Animated versus Static Images of Team Processes to Affect Knowledge Acquisition and Learning Efficiency

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Abstract

In this paper, the authors replicated previous work demonstrating that animating mechanical systems leads to more efficient knowledge acquisition and extended it by applying the same processes to human systems. Based on these data, it appears that using static images, rather than animated human relationships within a team structure, better supports learning of procedural and conceptual knowledge by novices. Additionally, using static images led to a reduction in the amount of effort required to apply that knowledge. It remains unclear however, if the static images will continue to support knowledge retention long-term.

Keywords: Simulation-Based Training, Instructional Efficiency, Information Presentation, Learning, Training

Introduction

The increased complexity of modern battlefields has created two major training issues. First, the amount of information a war fighter must possess prior to being deployed has dramatically increased. However, because the time allotted for basic and post-basic training has not, more information must be imparted to war fighters in the same, or shorter, timeframe (Stenmark, 2006; USMC Deployment Cycle Issues Report). It is therefore necessary for more efficient learning practices to be developed. Second, the focus of novice trainees' education must shift from the *acquisition* of declarative knowledge and procedural skills to the *application* of conceptual and integrated knowledge so trainees are better able to apply their knowledge to these ever more frequent, complex, novel situations in which they must perform. To that end, we are challenged with the need to improve higher-order cognitive skills while simultaneously increasing efficiency.

To answer the challenge, the military has invested in numerous simulation-based training environments to provide a replicable platform for improved efficiency and a context in which to practice and assess these types of skills. Unfortunately, the systems accomplished the stated goal: they provided replicