In this case, the learner must consider all elements and the relations among
them because the elements interact to produce meaning. Learning and understanding high
element interactivity material are difficult because high element interactivity imposes a
high working memory load.

Germane cognitive load (Paas & van Merrienboer, 1994) is “effective” or
essential cognitive load. It is caused by effortful learning necessary for schema
construction and automation. For example, withholding learning aids such as visual
simulations at certain point in learning forces the learners to mentally visualize the
processes by themselves and engage in deeper processing. It increases cognitive load but
the increase is germane in that it is likely to assist schema construction and better
information retention in the long run.

Extraneous cognitive load is caused by inappropriate instructional designs that
ignore working memory limits, fail to focus cognitive resources on schema construction
and automation. It is unnecessary load imposed on the working memory.

Intrinsic, germane and extraneous cognitive load are additive. When a heavy
extraneous cognitive load is added to a heavy intrinsic load, such as a poorly designed
instruction on an already difficult topic, the overall cognitive load may exceed the
learner’s working memory capacity. The aim of instruction should be to reduce
extraneous cognitive load caused by inappropriately designed instruction. Reducing
extraneous cognitive load frees working memory capacity and so may permit an increase
in germane cognitive load. However, it is important to note that the goal of instructional
design is not to merely reduce cognitive load, because germane cognitive load should be
maintained for essential information processing. Moreover, the benefits of efficient instructions may only be evident when the learning material is relatively difficult, in other words the cognitive load effects due to extraneous cognitive load can only be demonstrated using material that is high in element interactivity (Sweller & Chandler, 1994; Tindall-Ford, Chandler & Sweller, 1997). This is because if element interactivity is low while intrinsic cognitive load is also low, material can often be understood and learned even if extraneous load is high since the overall cognitive load does not exceed the working memory capacity. Therefore to ensure the differential effect of instructional presentation type and task type, the tasks need to be carefully designed so that they are not too difficult or cognitively overwhelming for the novice learners so that they can achieve meaningful learning, rather than stop making the effort which will ironically lead to decreased cognitive load. The tasks should not be too easy either for the experienced learners. If intrinsic cognitive load is low, even if extraneous cognitive load is high, their total cognitive capacity is still far from being exceeded.

A wide range of instructional principles are derived from the theory. Worked examples (in the form of a rote or repetition task in this study), split-attention effect, modality principle, redundancy effect and expertise-reversal effects are all directly relevant to multimedia learning and discussed from the cognitive load perspectives in the following sections.

*The Use of the “Rich” versus “Lean” Media in Learning*
The media richness theory (Daft & Lengel, 1984, 1986; Trevino, Lengel, & Daft, 1987) posits that media differ in the amount of "rich" information they can convey. In summary, richness in this context is a function of four factors: the capability of a medium (1) to provide immediate feedback, (2) to transmit verbal and non-verbal communication cues, (3) to provide a sense of personalization and (4) to simulate natural language. Communication media can be ranked along each of these factors from the richest to the leanest.

Media richness level has been proposed as one of the nine key factors that influence instructional technology selection (Strauss & Frost, 1999). It seems that educational technology can also be assessed in terms of the “richness” of the information they can deliver. Indeed, there are animations designed for simulations and manipulating objects to provide immediate feedback; text and graphics have been widely used to deliver both verbal and non-verbal information; social agency studies (e.g. Mayer, Sobko, & Mautone, 2003) have reported positive effects of educational technologies that take advantage of human voice and other social emotional cues to provide a sense of personalization and social intelligence.

Narrated animation is a relatively “rich” type of media compared to the static text and illustrations, both in terms of channels used and the additional content conveyed by the special nature of animation. The use of human voice can add another layer of social emotional cues to the animation. Although this study does not emphasize the social emotional “side effect” of the narrated animation, for an exploratory task, video and narrated animation seem more promising than text and images.
Can pure text and graphics be more expressive and/or persuasive than a video that has both audio-visual channels? A novel can give its reader more room for imagination (which is not equal but similar to creative thinking and problem solving) than a movie to its audience. In multimedia learning, do more cues and channels mean more effective ways to teach and to motivate? This rationale is reminiscent of Taft and Lengel’s media richness theory that the number of cues, perceptual channels, and synchronicity should be matched to the task’s complexity or the number of cues required for communicating in a certain task. In the meantime, Computer-Mediated Communication research suggests that the lack of social contextual cues can also stimulate cognitive deliberation and communicative behaviors that compensate for media limitations (Ramirez, Walther, Burgoon, & Sunnafrank, 2002).

A similar theme exists in multimedia learning, that is, the instructional media “richness” should be tailored to instructional content and learner knowledge. It cannot be so “lean” that it lacks the information that is essential to learning and consumes excessive cognitive resources. Neither should it be so “rich” that it makes learning too easy and hinders deeper cognitive processing – in other words, the learning material should neither “under-facilitate” nor “over-facilitate.”

Taking the stance of media choice research, choosing a medium is a process of matching the attributes of a medium to desired learning outcomes. However, such a process is only relevant if there is a strong relation between media and learning outcomes (Caspi & Gorsky, 2005). Therefore, when selecting educational technology tools, a primary factor to consider is their relevance to student performance. In this study, both
performance and motivation will be examined in determining media appropriateness for specific learning tasks.

Static or Animated? All-Visual or Audiovisual? Mixed Findings for Multimedia Presentations

Multimedia learning is characterized by presenting information in a combination of different modalities, i.e. information processing channels used by the learner such as auditory and visual (Penney, 1989), and modes, i.e. information representation formats such as words and pictures (Paivio, 1986).

Animation being a more recent addition in instructional technology has been evaluated in a variety of contexts. However, what has been called animation has often involved other aspects of communication situations (Ferguson & Hegarty, 1995). Before specifying the benefits and disadvantages of animations, researchers are often quick to point out these potentially confounding features.

Animation Is Not Equal to Interactivity. As Tverskty et al (2002) point out, many of the benefits of animation should be attributed to extra information or additional procedures conveyed by animation, rather than the animation of the information per se. Furthermore, animated contents are often interactive. Interactivity is known to benefit learners on its own, but it should not be confused with animation (Ferguson & Hegarty, 1995).

Nowadays, however, interactivity is becoming a more inherent function in animations in the form of stopping, starting, replaying, control of speed and even
zooming in and out. Such simple user interactions with presentations have also been found to facilitate perception and comprehension as simple user control reduces cognitive load (Mayer and Chandler, 2001).

It follows that one of the difficulties in explaining the effects of animations lies in the lack of correspondence or symmetry in content and/or functionality afforded by static and animated presentations. “In order to know if animation per se is facilitatory, animated graphics must be compared to informationally equivalent static graphics. That way, the contributions of animation can be separated from the contributions of graphics alone without confounding with content. There may be cases where this control is difficult to instantiate, for example, for an animation that shows a complex manner of motion where both spatial position and timing are of the essence” (Tversky, et al, 2002, p. 251).

Informational Equivalence. The lack of informational equivalence (Larkin & Simon, 1987) is also considered a major methodological weakness of media comparison studies in general (Mielke, 1968; McGrath, 1992) in that the presentation methods entail inherently different amount of information, which just cannot be equivalent due to the nature of the different media. When human voice is used to convey information in auditory channel, such as that used in the narrated animation in this study, it adds a layer of social-emotional cues which are absent in non-narrated static display. If the social contextual cues are not differentiated in experimental design, it will be hard to attribute the differences between treatment to one or a set of particular cues (Tanis & Postmes, 2003); but to make comparison groups truly comparable, the richness of such cues will have to be sacrificed (Mielke, 1968). For example, it would be inappropriate to compare
a direct manipulation interface to Face-to-Face human interaction in that the treatment
difference would then likely result from a sum of or any combination of the cues in the
latter condition, hence the explanation of the difference would be difficult and theoretical
contribution of such comparisons would be limited. Due to this difficulty of pinpointing
what is actually being manipulated, caution should be taken in explaining the effects of
different modalities.

The inherent difference between animated and static presentations determines that
informational equivalence is not only difficult to implement in a study like this, but also
impractical. In the proposed study, I concede that there may be potential content
differences – both informational and possibly socio-emotional – between the two types of
presentation and does not concern too much the comparability issue. This study treats the
two types of presentation media as two sets of attributes representative of the commonly
used instructional tools and aims to find out which presentation type serves which group
of learners better and for what type of task.

The Motivation Hypothesis and Contradicting Evidence. Some studies found that
animation can be attractive and intrinsically motivating to learners (Perez & White, 1985;
Rieber, 1991; Sirikasem & Shebilske, 1991). One may argue that animation could be
preferred just because of its interesting and motivating appeal, even if it adds no other
benefit to the learning content.

However, there is also research evidence contrary to the motivation hypothesis,
that animations are not universally preferred, and may not be used by the learners as often
as researchers hope. For example, after comparing a multimedia educational software
system that includes text, graphics, movies, and animated simulations with an
ingformationally equivalent environment that used text and still images, Pane, Corbett and
John (1996) found little evidence that the dynamic and multimedia presentations
enhanced student understanding of the lesson compared to a static visual-only version of
the lesson. Furthermore, students did not display significantly different attitudes towards
the two types of media. Although participants in their study were from the same subject
domain as the software system was designed for, on average they only viewed each
movie and simulation slightly more than once in the first part of the study and exactly
twice as recommended in the second part. The authors thus concluded that even relatively
motivated students cannot be relied on to take full advantage of the potential to explore
multimedia, interactive content. However, they also admitted that they only included
“high achievement” students, which might explain the use pattern of instructional
material and lack of significance for multimedia advantages. If there had been a
comparison group of novice and/or less motivated learners, a different pattern of learning
behavior and a consequent difference in performance might have been observed.

The Animated and Static Media Hypotheses. To date, recommendations regarding
the use of animations as effective instructional aid are still scarce. Research evidence
even points to the opposite direction that static, all-visual media can be as good or even
better than animated displays in promoting learning.

Two competing hypotheses have been proposed regarding the effectiveness of
static and animated media in learning (Mayer, Hagerty, Mayer, and Campbell, 2005).
Static media hypothesis states that static media such as still images, static diagrams and
printed text, offer cognitive processing affordances that lead to better learning (as measured by retention and transfer tests) compared with dynamic media such as animation and narration. Dynamic media hypothesis states the opposite.

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Static illustrations and text help learners

Manage intrinsic processing because learners can control the pace and order of presentation (i.e., learner control effect).

Reduce extraneous processing because learners see only frames that distinguish each major step (i.e., signaling effect).

Engage in germane processing because learners are encouraged to explain the changes from one frame to the next (active processing effect).

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Animation and narration help learners

Reduce extraneous processing because animation requires less effort to create mental pictorial representation (i.e., effort effect), narration requires less effort to create mental verbal representation (i.e., effort effect), and computer control requires less effort to make choices during learning (i.e., effort effect).

Engage in germane processing because narrated animation creates interest that motivates learners to exert more effort (i.e., interest effect).

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Table 2.1. Cognitive Processes in Learning With Static Illustrations and Text Versus With Animation and Narration (Mayer et al., 2005, p.257)
Potential advantages of animations and narration are listed in Table 1 from Mayer, Hegarty, Mayer and Campbell (p. 257, 2005). Animations and narrations offer a more realistic representation of the process to be explained, requiring less initial cognitive effort to receive the message than do static images and text in that the learner does not have to exert mental effort to visualize the dynamic process by mentally constructing a dynamic representation. In general, animations are good for conveying procedural knowledge (e.g. in software training) and can be used to direct the learner’s attention to important aspects of a display, and demonstrate the dynamics of a subject matter (Schnotz & Rasch, 2005). Schnotz and Rasch (2005) propose that animations can have two basic functions: a) they can reduce cognitive load by enabling cognitive processing that would otherwise be impossible; b) they can reduce cognitive load by facilitating cognitive processing that would otherwise require high mental effort and have found supporting evidence. At the same time, if the animation is narrated, the text is spoken rather than visually presented so the learner does not have to split visual attention. Animation with narration may also be more interesting, engaging, entertaining and motivating than static text and images. It follows that the learners may be more willing to engage in germane processing in the animation with narration condition. However, there is also the risk of distracting the learner from the central processing task by adding the more entertaining features in learning material. Moreover, the transient nature of animations and spoken words may also be a drawback that adds extraneous cognitive load by forcing the learner to hold previously presented frames or spoken words in the working memory. Perceptual and cognitive limitations may be
another explanation for failure of animations (Tversky et al, 2002) in that when learners play back animations, usually they still reinspect animation in motion which might make it difficult to perceive subtle changes simultaneously.

In contrast, discrete diagrams and images as illustrations easily allow comparison and reinspection of the details of the procedures (Tversky et al, 2002).

Proponents of static media also argue that the cognitive processing needed to animate or visualize the processes is necessary and should be encouraged because it is a form of germane cognitive load. There have been concerns with regard to not only how instructional materials can reduce extraneous cognitive load, but also how they may inadvertently reduce germane cognitive load associated with deeper meaningful cognitive processing (Mayer, Hegarty, Mayer, and Campbell, 2005; Sweller, 1999; Sweller, van Meerienboer, and Paas, 1998; van Merrienboer, 1997). Indeed, results from several studies prove that this concern is not unwarranted (Palmiter, Elkerton & Baggett, 1991; Palmiter & Elkerton, 1993).

Palmiter and colleagues compared animated and still graphics in instructions on how to use an on-line help system for Hypercard® (Palmiter, Elkerton & Baggett, 1991; Palmiter & Elkerton, 1993). Although the students using the animation completed the training task more quickly, they completed the testing task more slowly. Moreover, after a week, performance of students who had studied the text improved, but performance for those who had studied the animation declined. The advantage of long-term facilitation of text over animation was attributed to deeper processing of the text than of the animation.
Studies also suggest that behavioral interactivity stimulated by manipulating animated simulation does not parallel mental activity that is necessary for deeper cognitive processing, or germane cognitive load (Moreno and Valdez, 2005). Schnotz and Rasch (2005) tested the enabling and facilitating effects of non-narrated interactive simulations. They found evidence for these functions of animation: for half of the comprehension test questions, the animation group outperformed the static media group. However, they also found that for the other half of the test questions, the animations did not benefit learners with high learning prerequisite, and learners with low learning prerequisites performed even better with static pictures than with animated pictures. After close inspection of the two types of test questions that required different types of cognitive processing, the authors argue that animations can modify learner’s cognitive load in an unintended way and the facilitating function of animations can be hindering when it reduces germane cognitive load for those who are able to perform the mental simulations on their own but instead rely on the animation.

Interestingly, there is also evidence for the effectiveness of animated media in improving memory and performance in delayed tests. Fox, Lang, Chung, Lee, and Potter (2004) found that animated graphics can enhance both resource allocation to news stories and how much information people remember from science-related television news stories, compared to redundant text graphics or text alone. The animated graphics help both older and younger viewers store and retrieve the information from the news stories, as indicated by the cued and free recall data, both from delayed tests 2 and 7 days after the experiment. Boucheix and Guignard (2005)’s study, as another example, examines
the comprehension of a multimedia technical document about gear functioning by young pupils. Students with the lowest prior knowledge benefited the most from the animations. Effects of animation were observed in both the immediate comprehension test and delayed test. However, the different modalities of presentation did not have any effect for the participants having high prior knowledge.

In contrast, Mayer et al’s (2005) found significant support for the static media hypothesis in four experimental studies using four stimulus lessons on lightning, toilet tanks, ocean waves, and brakes, respectively. In all four experiments, they compared learning performance as a result of viewing animated display with narration versus static illustrations with text and found that the static media group scored significantly higher than the animation group in four out of eight tests of retention and transfer. No significant difference was found in the rest of the tests. These results were attributed to the advantage of static media that supposedly reduces extraneous cognitive load that animated display would have caused, such as attention to unimportant or irrelevant movement in animation or mental effort expended in holding frames in working memory to make the link between them. The study implied that animation may not be as effective as static media when depicting the operation of physical and mechanical systems, and suggested that learners be given control over the pace and order of animations by using slide bars and pause buttons; that animated presentation be broken down to meaningful segments corresponding to key steps in a process; and that active processing be encouraged by engaging learners with questions and exercises.
Other evidence that appears to support static media hypothesis is provided by research in computer software training. One would assume that the use of animated pictures and video to convey procedural knowledge must have proved to be effective (Tversky & Morrison, 2002). If they have been ineffective or even hindering learning, user testing and poor feedback would have pulled them off the market and we would not see them being used by leading vendors such as Adobe. Unless, as Norman (1988) pointed out, less successful features sometimes do survive.

Despite the current popularity of software training videos that in many aspects are similar to animated pictures, this is an area where animations do not always appear to be effective. In a series of studies that investigated the role of animation in teaching students how to use a Macintosh® computer, how to use the MacDraw® graphics editor, and how to use HyperCard® (Payne, Chesworth, & Hill, 1992; Dyck, 1995; Harrison, 1995, respectively), students receiving instructions in any type of a graphic, static (only for Harrison, 1995) or animated, performed better than those receiving no instruction, but did not outperform those in the equivalent text (Payne, et al, 1992; Dyck, 1995) or static graphic (Harrison, 1995) conditions.

However, one common limitation in these studies is that only novice learners were recruited. Therefore the findings may not be generalized to more experienced learners. The training tasks used in these studies are also relatively simple and might be completed by novices without approaching their limit of cognitive capacity.

Moreover, in the HyperCard® studies by Palmiter and colleagues, the animated version of tutorial consisted of only animated pictures, without either onscreen text or
narrated text. Participants in the animation group were allowed little control over the presentation, in other words they could not pause to review certain portion of the presentation or return to previous portions or fast forward to skip portions of the presentation. These implementations are no longer representative of today’s multimedia tutorials in software training. Differences in these aspects of the experimental procedure and the animation may have led to the different findings in these earlier studies.

Research on the effects of animation in teaching a variety of topics such as mechanical, biological, physical, operational, and computational systems have been inconclusive (Tversky, Morrison, & Betrancourt, 2002). Clark (2005) points out that evidence is not sufficient to establish guidelines for the best practice in animations. Animation’s ability to display movement should not be the only basis for claiming a greater effectiveness. More research is needed to help define the learning goals that best profit from animated treatments and clarify when and how animations should be used to meet the specific needs in learning.

*The Modality Effect.* In contrast to the debates over animated versus static presentations, empirical evidence in multimedia learning consistently suggests that multimodal presentations are superior to unimodal presentations in terms of how well the information presented can be learned and remembered (Low & Sweller, 2005).

Modality effect refers to the learning gain when information presented in a mixed mode, for example in both auditory and visual modalities, is more effective than when the same information is presented in a single modality. The modality principle in e-learning more specifically recommends presenting words as audio narration rather than onscreen
text (Clark & Mayer, 2003). In a series of studies that compare animation or graphics with concurrent narration to animation or graphics with concurrent onscreen text (identical to narration), learners who received animation or graphics with concurrent narration outperformed the onscreen text group in all transfer tests (Mayer and Moreno, 1998; Moreno and Mayer, 1999; Moreno, Mayer, Spires, and Lester, 2001; Mousavi, Low, and Sweller, 1995; O’Neil, Mayer, Herl, Niemi, Olin, and Thurman, 2000).

This effect in multimedia learning derives from split attention effect and can be explained by the cognitive load theory (Low & Sweller, 2005). According to modality effect, when multiple sources of information have to be mentally integrated, students can learn better when some written (hence visual) information is presented in spoken (i.e. auditory) form, under the premise that neither source of information (presented in visual and auditory forms) is easily intelligible in isolation. Otherwise, redundancy effect will likely occur and presenting information in more than one sensory channel would not be as effective.

Split-attention in learning occurs when learners have to split their attention between, and mentally integrate, multiple sources of information that is all essential for understanding the material (Ayres & Sweller, 2005). The consequences of split-attention effect include increased and unnecessary cognitive load induced by extraneous effort to integrate the physically or temporally disparate information, and negative impact on learning outcomes.

An example of split attention would be presenting the same spoken text also on screen, which requires the learner to split his/her visual attention to process redundant
information. Hence under certain, well-defined conditions, presenting some information in visual channel and other information in auditory channel can expand effective working memory capacity, hence reduce the cognitive load on one processing channel and substantially increase working memory capacity. This explanation is consistent with the dual-coding theory which assumes that working memory consists of separate processors for visual and auditory information.

The above mentioned studies on modality effect all compared unimodal and multimodal presentations within the same type, i.e. animation with concurrent narration versus with concurrent onscreen text, or static diagrams with narration versus text, so that they only differ in terms of the number of presentation modalities. Hence a hypothesis can be derived as pertaining to the modality principle if the two presentation media in this study only differ in terms of modality: Students learn better when software training material is presented in both visual and auditory forms than when the same information is presented in only visual form as text and graphics.

However, in the proposed study, the animation with narration condition and the static text and illustration condition differ not only in terms of the number of delivery channels, but also whether information is animated or static. Given the mixed results from research regarding the effectiveness of static and animated media, their effects may not be additive. The two conditions therefore are not directly comparable and the above hypothesis cannot be applied to this study directly due to potential confounding attributes of the two types of presentation.
Summarizing the findings about the general effectiveness of animation in instruction and its effects on cognitive load, motivation, and retention, the following hypotheses are formulated for multimedia tutorials in software training.

H1: Overall, learners using video tutorial experience less cognitive load than those using text tutorial.

H2: Learners using video tutorial will perform better on the retention test in comparison to learners using text tutorials.

In general animated pictures with narration are believed to be more motivating, entertaining, engaging, interesting, and compelling (Tversky et al, 2002; Mayer, Hagerty, Mayer, and Campbell, 2005). After weighing the evidence on both sides, this study follows the motivation hypothesis favoring animated pictures with narration over text with static images.

H3: Overall learners using video tutorial experience higher intrinsic motivation than those using text tutorial.

An important note following these hypotheses is that the primary purpose of this study is not to find out which type of presentation, static or animated, narrated or not, is more efficient and facilitative for learning in general, but which presentation mode facilitates learning for which group of learners – with more or less prior knowledge – and in what task environment. Hence this study is not just about which presentation is superior, in other words the main effect of media type is not the key, but interactions between presentation method, prior experience, and task type.
Individual Differences – Expertise Reversal Effect

The discussion above has centered on which mode or modality of presentation can effectively reduce extraneous cognitive load and at the same time facilitate learning by enhancing germane cognitive processing. Since the essential difference between learners with higher prior knowledge and those with lower prior knowledge leads to the different cognitive loads that they experience when studying the same learning material, it would be a reasonable extension of the research on presentation media by examining its efficiency in light of learner’s expertise or experience level, which has not received thorough investigation in multimedia learning research.

The Essential Difference in Learning with High Prior Knowledge Versus Low Prior Knowledge

From a cognitive load perspective, the major role of learning is acquisition and automation of schematic knowledge structures in long-term memory. Kalyuga and colleagues’ research on expertise reversal effect indicates that effectiveness of different instructional formats and procedures may significantly alter as the learner’s expertise develops in a domain (Kalyuga, 2005; Kalyuga, Ayres, Chandler, & Sweller, 2003; Kalyuga & Sweller, 2005).

According to cognitive learning theories, learners with more prior knowledge may be able to see higher-level structures in the material and analyze it using a conceptually driven approach. In contrast, novice learners may at best be able to find some randomly combined lower-level components and apply a data-driven analysis. This availability of
schema-based knowledge structures in long-term memory is the major factor determining such expert-novice differences (Kalyuga & Sweller, 2005).

The level of learner expertise determines the roles and relative weight of schema-based knowledge structures and instructional explanations in a specific learning task. For novice learners facing a new task, instruction provides the only available guidance. For experts with sufficient prior knowledge in the same task domain, the same task will be very familiar and they may have all necessary schemas available in long-term memory. For learners with intermediate levels of knowledge, schemas and instructions should complement each other.

The optimal learning results can be achieved if instructional guidance is provided for the learner to deal with all unlearned information, leaving no gaps or overlap with a learner’s own schemas for dealing with previously learned information. In absence of such instructional support, learners without previously acquired schemas have to resort to inefficient problem solving strategies such as trial and error or means-ends analysis, resulting in high extraneous cognitive load.

In some other situations, learners may find the instructional material overlapping with their schema-based knowledge in long-term memory. However, cognitive efficiency does not increase when both are available in learning because the learner may still attempt to cross-reference the related schemas and portions of the instruction and it unnecessarily consumes cognitive resources to do so. At times experts may even find instructional materials conflict with their own existing, sophisticated models (Kalyuga, 2005). In either case, an additional but unnecessary processing load is placed on the
working memory, leaving less cognitive capacity for more relevant and essential information processing. This is considered a major cause of the expertise reversal effect. In order to optimize cognitive load, instructional designs should be tailored to changing levels or at least different levels, of learner expertise in a specific domain.

Research findings related to expertise reversal effect indicate that many of the instructional principles based on Cognitive Load Theory for novice learners become less effective as expertise level increases. For example, the multimedia principle (Clark and Mayer, 2003), the modality principle (Low and Sweller, 2005) and the worked-out example principle (Renkl, 2005) that aim at reducing extraneous cognitive load for novice learners may prove inefficient, and even hurt the performance for more experienced learners, because presenting detailed explanations to learners who are already knowledgeable in that domain may interfere with retrieval and application of their own available schemas if they cannot avoid processing such redundant information (Kalyuga, 2005). Hence the cognitive theory of multimedia learning should be broadened so that it can provide instructional design recommendations for more experienced learners beyond the initial phase of skill acquisition (van Gog, Ericsson, Rikers, and Paas, 2005).

Learner Prior Knowledge and Instructional Efficiency

According to the contiguity principle and modality principle (Clark & Mayer, 2003), instructions that physically integrate multiple sources of information or use narrated text instead of on-screen text along with visual information can enhance
learning. However, as learner expertise increases, these instructional procedures can lose their advantage and even become disadvantageous compared to a split-source single-modality presentation. This is because information that is essential for novices becomes redundant for more experienced learners, resulting in the expertise reversal effect (Kalyuga, et al, 2003).

Kalyuga, Chandler, and Sweller (1998) found that inexperienced electrical trainees benefited from textual explanations integrated into the diagrams of electrical circuits, and unable to comprehend a diagram-only format. In contrast, the more experienced trainees performed significantly better with the electrical circuit diagram-only format and reported even less mental effort when studying the diagram-only format. For these more knowledgeable learners, the textual information is no longer essential and so when integrated with the diagram, was redundant and should be eliminated. Integrating text with diagrams to avoid split-attention effect for novices caused the redundancy effect for experts. Hence an expertise reversal effect is found because the explanatory material in an integrated format was superior for novices but inferior for more knowledgeable learners.

Instructional designs that follow the modality principle may also prove less efficient for experienced learners, in that auditory explanations may also become redundant for them. After a series of experiments instructions on using industrial manufacturing machinery, Kalyuga et al. (2000) demonstrated that learning may be hindered if experienced learners attend to the auditory explanations. They found that inexperienced learners benefited the most from studying a visually presented diagram
with simultaneous auditory explanations. After additional training, however, the relative advantage of presenting information through the additional auditory channel disappeared whereas the effectiveness of the diagram-only explanations increased. This is attributed to the fact that the same students became more experienced after further intensive training in the domain. The substantial advantage of diagram-only material over diagram with audio material reversed the results of the first experiment. Participants’ cognitive load ratings were collected immediately after each stage of training in these experiments, which clearly indicated a cognitive load interpretation of the results. This study demonstrates that prior knowledge level can turn modality effect into redundancy effect, again demonstrating an expertise reversal effect. Similarly, the Boucheix and Guignard (2005) study found that animation benefits novice trainees the most but makes no difference for more knowledgeable trainees.

In summary, what exactly are the differences between the two versions of stimulus tutorials in the present study? Between the static text-image and narrated animation, the major differences lie in the following aspects: (1) Ease and extent of visualization: It is admitted in this study that animated pictures with narration does convey more information than text and static images and makes it easier for the learner to visualize the process. The extra details of processes enabled by the animated pictures may be redundant for learners with more prior knowledge in that domain, in that they may not need all that aid in visualization. (2) Processing channels used: Narrated text has proved, by studies on modality principle and split-attention effect, to be cognitively less demanding hence more efficient than on-screen text when other information is presented
visually for novice learners. But again information delivered through one of these channels may become redundant once the learners gain experience. (3) Ease of navigation: Text affords better scanning, which will be more valuable for learners who know what they are looking for with some prior knowledge of the topic. For more experienced learners, text will make it easier for them to skip or do a quick search through out the content.

The differences between the two instruction presentation methods in these three aspects lead to the hypothesized interaction between Tutorial Type and Prior Experience, or the expertise reversal effect.

H4: High prior experience learners experience less cognitive load with static text and illustrations than with narrated animation, whereas low prior experience learners experience more cognitive load with static text and illustrations than with narrated animation.

H5: Learners with more prior experience perform better on retention test with static text and illustrations than with narrated animation, whereas learners with less prior experience perform better on retention test with narrated animation than with text and illustrations.

Individual Differences – Learning Style

Learners’ preferences should be taken into consideration in that they determine partially their motivation to learn and satisfaction with their learning experience. Research has shown that prior knowledge has significant effects on student learning in
hypermedia systems, in that experts and novices show different preferences in the use of hypermedia learning systems and need different levels of navigation support (Chen, Fan & Macredie, 2006). However, what the learner prefers may not always be the best for them. If the control that a learner chooses to exert is considered as a manifestation of learner preference, then learner control can have both benefits and pitfalls. It has been found that learners classified as “observers” tend to follow the default, linear steps of instruction whereas “explorers” tend to “jump around” and create their own path of learning, and they tend to learn better when the options they are given in learning are matched with their learning style (Liegle & Janicki, 2006). Therefore, learning style should be accounted for as it indicates learner preferences and learning strategy.

Designing Efficient Instruction for Different Types of Tasks

Instead of discussing which media type would be more effective, efficient, interesting, and motivating in general, this study provides two concrete contexts to examine this issue. The two types of tasks differ in terms of task goals and they demand different levels of cognitive effort. The two types of tasks also differ in terms of the control they allow the participants. For example, in this study, being “exploratory” means learners make the decision as to what instructional content to view and how long they stay on the learning task.

This study focuses on the procedural knowledge rather than creative use of the software. In particular for novice learners, who have to deal with the novel software interface, familiarizing themselves with all sorts of operations, they will more likely be
overwhelmed if in the very first session they are demanded to master the basic operation of a new application and at the same time, be creative. However, the exploratory task may still nurture curiosity and more creative use of the tools, which may lead to creativity.

*Worked-Out Example versus Exploration-Based Training Tasks, Cognitive Load, Learner Control, and Prior Knowledge*

A worked-out example presents a problem statement and provides explanations of all solution details and is a case of fully guided instruction. Exploratory learning environments and discovery learning represent a form of less or even relatively unguided instruction (Kalyuga, et al, 2003). A considerable number of studies have demonstrated that properly designed worked examples are often a better instructional alternative than conventional problem-solving techniques for initial skill acquisition (Renkl, 2005).

Conventional problem solving tasks confront the learner with a beginning state and a set of criteria for an acceptable goal state (van Merrienboer, Kirschner, and Kester, 2003). The learner uses a certain problem-solving method, applying tentative mental operations to generate a solution, to move from the given state to an acceptable goal state. Research overwhelmingly suggests that such conventional tasks consumes considerable working memory capacity. High extraneous cognitive load is caused by the use of weak problem-solving methods such as means–ends analysis (Sweller, 1988).

Researchers refer to cognitive load theory to devise alternative formats of learning tasks in a manner that reduces the extraneous cognitive load that would otherwise be
caused by conventional problem solving and to encourage schema construction processes. Learning tasks that take the form of worked-out examples present the learners not only a given state and a desired goal state but also with an example solution. Studying those examples first rather than performing conventional problem-solving tasks in initial schema construction may be beneficial, because it focuses learner’s attention on the problem states and associated solution steps, so that it reduces extraneous cognitive load and makes it possible or easier to induce generalized solutions or schemas. Direct instructional guidance such as worked examples provides a strong substitute for a cognitive central executive. It shows the learner exactly how to execute the steps to complete a task. In contrast, problem solving or exploratory learning provides the least effective scaffolding during the initial stages of learning (Kalyuga, Chandler, Tuovinen, & Sweller, 2001). Experimental evidence has been found for the prediction that studying worked-out examples facilitates schema construction and transfer performance more than actually solving the equivalent problems does (Cooper and Sweller, 1987; see Sweller et al., 1998, for an overview).

Exploration-based type of tasks allow more learner control compared to a repetition task. Learner control has been found to have positive effects, but not unconditional. To date research has yielded mixed findings regarding the effects of learner control. Kinzie, Sullivan and Berdel (1988) found that students allowed learner control over content review scored higher in post-test than students who did not have this choice. They concluded that students given limited control over instruction can adjust their study behaviors appropriately and achieve greater learning in the same amount of
time than can students not given such control. Also, simple user interaction with multimedia messages, in essence user control over the words and pictures presented, such as providing the “continue” button or playback controls to the user can reduce cognitive load and enable progressive model building (Mayer and Chandler, 2001). However, research also suggests that when learners are given the control of the amount of instruction, they tend to rush through the task (Murphy & Davidson, 1991) and select fewer options (Ross & Rakow, 1981) than learners under program control. User control could also be taxing on working memory capacity, and can lead to poor recognition and memory (Eveland & Dunwoody, 2002; Neiderhauser, Reynolds, Salmen and Skolmoski, 2000). This might also explain the finding in Martens, Gulikers and Bastiaens’ study (2004) that although learner control leads to more explorative behavior, no difference was observed in the learning results.

In light of this research on learner control, it is most likely that novice learners will not perform as satisfactorily in an exploratory task as in a repetition task. Indeed, Wiedenbeck et al. (2000) found that learners who receive exploratory training tasks only practice procedures selectively, fail to consolidate skills through repetition, and do not devise activities that would extend their knowledge beyond the scope of the training materials. While exploration offers the potential for innovation by the learner, it invites the danger of insufficient repetition in practice.

Wiedenbeck and Zila (1997) found that even experienced computer users learning a new computer application were less successful when they carried out more open-ended exploration practice than when they carried out exercises specified in the manual. Despite
this discouraging finding, some researchers recommend that more advanced learners be given more instructional control. As learners continue to improve their performance in a domain, they will seek increasing independence in learning after formal education and eventually become a self-regulated learner. They will need to shape their own learning experience, diagnose their needs for improvement, monitor their performance and evaluate this whole process (Zimmerman, 2002). Advanced learners are believed to be capable of self-assessment, and adjust both their cognitive mechanisms and learning activities to meet their own learning needs (Ericsson, 2002). Empirical studies in general support this argument. Hence it is recommended that in instructional design, more control should be given to the advanced learners so that they can to some extent, determine their own learning activities. Other studies also suggest learner control may be more effective for learners with more prior knowledge (Lee & Lee, 1991) or higher meta-cognitive skills (Young, 1996). In a study by Tuovinen and Sweller (1999), worked-examples practice was compared with free-exploration practice for students learning to develop sophisticated computational fields for databases. For students with relevant prior knowledge, no difference was observed in the efficiency of learning in terms of performance and mental effort between the two formats of practice. However, the students with no prior content knowledge experienced much more efficient learning when involved in the worked examples practice than in the exploration practice. This finding is consistent with the “expertise reversal effect” (Kalyuga, Ayres, Chandler, & Sweller, 2003). With increasing expertise and for demanding content, exploration is more efficient than worked examples (Kalyuga, Chandler, & Sweller, 2001).
H6: Overall, rote task will lead to better performance on the retention test than exploratory tasks.

H7: Novice learners will experience higher cognitive load in exploratory tasks than in rote task, while task type will have less impact on the cognitive load of experienced learners.

H8: Novice learners in rote task will perform better on the retention test than novice learners in exploratory tasks, while performance of experienced learners will suffer less than that of novice learners in exploratory tasks.

Learner Control and Motivation

The cognitive advantage and disadvantage of learner control are not completely clear. However, researchers agree to a large extent that when learners are given the license to make some instructional decisions for themselves and feel in control in learning, they tend to be more intrinsically motivated and explore more, which is considered as an indicator of curiosity (Martens, Gulikers and Bastiaens, 2004), although this relationship between learner control, motivation and exploratory behavior may not lead to better performance. Flowerday and Schraw (2003) found that giving choices to students in learning led to more positive attitude and effort, which is affective engagement in learning, but not cognitive task performance.

The psychological explanation for this link between learner control and intrinsic motivation can be traced to Self Determination Theory (Ryan & Deci, 2000). According to this theory, autonomy, competence, and relatedness are the three most important
factors that contribute to one’s intrinsic motivation to engage in a specific activity and promote autonomous regulation for extrinsically motivated behaviors. According to Ryan and Deci (2000), the sense of control contributes to feelings of autonomy which is one of the three social-environmental factors that sustain or enhance intrinsic motivation.

Csikszentmihalyi (1975) defines intrinsic motivation as a drive from within the self to carry out an activity, from which the reward is derived from the enjoyment of the activity itself. An activity that is just lightly intrinsically motivating can become all-encompassing to the extent that the individual experiences a sense of total involvement, losing track of time, space, and other situational awareness. He refers to this state as a state of flow, or a flow experience.

Intrinsic motivation has been examined in various task domains and learning environments to determine what induces high intrinsic motivation or flow. Features that contribute to flow or intrinsic motivation have been classified into four categories: challenge, curiosity, control and fantasy (Malone and Lepper, 1987). According to this classification, for intrinsic motivation to occur, learner should feel challenge, or a match between the task and his skills. If a task is too hard or too easy, the learner will likely lose interest. In addition, learners should have preferably self-set goals that are possible to attain but with certain level of uncertainty. Curiosity results from situational complexity, and any arousal caused by incongruity and discrepancy. For example sensory curiosity can be evoked by attention-getting features such as the novelty effect of animated content with audio in computer software (Lepper and Malone, 1987), whereas cognitive curiosity is aroused by inconsistencies between what is expected by and what actually occurs to the
learner. It motivates the learner to expend cognitive resources to resolve the inconsistency through exploration. Control, or autonomy in self-determination theory (Ryan and Deci, 2000), is considered as one important factor that enhances the feeling of intrinsic motivation because learners are given a sense of control over choices they may take in learning. Fantasy in the forms of metaphors evokes mental images of situations not actually present and helps learners feel directly involved with objects in the domain so that the computer and interface become invisible.

In computer interface design, a similar concept would be Hutchins, Hollan, and Norman (1985)’s concept of engagement that is used to explain the motivational effects of interaction styles on users. They define engagement as a feeling of working directly on the objects of interest in the world rather than on surrogates.

Both concepts of flow and engagement have been used in the Technology Acceptance Model and found to mediate the effects of interface or interaction style on user performance (Davis and Wiedenbeck, 2001). Generally this paradigm of research suggests engaging or intrinsically motivating learning environment leads to greater perceived ease of use and usefulness, which ultimately contributes to better learning and performance.

Back in the cognitive theory of multimedia learning framework, it is also important to note that concepts such as germane cognitive load and deliberate practice will have positive effects on performance only if learners are motivated to put in the effort. Motivation is thus both a mediating variable and an important constraint on effectiveness (van Gog, et al, 2005). Paas, Tuovinen, van Merrienboer, and Darabi (2005)
argue that both mental effort and performance have cognitive and motivational components, and that learning environment should be coupled with motivation to achieve more meaningful learning. Their study shows that the exploration practice groups demonstrate the highest task involvement, consistent with the common belief that discovery and exploratory learning environments are motivating for learners. They also speculate that prior knowledge and involvement or motivation are also correlated.

Having an exploratory learning task as a comparison to a repetition task can also reflect the different meanings that “time on task” has for the two task types. In repetition task, task completion time will be used strictly as a performance metric, as the participants will be instructed to “finish the task as fast as they can.” In contrast, when exploring or browsing, time on task may be a good indicator of learner’s state of “flow”.

The exploratory learning task also highlights the relevance of the concept “flow” to the study. Given the close interrelationships among flow, control, motivation, and exploratory behavior, there may be a larger chance to observe difference in “flow” between more and less experienced learners in the exploratory task, where participants partially define the learning goal and are encouraged to explore.

H9: Exploratory tasks are more likely to induce intrinsic motivation and flow than rote task.

As stated in Hypothesis 6, learners in the rote task may outperform those in exploratory tasks. Also hypothesized is the advantage of video tutorial over text tutorial in saving cognitive resources. If text tutorial consumes more cognitive resources, novice learners are more likely to be overloaded in an exploratory learning task when they use a
text tutorial than when they use a video tutorial, while experienced learners are less subject to cognitive overload induced by task type (H7). Hence the following hypothesis predicts the interaction of tutorial type and task type.

H10: Retention test performance of learners using video tutorial will be affected by task type to a lesser degree than that of learners using text tutorial.

With the exploratory task, where learners will likely engage in more browsing, there may also be larger chances to find out which presentation media encourages the learner to access more information, as good persuasive technology should do.

RQ1: Will instruction presentation methods affect learners’ exploratory behavior?

For novices working on a rote task, the narrated animation will mainly have a facilitating function in that it might be much easier for them to observe the procedures involved in creating an object or the immediate effect of a certain tool than to perform the corresponding mental simulation on their own with only descriptive text and static pictures. Note the animation has a facilitating function instead of enabling function because the text and static pictures version of the tutorial is designed such that it delivers the same basic information as the animated version and a learner should be able to complete the repetition task without the additional information in the animation. Following the modality principle, presenting verbal information through auditory channel should be another advantage in learning, saving them the cognitive resources that would have been expended in processing text in visual form and allowing them to focus more on the task. In this sense, the animated tutorial may be more efficient and imposes less cognitive load on the novice learners. As a result, novice learners are expected to
complete the repetition task faster and with higher accuracy when they use an animated audio-visual tutorial than when they use a static visual-only version. In contrast, the additional information presented in the animation as well as through the auditory channel might be redundant for an experienced learner. Hence experienced learners using the static visual-only tutorial might outperform their counterparts using the animated AV version due to the diminished facilitating function of animation and the redundancy effect. The motivating effect of animations may not be revealed in a repetition task, with a clearly defined goal and perceived time constraint, learners may be more externally motivated than internally motivated to complete the task. Moreover, there will be little room for the learners to obtain and practice additional knowledge that is not required by this task.

In an exploratory task, the animated tutorial may have a primarily enabling function for both novice and experienced learners. This is based on the assumption that animated tutorials are more interesting, motivating, and expressive, i.e. able to show all the details of the “fanfares” of the tools and effects in the software that would otherwise be impossible to convey through the use of text and static images. One of the consequences of increased motivation is more exploratory behavior, which will result in longer time on task. If overall performance is characterized by the amount of tutorial viewed, number of tools and features of the software tried, and creative use of the combination of the tools and features in the final product, both novice and experienced learners are expected to perform better when they use the animated AV version of the tutorial.
Relationship between Pattern of Instructional Material Use and Learning Outcomes

This study will also yield descriptive data on how learners actually use the learning material in repeated practice. For example, the performance difference might be attributable to the frequency and timing of use of the stimulus tutorials, and the patterns of use within high-performance and low-performance subjects may further differ within each group when learners are working on different types of tasks. Process-tracing methods such as click stream could be used to capture differences between novice and experienced learners during practice, as this data might help researchers better understand the mechanisms that underlie schema acquisition (van Gog, et al, 2005).

In the paradigm of multimedia learning research, many studies compare multimodal and animated presentations to static uni-modal presentations that teach primarily declarative knowledge such as formation of lightning and helicopter lifting that do not require hands-on practice (e.g. Mayer and colleagues’ studies in multimedia learning). In most of these studies, participants are allowed one-time access to learning material followed by retention and transfer tests that consist of paper-and-pencil questionnaires. Such measures of learning outcomes have an inherent limitation in that learning does not stop after initial study and practice.

Repetition and innovation are two important means for skill improvement (Lesgold, 1984). Software training in particular requires repetition, often encouraging students to review instructional material more than one time to consolidate and further automate their skills. This study allows the subjects to go back to the learning material to
simulate authentic learning situations. Process data that pertain to how instructional materials are used provide valuable insights where repeated use of the learning material is allowed and even encouraged.

Finally, knowing more about the processes in actual use of instructional material helps us make recommendations on types of presentation appropriate for learners with different level of prior knowledge, for different tasks or training purposes.

There are alternative explanations for learners’ “unexpectedly” low use of multimedia, interactive content in Pane, Corbett and John (1996)’s study. First, only “high achievement” students who were considered highly motivated were included for the study. Videos and animated simulations might work differently for another group of learners, who have little or zero background knowledge, and are not highly motivated. Second, software system only logged how often movies and simulations were played, no corresponding data were obtained about use of static text and graphics, hence it was impossible to compare students’ use of static content to their counterparts’ use of multimedia content. Lastly, the multimedia system used in Pane et al (1996)’s study was designed to deliver declarative knowledge. In software training, however, most of the videos or animated presentations are about procedural knowledge, showing steps that learners will need to follow and repeat when performing training tasks. Although participants in their study did go back to review the content when answering test questions, a repetition or procedural task that serves as a retention or transfer test in software training is still different in several ways than a question designed for a declarative knowledge retention or transfer test. Hence the pattern of use of instructional
material for a different type of task in a different domain may offer different insights. A research question related to the use of instructional material arises:

RQ2: How is the use of instructional materials, characterized through click-stream data, associated with performance and other learning outcomes?

In summary, the research questions and hypotheses of this study are:

H1: Overall, learners using video tutorial experience less cognitive load than those using text tutorial.

H2: Learners using video tutorial will perform better on the retention test in comparison to learners using text tutorials.

H3: Overall learners using video tutorial experience higher intrinsic motivation than those using text tutorial.

H4: High prior experience learners experience less cognitive load with static text and illustrations than with narrated animation; low prior experience learners experience more cognitive load with static text and illustrations than with narrated animation.

H5: Learners with more prior experience perform better on retention test with static text and illustrations than with narrated animation; learners with less prior experience perform better on retention test with narrated animation than with text and illustrations.

H6: Overall, rote task will lead to better performance on the retention test than exploratory tasks.
H7: Novice learners will experience higher cognitive load in exploratory tasks than in rote task, while task type will have less impact on the cognitive load of experienced learners.

H8: Novice learners in rote task will perform better on the retention test than novice learners in exploratory tasks, while performance of experienced learners will suffer less than that of novice learners in exploratory tasks.

H9: Exploratory tasks are more likely to induce intrinsic motivation and flow than rote task.

H10: Retention test performance of learners using video tutorial will be affected by task type to a lesser degree than that of learners using text tutorial.

RQ1: Will instruction presentation methods affect learners’ exploratory behavior?

RQ2: How is the use of instructional materials, characterized through click-stream data, associated with performance and other learning outcomes?
CHAPTER 3

METHOD

Design

This study uses a 2 (Tutorial Type: text and static images vs. animated pictures with narration) x 3 (Task Type: rote vs. exploration without tips vs. exploration with tips), experimental design.

Both Tutorial Type and Task Type are between-subject factors. The manipulation of Tutorial Type is reflected in two types of tutorials, each presenting the instructional material using a different media: static text with graphic illustrations, versus animated pictures with narration (see Figures 3.1 – 3.6 for screen shots from the two versions of tutorials). Participants were then randomly assigned to one of six conditions, using one of the two tutorials to complete a rote task, an exploratory learning task, or an exploratory task with additional instructional content. The extra instructions in the stimuli for Explore with Tips conditions are labeled “tips” which introduce advanced or additional features with examples. This manipulation is considered to be a “scaffolding” function of the instructional content. The Task Type manipulation is also reflected in the task instructions (see Figures 3.7 – 3.10 for screen shots of the instruction pages).
3c) Now, we want to add a bit more pink to bring in some pastels. To do this, we add one more anchor point to the gradient.

Click on the Fill color box to bring up the gradient editing panel. Roll mouse under the gradient bar. When cursor becomes ✧, click to add the anchor point. Click on the added point to select pink #FF69B4 on the palette. Press Enter to apply.

(To delete an anchor point on the gradient, click on it and drag it off the gradient editing panel.)

3d) After the two pink colors are selected, the rectangle takes on a fantastic gradient fill. Click off of the rectangle and the gradient handles will disappear.

It is a common technique to use gradient effect plus different highlight colors to create such 3-D gel look and feel.

*Figure 3.1: Tutorial page – static images with text, without tips*
3c) Now, we want to add a bit more pink to bring in some pastels. To do this, we add one more anchor point to the gradient.

Click on the Fill color box to bring up the gradient editing panel. Roll mouse under the gradient bar. When cursor becomes +, click to add the anchor point. **Click on the added point to select** \#F8F6FF on the palette. **Press Enter to apply.**

(To delete an anchor point on the gradient, click on it and drag it off the gradient editing panel.)

3d) After the two pink colors are selected, the rectangle takes on a fantastic gradient fill. Click off of the rectangle and the gradient handles will disappear.

It is a common technique to use gradient effect plus different highlight colors to create such 3D gel look and feel.

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**Tip 1:** By the way, you can use the gradient handles and its origin point to further manipulate the gradient.

**Tip 2:** Want to create those fancy fill effects? Try the following gradients...

---

*Figure 3.2: Tutorial Page – Static Images with Text, with Tips*
Tip 1:
By the way, you can use the gradient handles and its origin point to further manipulate the gradient.

Here's how:
Right now the origin point of the gradient is at the center of the rectangle. Click and drag it to the left, or even off the canvas, to see how the rectangle moves and flows from this point.

Then adjust the length, or the ending point, of the gradient by clicking and dragging the squares at the end of the handles:

Did you notice that you can also rotate the handle by dragging it towards any direction? You can move the origin point after adjusting the handles too. That's right, you can get some crazy effect if you do both.

Figure 3.3: Text Tip Expanded
Step 1: The Background Rounded-Rectangle and Gradient Effect

1) Rounded Rectangle

2) Fill and Stroke Colors

3) Starburst Gradient

Step 2: Doughnut Shape and Fill Texture >>

Figure 3.4: Tutorial Page – Animated Pictures with Narration, without Tips
2) **Fill and Stroke Colors**

3) **Starburst Gradient**

**Tip 1:** Use the gradient handles and its origin point to further manipulate the gradient.

---

*Figure 3.5: Tutorial page – Animated Pictures with Narration, with Tips*
Participants

Participants were 153 college students from a large Midwestern university. There are 48 (31%) males and 105 (69%) females in the sample. The majority (71.1%) of the participants had minimal to some prior knowledge in the task domain pertaining to this study, according to their self-reported familiarity (≤ 4 on a 7-point scale) with design concepts and prior use of two popular software programs in graphic design. These participants were recruited from introductory Communication classes. The rest of the
sample (28.9%) was composed of students recruited from introductory Visual Communication classes and learners who had received training related to the task domain in similar classes, with a self-reported prior experience of above 4 on a 7-point scale. Participants were recruited from these different classes with the goal of obtaining some variance in expertise level to test hypotheses about the effects of Prior Experience.

**Stimuli and Task Instructions**

*Tutorials.* Macromedia Fireworks 8, Dreamweaver 8, Flash 8 and Captivate 3 were used to create the tutorials. Some content of the tutorial was adapted from Fireworks 8 online help system, training videos published on Lynda.com, other tutorials online for Fireworks (e.g. http://www.playingwithfire.com/), as well as existing tutorials developed for an introductory Visual Communication course. The tutorial focused primarily on procedural knowledge about how to use certain tools in the software to achieve certain effects, with some introduction to basic concepts in visual design. Specifically, the tutorial introduced fill and stroke colors and options for shapes and fonts. The tutorial began with a simple practice of the shape tool, introduced fill and stroke colors, then gradually added changes to the look of the shapes using gradients, patterns, opacity levels and other creative combinations of tools, and ended with some similar effects for text. The final product is an image composed of two shapes and some text, all of which with fill and stroke colors, patterns and gradient effects, and different opacity levels.
The tutorial stimuli in this study were created in Captivate 3.0, a software program that automatically generates the anchors for each slide created. Hence with simple instruction and after brief initial interaction, participants learned how to jump to key steps without having to fumble through the whole video using the progress bar. The animation plays at a rate of 30 flash frames per second and is smooth enough to be comparable to a training video that has a higher frame rate. Therefore in data analysis and the following discussion, the animated version of tutorial is referred to as “video” in a simplified term.

Two versions of tutorials with close-to-identical content were created. The major differences between the two versions lie in the different types of delivery method and availability of optional content. One version is presented with static text and graphic illustrations; the other, animated pictures with narrated text. Both versions of the tutorial delivered the same content that includes information relevant to both rote and exploratory tasks.

The images in the static mode are screen captures taken from the narrated animation. All of these images correspond to an intermediate step or concept to be explained. In the animated presentation, the narrated text was a close adaptation from the text in the static mode. By nature, the audio-visual materials give more information about the process or procedures. In this experiment, the audio-visual stimulus was carefully designed to match as closely as possible the static presentation in terms of content without extraneous social and emotional indicators such as narrator accent, exaggerated intonations or humorous comments.
For both versions of the tutorial, the instructional content was chunked into three major segments, each explaining either an important feature of the software or an important concept in visual design. The three-part tutorials are displayed in a browser window, beginning with an introduction page that gives out the task instruction, followed by instructional content on three separate pages. Links to the introduction page and the key steps are listed in the navigation area on both the top and the bottom of the page.

It has been recommended that user manuals include full screen images and present instructions and images side by side in a left-to-right reading order to shorten training time and enhance retention for computer programs such as word processing (van der Meij, 2000). The full screen images of the full view of software interface provide consistent contextual cues that serve as the frame of reference for the trainee. Placing the corresponding text instruction and graphics side by side is also in accordance with the “Contiguity Principle” that may reduce extraneous cognitive load (Clark & Mayer, 2003).

However, despite the benefits of full screen images and the side-by-side page layout, this finding could not serve as a complete guide for the design of the static text-image tutorial in this study. Presenting both full screen images and text instruction side by side would enlarge the tutorial browser window considerably and may reduce readability. To ensure content contiguity and reduce split attention, in the static text-image tutorial, when tools or features of the software were introduced the first time, full screen images were used. Then the instructional support – in this case the rest of the interface or ambience – gradually faded in the illustrations and only focused on the tools or features. All text instructions in the text-image version of the tutorial were placed
immediately above the corresponding graphic illustrations. In the animated version, however, most of the clips showed the full view of the software interface so participants could have a consistent frame of reference throughout the tutorial. This was one of the key differences between the text and animated stimuli.

Task Instructions. The task was designed so that it is not too complicated to perform for the novice learners. On the other hand, it should not be so basic that the more experienced learners will not even need to use the tutorial to complete the task. In other words, if the task is too difficult, cognitive load imposed on the learner is so high that it exceeds the maximum capacity of the learners; if it is too simple, the cognitive load will be so low that even in a poorly designed learning environment, both experienced and novice learners can complete the task without investing much mental effort. In either case, it will be hard to detect any effect on performance or learning outcome due to the experimental factors.

The task instructions are essentially the same for conditions within each Task Type, regardless of tutorial presentation type. The rote task in this experiment used the tutorial as a worked-out example that provided the whole solution. All that the participants needed to do was to follow the steps in exactly the same order, and execute the commands in exactly the same way, to produce the same image as in the tutorial. In the text version of the tutorial, task instruction was provided on the introduction page along with the finished sample graphic (Figure 3.7). In the animated tutorial conditions, the task instruction was provided in a video clip, so the introduction pages for all three types of tasks in the animated tutorial conditions looked the same. Participants were
given the opportunity to familiarize themselves with the video playback controls in the popup window when as they viewed the instruction clip.

The exploratory tasks had a relatively loosely defined goal. They encouraged the participants to use the tutorial as a reference tool to explore on their own. In the two exploratory tasks conditions, repetition of the steps in the tutorial was not mandatory; the participants were free to decide how much to explore, and how much or which instruction to follow. Participants were instructed to create an image of their choice, using the tools and features introduced in the tutorial in creative combinations. In the Explore-with-Tips condition, participants were instructed to take advantage of the “cool extras” presented in the tips and explore beyond the requirements of the core task.

![Welcome to the Fireworks Tutorial!](image)

Figure 3.7: Task Instruction – Rote, Text
Task instruction

1. Welcome! This tutorial shows you how to create "eye candy" - you have probably seen similar graphical decorations on your favorite websites. Now it is your turn to create one for your own website: myname.com.

2. This tutorial is here to help, but at the same time, try to explore on your own - your final graphic should look different from the one below, and should contain: 1) at least two shapes; 2) some text, all with some fill colors and effects.

Explore the features and do something different every step!

Enter your ID  Start

Figure 3.8: Task instruction – Explore, Text
Welcome to the Fireworks Tutorial!

**Task instruction**

1. Welcome! This tutorial shows you how to create “eye candy” - you have probably seen similar graphical decorations on your favorite websites. Now it is your turn to create one for your own website: myname.com.

2. This tutorial is here to help, but at the same time, try to explore on your own - your final graphic should look different from the one below, and should contain: 1) at least two shapes; 2) some text, all with some fill colors and effects.

3. Also, as you progress through the tutorial, remember to use the Power Learner Tips that provide cool visual effects that can make your design interesting.

   Click on the ⚪️ to expand the Power Learner Tips, and discover the exciting “extras”!

---

**Figure 3.9:** Task instruction – Explore with Tips, Text
Procedures

The experiments were conducted in a PC computer lab. Participants signed up for sessions online and arrived in groups of 5-13. All participants viewed the tutorials in Internet Explore 6, and used the software application Macromedia Fireworks 8 to create the graphics on computers running Windows XP. Participants assigned to the animated tutorial with voice-over conditions used headphones when viewing the tutorial.

Prior to the lab session, participants were asked to fill out the pre-test questionnaire with measures of learning style, prior experience in graphic design and related software, preference for Tutorial Type, and general interest in the subject of this
study. Participants were sent a link to the online questionnaire in a reminder email a day before their lab session.

When they signed up for the study, participants were randomly assigned to one of six conditions, using either text or animated version of the tutorial to complete one of the three tasks: Rote, Explore, or Explore with Tips. With random assignment done before the experiments, only participants from the same condition would come to each session so that the experimenter could give the same instruction to all participants in that session, making the experimental manipulation of Task Type easier and more effective. The task instructions were critical in the manipulation of task types, hence it was important for the experimenter to reiterate, and elaborate if necessary, the instructions to the participants at the beginning of the experiment.

Upon arrival, participants were seated with at least one vacant seat between each other. The experimenter then introduced the procedures of the study which included two parts: a learning task in which the participants would use the tutorial to create a graphic, and a second task in which they would create a graphic on their own, without access to the tutorial. The participants were told that the second task was not a test for them, but rather a test for the designers who created these tutorials and wanted to see how well the tutorials helped students understand the software. Participants hence were informed of a “test” after the tutorial but were not given the details about what graphic they would have to create for the test.

The experimenter first read the task instructions out loud before participants clicked on the Start button on the introduction page to begin the learning task. After the
learning task, participants continued to fill out the first post-test questionnaire in the same browser window that the tutorials are displayed, by following the Evaluation link at the end of the tutorial.

After they finished post-test 1, they were directed to a screen with instructions to “Pause” and “Let the researcher know that you have come to this page.” The participants should then signal to the experimenter who would come to their seat, save and close their graphic file created during the tutorial, and set up a new canvas for them. The participants then clicked on a link on the “Pause” page to go to the second task of this study. In the second part of the study, participants were asked to re-create the same graphic as shown in the tutorial, which is in essence a retention test. Figure 3.11 displays the test instruction page that also includes a few hints for completing the task. It is not uncommon to use instructions in the same format for retention and transfer tests across conditions of different presentation media. For example, Mautone and Mayer (2001) studied the effectiveness of signaling as a cognitive guide in three media environments: printed text, spoken text and narrated animation. They asked participants to answer the same set of questions on paper for retention and transfer tests for all three media environments. Similarly, Moreno and Mayer (2002) used the same paper-and-pencil questionnaires for retention and transfer tests following each of the three experiments which employed multimedia stimuli ranging from static text and images to narrated animations. In the retention test, participants were instructed to re-create the same graphic shown in the tutorial. Since this graphic only requires knowledge of the essential features and procedures introduced in the core task in the tutorial, none of the tip content was tested.
Without access to the tutorial, try creating the graphic below. It is the same one as shown in the tutorial. Try your best for both speed and accuracy. Use the techniques you have learned in the tutorial to make your graphic look as close to this sample graphic as possible, and finish as fast as you can.

Hints:

- Colors used in the gradient fill are: pink #993366, lighter pink #FF66FF, and black.
- Rounded rectangle opacity = 25; Doughnut shape opacity = 60.
- Text Fill Texture is "Grid 4" at 50%; stroke Tip size = 5.

Don't worry if you don't know the exact sizes or colors used in the example. Just pick the ones that look closest to those in the graphic below.

Come back to this page and click on the link below, when you think you've done the best you can to complete this task.

Click on this link to answer the last few questions and finish up!

---

**Figure 3.11:** Retention Test Instruction Page
During the study, links within the tutorial and on the instruction pages that participants clicked on, along with corresponding time tags, were logged by a computer program so that the tutorial usage and the time that participants spent working on the learning task and retention test could be inferred from the click-stream data log.

**Measures**

Pre-test questionnaire captured a number of constructs. Except for Prior Knowledge which was intended to be used as a covariate and was a key variable in the analysis, all other measures in the pre-test were essentially control variables.

*Demographics.* Information about participants’ gender, major, and year in college were collected in the pre-test questionnaire.

*Prior Experience.* Prior Experience was used as a covariate in the General Linear Model analysis. Subjective ratings were collected on the frequency of use and familiarity with software imaging tools and some common concepts in graphic design that are covered in the stimulus tutorial. Each of the prior experiences was measured with either a 7-point scale that follows a question “How familiar are you with …” using anchor points “I’m a complete novice – I have some experience – I’m an expert” corresponding to 1, 4 and 7 on the scale, or “how often do you use …” using anchors “Never – Occasionally – Sometimes – Often– Frequently” corresponding to 1, 2, 4, 6, and 7 on the scale. The ratings on these scales were then tallied into a composite measure, representing participants on a continuum from novice to experienced learners.
Computer Self-Efficacy. Participants also rated their agreement with several statements about their general computer self-efficacy, including “I feel nervous when dealing with new computer interfaces”, “I learn new software programs quickly”.

Preference for Learner Control. Two 7-point Likert scales, “follow instructions – do what I’m told to do” and “explore on my own” following the question “When I’m learning, I would like to –”, were used to measure participants’ preference for learner control. Preference for learner control may overlap with some items in Field Dependency in Kolb’s Learning Style Inventory (1976, 1999).

Preference for Tutorial Type. Participants were asked about their instruction media preference in when learning in general and when learning to use new graphic design software. Between narrated animation and static text and illustration. The two options are “Static images with print text” and “Videos with narration,” on a 7-point scale (1 = Strongly Prefer, 2 = Somewhat Prefer, 3 = Slightly Prefer, 4 = No Preference, 5 = Slightly Prefer, 6 = Somewhat Prefer, 7 =Strongly Prefer).

Learning Style Inventory. Kolb’s Learning Style Inventory was used to categorize participants into one of the following four types of learners: Concrete learners, Abstract learners, Reflective observers, Active experimenters (Kolb, 1999).

Motivation. In the pre-test, general motivation and relevance of the study to the participant were measured with items such as “Learning how to use a software program is fun,” “I enjoy working with graphics,” and “I chose to participate in this study because I am interested in the topic of this study” on 7-point Likert scales (1 = Strongly disagree, 7 = Strongly Agree).
*Time on Task.* The amount of time participants spent working on the learning task was calculated using the time tags logged by the browser. Before the task, participants were given task instructions and did not have access to the tutorial until they clicked on a “start” button when they were ready. They worked on the task using the tutorial till they thought they had finished the task or had done their best to do so. After clicking on the Finish button to quit the task, participants continued on to the first post-test questionnaire. During this whole process, all the links that participants clicked were logged by a software program.

*Navigational Behavior / Exploratory Use.* Links and tips clicked during tutorial with corresponding time tags were logged by software program.

Immediately after learning task was the first part of the post-test questionnaire which included measures of cognitive load / task difficulty, measures of flow, Task Type manipulation check, intrinsic and continuing motivation, satisfaction with learning experience, perceived ease of use and other attributes of the tutorial.

*Cognitive Load.* Subjective ratings of task difficulty have been used extensively by researchers and have proved to be reliable measures of cognitive load (Clark, Ayers, & Sweller, 2005; Kalyuga, Chandler, and Sweller, 2000; Mayer & Chandler, 2001; Paas, Tuovinen, Tabbers, & van Gerven, 2003; Paas & van Merrienboer, 1993, 1994). This easy-to-implement method to measure cognitive load was selected for this study because it is less intrusive on primary task performance compared to other methods such as dual-task method (Brünken, Plass & Leutner, 2004).
In this study, participants were asked “How difficult was it for you to…” with two endings: “complete this task” and “understand the tutorial,” both measured with a 7-point scale (1 = Very easy” 4 = Just about right, 7 = Very difficult). Two other items, “this task involves too many steps”, “it takes too long to complete this task” measured with 7-point scales (1 = Strongly Disagree, 7 = Strongly Agree) were used in combination with the task difficulty and complexity scales as measures of cognitive load.

**Learner Control / Task Type Manipulation Check.** Participants were asked how much control over their learning experience they thought they had received. This may overlap with items measuring perceived control in the items used to measure Flow.

**Flow.** Measures of flow are adapted from Ghani and Deshpande (1994) with 15 questions measuring the five components of flow experience as Pleasure, Concentration, Control, Exploration, and Challenge. Immediately following the learning task, participants rated their feelings during the task they just completed.

**Continuing Motivation.** Slightly different from the measure of continuing motivation used in the Rieber (1991) study, which asked the participants to choose one out of three comparable activities and actually finish the chosen activity, this study measured continuing motivation with items including “Would you like to learn more about Fireworks?”, “Would you like to practice more with the techniques introduced in the tutorial?”, and “Would you like to view more tutorials like the one you just used?”, all measured with 7-point scales (1 = Not at all, 7 = Very much; adapted from Reisslein et al, 2005).
Tutorial Affordances and Ease of Use. Perceived helpfulness of tutorial content was measured by “The tutorial was helpful” and other items measuring perceived ease of use and usefulness of the tutorial adapted from Davis and Wiedenbeck’s study (2001), such as “The overall content of tutorial was easy to learn” “The tutorial was easy to use.” “The tutorial was confusing” (reverse coded), and “I was able to get the information I needed from the tutorial.”

Satisfaction with Learning Experience and Outcome. Subjective ratings of satisfaction with learning experience were collected with 7-point scales using items “Overall, how satisfied are you with this experience of learning how to use this software?” “Overall, how satisfied are you with your performance on the task?”

Task Specific Self-Efficacy. The self-efficacy scale is adapted from Compeau and Higgins’ (1995) computer self-efficacy scale and includes 8 items. Participants rated these items such as “I can complete a similar task using Fireworks if there is no one around to tell me what to do as I go” on an 11-point scale (0 = Absolutely cannot, 1 = Not at all confident, 5 = Moderately confident, 10 = Totally confident).

Retention Test Performance. Both accuracy and speed are indicators of retention test performance. A 10-point grading scheme was used to assess the quality of the graphic that participants created during the retention test. Points were allocated to the shapes created, fill gradient and colors used in the gradient, type and amount of fill texture, opacity levels, text fill color and texture, text stroke color and tip size. The resulting score is used as the accuracy measure. The amount of time that participants spent working on the retention test is used as the speed measure.
CHAPTER 4

RESULTS

The Statistical Package for Social Science, version 16 was used in all data analysis. Hypotheses and research questions were tested using General Linear Model (GLM) and a 2 (Text vs. Video) x 3 (Rote vs. Explore vs. Explore with Tips) design. While this model was central to the data analysis efforts, different covariates were introduced depending on the dependent variable of interest.

Individual Differences

Prior Experience with Design Software. The key individual difference variable used as a covariate was prior experience. Nine items were used to tap this construct. Two items on prior experience with two software applications, Fireworks and Photoshop, as well as 7 items on familiarity with specific graphic design concepts were used as the composite measure of Prior Experience (Cronbach’s $\alpha = .94$) by averaging the individual items ($M = 3.18, SD = 1.58$). This composite measure of prior experience was correlated with the “how often do you use a software application to create graphics” on a 7-point scale ($1 = $Never, $7 = $Frequently), $r(149) = .69, p < .01$. Table 1 displays the inter-item correlation matrix for Prior Experience.
<table>
<thead>
<tr>
<th>Items</th>
<th>Item 1</th>
<th>Item 2</th>
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<tr>
<td>3. Text tool</td>
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<td>4. Shape tool</td>
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<tr>
<td>5. Fill and Stroke colors</td>
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<td>0.89</td>
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<td></td>
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<td>6. Gradients</td>
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<td>0.59</td>
<td>0.72</td>
<td>0.78</td>
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<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>7. Textures</td>
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<td>0.72</td>
<td>0.78</td>
<td>0.75</td>
<td>0.91</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Transparency / Opacity</td>
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<td>0.67</td>
<td>0.65</td>
<td>0.75</td>
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<tr>
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<td>0.66</td>
<td>0.83</td>
<td>0.85</td>
<td>0.81</td>
<td></td>
</tr>
</tbody>
</table>

Note. * All correlations are significant at the 0.01 level.

*Table 4.1: Prior Experience Scale Correlation Matrix

Learning Style – Observer vs. Experimenter. Kolb’s learning Style Inventory (1999) was used to classify learners into two types, active experimenters and reflective observers, based on their scores along the active experimentation (AE) – reflective observation (RO) dimension. The AE – RO dimension is relevant to this study’s Task Type manipulation (see similar classification in Liegle and Janicki, 2006). Using Kolb’s method to combine the scores, by subtracting RO scores from AE scores, 30% of participants in this study can be classified as observers and 64% were explorers. Five participants showed a balanced orientation towards active experimentation and reflective observation. None of the reviewed studies using Kolb’s Learning Style Inventory
explained how learners with a balanced learning style were treated in the data analysis. It seems such learners would have to be excluded from analysis if not forced into either group. Therefore these learners with a balanced AE – RO learning style were excluded from the analysis. To examine whether the AE – RO dimension of learning style can have any effect on learning outcomes, Learning Style was introduced as a third factor in addition to Tutorial Type and Task Type. Using a 2 (Text vs. Video) x 3 (Rote vs. Explore vs. Explore with Tips) x 2 (AE vs. RO) three-way ANOVA, effects of learning style on cognitive load and retention test performance were examined. No significant effect of AE – RO learning style was found.

*Learner Preference – Tutorial Type.* On a 7-point scale (1 = Strongly prefer static images with print text, 4 = No preference, 7 = Strongly prefer videos with narration), participants rated their preference for tutorial type when “learning to use new graphic design software” and “learning in general.” These two items, which were correlated, \( r = .53, p < .01 \), were averaged to create a composite score for Learner Preference (\( M = 3.97, SD = 1.54 \)), which was used as the second covariate in the analyses.

*General Motivation.* Participants’ general interest in the study and domain of graphic design was measured with four items in the pretest: “Learning how to create graphics in a software program is useful,” “I chose to participate in this study because I am interested in the topic of this study,” “I enjoy working with graphics,” and “Learning how to use a software program is fun.” The items were evaluated on a 7-point scale (1 = Strongly Disagree, 7 = Strongly Agree). The items were significantly correlated with one another and the Cronbach’s \( \alpha = .86 \).
Correlation Among Individual Differences. Correlation between Prior Experience and General Motivation was significant, $r = .39$, $p < .01$, indicating that learners with more experience were more interested in the topic of this study. To ensure comparable distribution of individual differences across the different conditions, each of the four individual difference variables discussed in this section were submitted to a separate 2 (Text vs. Video) $\times$ 3 (Rote vs. Explore vs. Explore with Tips) ANOVA. Though Prior Experience and General Motivation were slightly higher in the Text conditions than in the Video conditions (see Table 2), there were no statistically significant differences between experimental conditions for any of these individual differences. These findings are encouraging because findings related to the dependent variables can be interpreted with the confidence that they are not confounded by the unequal distribution of individual differences.
Table 4.2: Individual Differences by Experimental Condition

<table>
<thead>
<tr>
<th>Prior Experience</th>
<th>Text</th>
<th>Video</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Rote</td>
</tr>
<tr>
<td>M</td>
<td>3.48</td>
<td>3.65</td>
</tr>
<tr>
<td>SD</td>
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<td>1.59</td>
</tr>
<tr>
<td>AE, RO*</td>
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<td>47</td>
</tr>
<tr>
<td></td>
<td>RO</td>
<td>20</td>
</tr>
<tr>
<td>Tutorial Type Preference</td>
<td>M</td>
<td>4.04</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.66</td>
</tr>
<tr>
<td>General Motivation</td>
<td>M</td>
<td>4.58</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>1.53</td>
</tr>
</tbody>
</table>

Note. *Frequencies are displayed for AE – RO learning style.

Learner Control / Task Type Manipulation Check

The Rote, Explore, and Explore with Tips tasks in this study should afford increasing degrees of learner control, in that the exploratory tasks and extra instructional content in the form of tips allow learners to make more instructional decisions as to what and how they learn. Four items in the post-test that immediately follows the tutorial learning phase were used to check the effectiveness of the Task Type manipulation: the task – “gives me plenty of freedom to explore,” “encourages me to be creative,” “requires strict repetition of steps introduced in the tutorial (reverse coded),” and “leaves little room for experimentation with the tools and features of the software (reverse coded).”
Ratings for these items are averaged to produce the composite measure of Learner Control (Cronbach’s $\alpha = .73$).

A 2 (Tutorial Type: text or video) x 3 (Task Type: rote or explore or explore with tips) ANCOVA, with Prior Experience and Learner Preference of Tutorial Type as covariates, was examined to test the effects of the experimental factors on Learner Control. Main effect of Task Type was significant, $F(2, 139) = 21.28, p < .001$. Simple comparisons reveal that Rote task ($M = 3.73$, $SD = 1.20$) affords less learner control than the other two types of tasks, Explore ($M = 4.90$, $SD = 1.03$) and Explore with Tips ($M = 5.07$, $SD = 1.26$). The differences between the Rote and the Explore tasks were significant at $p < .01$, whereas the difference between the two Explore tasks was not significant. In short, as expected, the explore tasks offered more learner control than the rote task, though there was no difference between the Explore and Explore with Tip condition.

No manipulation check was performed for the Tutorial Type factor, since the treatment difference between the factor’s two levels, text or video, is self-explanatory and sufficiently evident.

<table>
<thead>
<tr>
<th></th>
<th>Task Type Manip Check</th>
<th></th>
<th></th>
<th>E + Tips</th>
<th></th>
<th></th>
<th>E + Tips</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total</td>
<td>Text</td>
<td>Video</td>
<td></td>
<td>Text</td>
<td>Video</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Rote</td>
<td>3.63</td>
<td>4.76</td>
<td>4.97</td>
<td>4.49</td>
<td>4.75</td>
<td>4.98</td>
</tr>
<tr>
<td></td>
<td>Explore</td>
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<td>3.63</td>
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<td>4.97</td>
<td>3.75</td>
<td>4.98</td>
</tr>
<tr>
<td></td>
<td>E + Tips</td>
<td>4.97</td>
<td>4.75</td>
<td>4.98</td>
<td>5.23</td>
<td>4.98</td>
<td>5.23</td>
</tr>
</tbody>
</table>

Table 4.3: Task Type Manipulation Check Using Learner Control as the DV
Dependent Variables

Cognitive Load. Participants rated whether “This task involves too many steps,” and “This task takes too long to complete,” on a 7-point scale (1 = Strongly Disagree, 7 = Strongly Agree). They were also asked “How difficult was it for you to complete this task,” and “How difficult was it for you to understand the tutorial,” on a 7-point scale (1 = Very easy, 7 = Very difficult). These four items are used to construct the composite measure of Cognitive Load (Cronbach’s $\alpha = .87$). Hence the higher the averaged rating, the higher cognitive load a participant experienced when learning the tutorial.

When Cognitive Load was entered as the dependent variable in the Tutorial Type X Task Type two-way ANOVA, with Prior Experience and Learner Preference of Tutorial Type as covariates, the main effect of Tutorial Type was significant, $F(1, 140) = 14.38, p < .001$, partial $\eta^2 = .09$. This result shows that static images with print text imposes higher cognitive load ($M = 3.26, SD = 1.45$) on the learner than does animated images with narration ($M = 2.51, SD = 1.29$) in a graphic software training context. Hence hypothesis 1 is supported. Although the effect of Task Type is only near significant, $F(2, 140) = 2.83, p = .06$, partial $\eta^2 = .04$, the pattern of results suggests that the Explore task is less cognitively demanding ($M = 2.36, SD = 1.09$) than Rote ($M = 2.88, SD = 1.45$) and Explore with Tips tasks ($M = 3.12, SD = 1.45$). In light of the Tutorial Type main effect, click-stream data from the text and video Explore with Tips conditions were examined and revealed that the Text group did not explore more than the video group ($M_{text-exploreTips} = 2.71, M_{video-exploreTips} = 3.45, p > .05$).
The effect of Prior Experience on Cognitive Load was significant, $F(1, 140) = 20.41, p < .001$, partial $\eta^2 = .13$. However, the target interaction between Prior Experience and the experimental factors (hypothesis 4 and hypothesis 7) was not significant. Not surprisingly, Prior Experience is negatively correlated to Cognitive Load ($r = 0.29, p < .01$), suggesting that the task imposes less cognitive load on the more experienced learners during tutorial learning phase. An additional item “I tried my best in this task” was used as a corroborating measure. A significant effect of Task Type on this item was found, $F(2, 139) = 7.34$, partial $\eta^2 = .10, p < .01$. Simple main effect comparisons using Least Significant Difference method showed that participants in the Rote task conditions perceived themselves to have tried significantly harder than those in the Explore with Tips conditions.

Figure 4.1: Cognitive Load by Experimental Condition
Table 4.4: Cognitive Load, Time on Tutorial, Time on Retention Test, and Retention Test Score by Experimental Conditions

Retention Test Performance. Speed and accuracy are two aspects of retention test performance. When a participant clicked on a hyperlink or a button in the tutorial website, a tracking program captured the clicks together with a time tag. Time on task during tutorial learning phase and time spent on retention test were calculated by subtracting the time of the click on the start link from the time of the click on the end link.

The time participants spent on task during tutorial learning phase ranges from 8.75 to 46.17 minutes ($M = 21.66, SD = 7.82$). It took the participants an average of 8.35
minutes ($SD = 4.07$) to finish the retention test, ranging from as short as 3.08 minutes to 35.02 minutes.

Time on task can have multiple implications for cognitive load, flow, and performance measures. An excessively long time spent on task could mean frustration and difficulty in completing the task. On the other hand, it could be an indicator of flow and high level of intrinsic motivation, when the learner is deeply absorbed in the task and becomes unaware of the passing of time. A very short time spent on task can also have two implications: lack of interest in the task, or easiness in completing the task. In the Tutorial Type x Task Type ANCOVA on retention test time, time spent on tutorial is used as a covariate to control for its effect, in addition to the aforementioned two covariates.

Tutorial Type main effect was significant, $F(1, 127) = 4.06$, partial $\eta^2 = .03, p < .05$, favoring Video ($M = 7.81, SD = 3.21$) over Text ($M = 9.10, SD = 4.91$), yielding partial support for hypothesis 2 that predicts better performance with video than with text. In addition, the main effect of Task Type was also significant, $F(2, 127) = 3.45$, partial $\eta^2 = .05, p < .05$. Simple main effect comparisons using least significant difference (LSD) show that learners in the Rote Task finished the retention test faster ($M = 7.18, SD = 2.58$) than those in the Explore Task ($M = 9.26, SD = 5.58$), providing partial support for hypothesis 6 that predicts better performance with rote task than with the exploratory tasks.
The retention test graphics were evaluated for accuracy and a score was assigned to each participant’s graphic based on a 10-point grading scheme ($M = 7.60$, $SD = 2.52$). Inter-coder reliability was calculated based on two coders’ grading of 25% of the total graphics (Krippendorff's Alpha = .95). Sample graphics with corresponding scores are shown in Figures 4.3, 4.4, and 4.5.
Figure 4.3: Sample Graphic, Retention Test Score = 2.

Figure 4.4: Sample Graphic, Retention Test Score = 6.
When test accuracy was entered as a dependent variable, time on retention test was added as a third covariate in the Tutorial Type x Task Type ANCOVA, to control for the benefits in accuracy. Time on test was controlled for to account for the tradeoffs between speed and accuracy. Main effect of Task Type was significant, $F(2, 130) = 4.35$, partial $\eta^2 = .06$, $p < .05$. Simple main effect comparisons showed that the Explore with Tips task led to lower retention test scores ($M = 6.81$, $SD = .34$) than the other two types of tasks, Rote ($M = 8.05$, $SD = .31$) and Explore ($M = 8.09$, $SD = .43$). Hence both retention test speed and accuracy results lend support to hypothesis 6 about the performance difference caused by different task types, with the Rote task group finishing the retention test in the shortest time, and the Explore with Tips group getting the lowest score. The interaction of Task Type and Tutorial Type on retention test performance is not significant, therefore hypothesis 10 is rejected. Also observed was a significant effect of covariate Prior Experience $F(1, 130) = 13.73$, partial $\eta^2 = .10$, $p < .01$. Correlation
analysis indicated that the more experienced learners tended to get higher scores \(r = .271, p < .01\). The hypothesized interaction of Prior Experience and experimental factors was not significant (hypotheses 5 and 8).

Participants in the Video conditions scored higher than those in the Text conditions, although the main effect of Tutorial Type was not significant. Additional test was performed but no quadratic relationship was found between the retention test scores and time on test. Experimental group means of retention test scores, tutorial learning time, and time on retention test are reported in Table 4.4.

![Figure 4.6: Retention Test Scores by Experimental Condition](image)

*Figure 4.6: Retention Test Scores by Experimental Condition*

**Flow.** The *Flow* scale consists of 16 items. Results of an initial principal axis factor analysis confirmed the four sub-dimensions of the scale as used in previous research (Gbani & Deshpande, 1994; Montgomery, Sharafi, & Hedman, 2004):
Enjoyment (Cronbach’s $\alpha = .95$), Concentration ($\alpha = .90$), Control ($\alpha = .94$), Exploration ($\alpha = .81$). All items were assessed with 7-point semantic differential scales in the questionnaire and reverse-coded in data analysis so that higher scores correspond to higher degrees of flow. Two additional items measuring participants’ perceived challenge of the task and their skills in the task were measured on a 9-point scale ($1 = \text{Low}, 5 = \text{Medium}, 9 = \text{High}$), which were analyzed separately. All the Flow measures are analyzed using the same Tutorial Type x Task Type ANCOVA with Prior Experience and Tutorial Type Preference as covariates. Each sub-dimension of Flow was entered as a dependent variable.

No significant effect of Tutorial Type or Task Type was observed for Enjoyment, although the means pattern shows that the Explore task offered more enjoyment ($M = 5.54, SD = 1.42$) than the Rote ($M = 5.15, SD = 1.52$) or the Explore with Tips ($M = 5.30, SD = 1.59$) task. Effect of the covariate, Prior Experience, was significant, $F(1, 140) = 5.40$, partial $\eta^2 = .04, p < .05$. Prior Experience is positively correlated with Enjoyment ($\alpha = .20, p < .05$).

When Concentration was entered as a dependent variable, no significant effect was observed. However, the pattern revealed by the experimental group means shows that among the three tasks, the Explore group concentrated the most during the tutorial learning phase ($M = 5.70, SD = 1.06$), followed by the Rote group ($M = 5.45, SD = 1.32$) and the Explore with Tips group ($M = 5.22, SD = 1.32$).

A significant main effect of Tutorial Type on the Control dimension of flow suggests that participants in the Video conditions felt significantly more in Control than
those in the Text condition, $F(1, 140) = 4.70$, partial $\eta^2 = .03$, $p < .05$. The absence of the Task Type main effect and the observation that Text – Explore with Tips group felt the least in control indicate giving the learner more instructional options does not necessarily make the learner feel “in control.” Prior Experience also has a significant effect on the Control dimension of Flow, $F(1, 140) = 33.20$, partial $\eta^2 = .19$, $p < .001$. Correlation analysis shows that the more experienced learners tended to feel more in control ($r = .39$, $p < .01$).

![Figure 4.7: Control – Sub-Dimension of Flow](image)

The Exploration dimension of Flow measures the exploratory use of the tutorial. Consistent with the result of Task Type manipulation check, Task Type main effect is significant, $F(2, 140) = 4.85$, partial $\eta^2 = .06$, $p < .05$. 

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The challenge-skill difference was calculated by taking the absolute value of the difference between perceived task challenge and participant’s skill in the task. Hence the smaller this difference between the two, the more balanced the perceived challenge of task to the learner’s skill. The optimal level of challenge that matches one’s skill level has been linked to the state of flow (Csikszentmihalyi, 1975), as the magnitude of the challenge-skill difference is negatively related to the quality of subjective experience (Moneta & Csikszentmihalyi, 1996). In this study, however, the challenge-skill difference is not correlated with any of the sub-scales of Flow, and does not vary significantly across the experimental groups.
<table>
<thead>
<tr>
<th></th>
<th>Enjoyment</th>
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<th>Control</th>
<th>Exploration</th>
<th>Continuing Motivation</th>
<th>Self-Efficacy</th>
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</thead>
<tbody>
<tr>
<td></td>
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<td>Explore</td>
<td>E + Tips</td>
<td>Total</td>
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</tr>
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<tr>
<td>SD</td>
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<td>1.96</td>
<td>1.70</td>
<td>1.40</td>
<td>1.62</td>
</tr>
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</table>

Table 4.5: Group Means for Enjoyment, Concentration, Control, and Exploration Dimensions of Flow

**Continuing and Intrinsic Motivation.** The Continuing Motivation scale includes three items: “I would like to learn more about Fireworks,” “I would like to practice more with the techniques introduced in the tutorial,” and “I would like to view more tutorials like the one I just used” (Cronbach’s α = .94). The ANCOVA result confirms the lack of difference in motivation across experimental groups, rejecting the hypothesized motivational advantage of animated images with narration and exploratory tasks (hypotheses 3 and 9). The only significant relationship is between covariate Prior
Experience and continuing motivation, $F(1, 134) = 16.23$, partial $\eta^2 = .11$, $p < .001$, which is foreshadowed by the significant positive relationship between Prior Experience and General Motivation. No significant effects are found for the other three items that tap intrinsic motivation, “The tutorial was entertaining,” “The tutorial gave good examples,” and “The tutorial inspired me.”

Satisfaction with Learning Experience. Participants’ satisfaction with the learning experience did not vary significantly across experimental conditions ($M = 5.31$, $SD = 1.57$). Prior Experience is found to be positively correlated with Satisfaction ($r = .24$, $p < .01$).

Self-Efficacy. The same Tutorial Type x Task Type ANCOVA with Prior Experience and Tutorial Type Preference as covariates is performed on self-efficacy (scale reliability $\alpha = .86$). A significant effect of Tutorial Type is observed, $F(1, 140) = 14.92$, partial $\eta^2 = .10$, $p < .001$, showing a clear gain in self-efficacy among learners using the video tutorial ($M = 9.20$, $SD = 1.40$) compared to those using the text version ($M = 8.55$, $SD = 1.64$). Prior Experience has a significant effect on Self-Efficacy, $F(1, 140) = 29.29$, partial $\eta^2 = .17$, $p < .01$. Correlation between Prior Experience and Self-Efficacy is positive and significant ($r = .34$, $p < .01$).

Tutorial Attributes

Mental imagery. Mental Imagery scale measures the effort that is required to mentally visualize the tutorial content and consists of two items: “It took a lot of effort to mentally visualize the processes shown in the tutorial” and “I had to fill in the gaps
between steps shown in the tutorial.” Patterns of results are consistent with those of cognitive load. Consistent with previous research, the video or animated pictures version of the tutorial in this study shows an advantage in helping participants visualize the learning material.

A significant main effect of Tutorial Type on mental visualization suggests that text tutorial \((M = 3.46, SD = 1.96)\) requires more mental effort to visualize the processes than Video \((M = 2.52, SD = 1.62)\), \(F(1, 139) = 15.37, \text{partial } \eta^2 = .10, p < .01\). Prior experience has a significant effect, \(F(1, 139) = 14.01, \text{partial } \eta^2 = .09, p < .01\), but does not interact with either of the experimental factors. There is also a significant main effect of Tutorial Type on gap-filling effort: participants using text tutorial had to fill in the gaps between steps more than those using the video version, \(F(1, 140) = 10.50, \text{partial } \eta^2 = .07, p < .01\). Prior experience has a significant effect, \(F(1, 140) = 8.67, \text{partial } \eta^2 = .06, p < .01\), but does not interact with either of the experimental factor. The negative correlations between \textit{Prior Experience} and \textit{Mental Visualization} \((r = -.26, p < .01)\) and gap-filling effort \((r = -.19, p < .05)\) suggest that less experienced learners had to expend more effort to create mental representations of the learning material.

\textit{Tutorial Affordances and Perceived Ease of Use}. The same Tutorial Type x Task Type ANCOVA was performed on six items pertaining to tutorial affordances and perceived ease of use: “I could easily control the pace at which I viewed the tutorial content,” “I could easily navigate the tutorial,” “It was easy to preview the tutorial to decide if I needed to skip any content,” “The tutorial enables me to search and find
information faster,” and “The tutorial clearly distinguishes each major step,” all measured with a 7-point scale (1 = Strongly Disagree, 7 = Strongly Agree).

Tutorial and task types did not affect the perceived affordances and ease of use except for the last item about distinguishing major steps in instructional content, where Tutorial Type has a significant effect, $F(1, 139) = 5.06$, partial $\eta^2 = .04$, $p < .05$, favoring Video over Text. Main effect of Task Type is also significant, $F(2, 139) = 4.16$, partial $\eta^2 = .06$, $p < .05$. Simple main effect comparisons using Least Significant Difference Method show that the Explore with Tips group rated the tutorial significantly lower than the other two types of tasks in terms of distinguishing major steps. A further inspection of the significant Tutorial Type x Task Type interaction ($F[2, 139] = 4.30$, partial $\eta^2 = .06$, $p < .05$) reveals that Text – Explore with Tips condition may be the cause of the significant differences between Task Types and the interaction of Tutorial Type and Task Type. An independent t-test performed on the group means of Video – Explore with Tips and Text – Explore with Tips found that the difference between these two groups is significant (see experimental group means in Table 4.6).
| Table 4.6: Tutorial Affordances by Experimental Condition |
|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
|                  |                 |                 |                 |                 |                 |                 |
|                  | Total | Rote | Explore | Tips | Total | Rote | Explore | Tips |
| **Mental Visualization** |       |       |         |      |       |       |         |      |
| M                | 3.46  | 3.42  | 3.15    | 3.62 | 2.52  | 2.64  | 1.75    | 3.00 |
| SD               | 1.96  | 2.02  | 1.72    | 2.04 | 1.62  | 1.61  | 0.97    | 1.88 |
| **Fill in Gaps** |       |       |         |      |       |       |         |      |
| M                | 2.97  | 2.69  | 2.77    | 3.31 | 2.25  | 2.46  | 1.55    | 2.52 |
| SD               | 1.80  | 1.49  | 1.74    | 2.07 | 1.36  | 1.41  | 1.05    | 1.38 |
| **Pace Control** |       |       |         |      |       |       |         |      |
| M                | 5.88  | 6.12  | 6.00    | 5.62 | 5.74  | 5.43  | 6.25    | 5.78 |
| SD               | 1.53  | 1.54  | 1.08    | 1.70 | 1.54  | 1.79  | 1.29    | 1.20 |
| **Ease of navigation** |       |       |         |      |       |       |         |      |
| M                | 5.82  | 6.08  | 5.92    | 5.55 | 5.89  | 5.76  | 6.20    | 5.83 |
| SD               | 1.64  | 1.67  | 1.12    | 1.80 | 1.32  | 1.30  | 1.24    | 1.44 |
| **Easy Preview** |       |       |         |      |       |       |         |      |
| M                | 4.74  | 4.81  | 4.62    | 4.72 | 4.56  | 4.57  | 4.45    | 4.65 |
| SD               | 1.81  | 2.02  | 1.76    | 1.69 | 1.64  | 1.44  | 1.99    | 1.70 |
| **FasterSearch** |       |       |         |      |       |       |         |      |
| M                | 4.62  | 4.92  | 4.15    | 4.55 | 4.89  | 4.84  | 4.95    | 4.91 |
| SD               | 1.67  | 1.55  | 1.95    | 1.64 | 1.65  | 1.61  | 1.73    | 1.73 |
| **Distinguished Major Steps** |       |       |         |      |       |       |         |      |
| M                | 5.63  | 6.19  | 6.00    | 4.97 | 6.11  | 5.92  | 6.55    | 6.04 |
| SD               | 1.69  | 1.41  | 0.91    | 1.97 | 1.01  | 1.20  | 0.69    | 0.82 |
CHAPTER 5

DISCUSSION

Findings and Theoretical Implications

This study seeks to tackle unresolved questions about instructional media in multimedia learning research and has found support for the dynamic media hypothesis. The primary finding of this study is that in three task environments that differ in learner control, animated instructions with narration leads to better performance on retention test and imposes less cognitive load on the learner. Increasing levels of learner control may not benefit learners when learners do not have enough prior experience, and when more instructional options interfere with the usability of the instructional material.

Primary Findings Supporting the Dynamic Media Hypothesis. Retention test performance results provide solid evidence for the benefits of presenting instructional content with animated pictures and narrated text in software training. For both novice and experienced learners, the animated tutorial helped them complete the retention test faster than their counterparts using the text version, without trading off accuracy. Cognitive load is used to explain this finding. Animated pictures with narration helps reduce cognitive load, at least the perception of it.
The significant main effect of tutorial type on self-efficacy following the tutorial learning phase clearly indicates that the animated and narrated version of tutorial enhanced learner confidence in their skills. Results on mental imagery confirm that the text tutorial consumes more cognitive resource to mentally visualize and fill in the gaps when processing the instructional content. Findings regarding the affordances and ease of use further explain the benefits of narrated animation. The speculated usability issues of narrated animations proved to be insignificant, which serves as further evidence that narrated animations are at least as easy to use as static text and images. Particularly encouraging is the affordance of narrated animation that helps distinguish major steps in instructional content.

**Findings about Learner Control.** Overall, this study finds the type of learning task to affect both speed and accuracy of retention test performance. Learners in the rote task conditions finished the retention test faster and with higher accuracy scores than those in exploratory tasks.

Although Task Type main effect on cognitive load is not significant, interesting patterns involving perceived cognitive load and learner control emerged. Cognitive load measures in this study consist of items about perceived task complexity and difficulty. Results also suggest that participants perceived themselves to have tried harder in the Rote task than in Explore task, and the least in Explore with Tips task. However, findings about cognitive load indicate that the perception of task complexity and difficulty did not vary significantly for the three types of tasks. While the group means of the three task types reveal that cognitive load is higher in the Explore with Tips conditions than in the
Explore conditions, participants’ self-reported effort is lower in the Explore with Tips conditions than in the Explore conditions. This implies that when cognitive load is perceived to be high, learners may choose to loosen their expectation of performance or lose motivation, therefore expending less mental effort than they would otherwise. However, there is ambiguity in the meaning of the item “I have tried my best in this task.” Participants may have been rating the completeness and quality of their graphics produced during the tutorial learning phase, or the degree to which they utilized the tutorial, rather than the actual amount of mental effort they exerted during this phase.

*What happened in the Text – Explore with Tips condition.* Although the hypothesized interaction of tutorial type and task type on performance measures was not significant, patterns of the experimental group means for performance and other dependent variables point to the Text – Explore with Tips condition that produced highest cognitive load, lowest self-efficacy, least enjoyment, concentration, and control (dimensions of flow), and lowest retention test score, although the difference between this group and the other five treatment groups is not significant. Click-stream data from the text and video Explore with Tips conditions indicate that the Text group did not explore more than the video group.

*Absence of Variation in Flow and Intrinsic Motivation.* The lack of variances in intrinsic motivation and flow across experimental conditions is not surprising. The content of tutorials was designed to produce such that social emotional cues such as humor, individual charismatic or personality characteristics were minimized. Many training videos nowadays take advantage of the expressiveness of the animated, audio-
visual media to promote the uniqueness brought by social cues, so that the content can be more entertaining.

The balance between perceived task challenge and skill level did not predict flow. In this study, this variable does not correlate with the other dimensions of Flow. This means even if the learner perceives the challenge level to be comparable to his or her skills in the task, the learner does not necessarily experience flow. Overall, the results of Flow and motivation measures suggest a lack of motivational differences across tutorial types and task types. Limited capacity can be expanded to some extent through greater involvement or through motivation. But that does not appear to be the case for the advantage that the narrated animation has over the text in this study. This study focuses more on the cognitive aspects of learning, although admitting the potentials of motivation. In a follow up study, motivation levels could be manipulated to bring out the dynamics in learning.

Absence of the Interaction of Prior Experience and Experimental Factors. This study has found significant effects of prior experience on several learning process and outcome variables. However, the hypothesized interaction of prior experience and experimental factors was not found. This may be attributed to the distribution of prior experience level in the sample, as the majority of the participants were novice learners in the study task domain. Prior experience can be further manipulated by recruiting from more advanced graphic design classes, then more observable differences may be found in the learning strategies and learning outcomes of novice and experienced learners.
Practical Implications

Implementation of the animated tutorial in this study emulated training videos produced by a popular web site. The videos chunked instructional content into short clips with descriptive titles. The added screen captures corresponding to the animation clips show the end product and signal the objective of each clip, which may have been the key in helping learners distinguish major steps. Designers should not only focus on the instructional content and presentation per se, but also pay attention to the overall information structure and organization.

In the experiments, participants were first shown the browser window of the tutorial. Ideally, the tutorial window and the software workspace of Fireworks should be displayed side by side, so that participants can see both at the same time to minimize split-attention. Given the large size of the tutorial browser window, however, it would be impossible to tile both windows on a 19” LCD, unless the application window of Fireworks is shrunk to less than ¼ of the screen size which will be difficult to work with. Therefore, the tutorial and the Fireworks application window were set up to be both maximized and displayed on top of each other. Participants had to toggle back and forth between the two windows on the screen. As a result of this setup, participants would need to hold the text and images or a portion of the animation they have viewed in their mind when they switch from the tutorial window to the Fireworks workspace.

Limitations

Stimuli. In the animated version, however, most of the clips show the full view of the software interface so participants could have a consistent frame of reference
throughout the tutorial. This becomes a key difference between the text and animated stimuli. The many differences between the two versions of the tutorial make it difficult to pin down the attribute or set of attributes that contribute to the observed effects of tutorial type.

*Measure of Prior Experience.* Self-reported ratings of familiarity with domain-specific software applications and design concepts may not be an accurate reflection of prior experience. More objective measures such as a screening test consisting of multiple-choice questions about how to create graphics in Fireworks may yield a more accurate score that represents learners’ prior experience in the study domain.

*Short time span of learning phase in experiment.* For novice learners, the skills acquired in a mere 20-30 minutes are quite limited. Moreover, this study does not include a transfer test as an important measure of the ability to apply knowledge in novel situations. This is due to the concern that with both retention and transfer tests in one study, participants may be affected by fatigue towards the end of the experiment. Internal validity may also suffer from potential carryover effect from one test to the other. Running two separate experiments, with one test in each, significantly shortens the study and avoids the need for counterbalancing the tests.

Studies in software training normally use several tasks of similar types for averaged performance measures (e.g. Dutke, & Reimer, 2000), and less often a formal retention test. However, in this study, only one retention test was used considering that participants only had a limited attention span and the learning task already took participants on average 20 minutes to complete.
It is suggested in learning theories that the average adult attention span is 22 minutes (Ward & Lee, 1995), hence a training session should last no longer than 20 to 25 minutes. This is why a lot of the experimental studies that employ learning modules limit their experimental sessions to no more than 40 minutes. Liegle and Janicki (2006) found that even if their participants had up to 45 minutes to complete the learning modules in an experiment, on average participants spent less than 20 minutes.

Similarly, in this study, participants had 60 minutes to complete the study that includes the tutorial learning phase and the retention test. However, the average time participants spent on the learning task was 21.66 minutes. Longer or multiple training sessions over a period of time may lead to different results. Therefore results of this study may reflect only short-term learning strategies and outcomes which can selectively inform instructional technology and message design. That is the limitation of any one-shot experimental study.

**Experimental Procedures.** Randomization could have been compromised due to the absence of within-session random assignment. Participants in each session were assigned to the same experimental condition.

**Future Research**

In this study, the retention test was administered after post-test 1, instead of right after the transfer test. Some studies recommend delayed test rather than immediate retention test right after the presentation of the tutorial to measure deeper processing or information retention over a longer period of time (e.g. Palmiter et al, 1991). The
rationale of not having a retention test immediately after the preview of tutorial is that the ultimate goal of software training is to enable the learner to apply the procedural knowledge in future, novel situations. The retention test in this study is a hands-on task that follows the first post-test questionnaire. The time lag may not be long enough for this test to qualify as a delayed one.

In a separate study with the same experimental design, with a transfer test or a free design task, the effect of exploration and learner control may be further investigated with the data on learner’s ability to transfer what they learn from the tutorial, continuing motivation or perseverance in a free design task. The measurement of quality of a free design product will still be a challenge, since novice students with little prior experience may not be able to produce a meaningful graphic.

A common strategy used by students observed during the learning phase is resize and arrange the software and tutorial browser windows so that they can see both at the same time, making it easier to compare and refer to tutorial while working on the graphic, so that they don’t have to keep too much information in the working memory. This is an interesting observation during the experiment. It seems that learners can adapt their learning strategies to reduce cognitive load. However, learner adaptation can be as volatile as learner preferences and learner control. Studies have found that in many situations, learners lack the metacognitive skills necessary to monitor and adjust their learning when given control over instruction (Merrill, 1984; Clark, 1983). Instructional options that learners choose and prefer may not be the most appropriate (Clark, 1982). It is necessary to identify what kind of instructional options the learners can be trusted with.
For example, research shows learners may have difficulty handling the scope of instructional content and the complexity of task in early learning phase (Leutner, 2000). But in general, simple learner control of instructional presentation such as stopping, starting, replaying, control of speed and even zooming in and out have been found to facilitate perception and comprehension (Mayer and Chandler, 2001). Learner control can be further categorized based on such evidence.
LIST OF REFERENCES


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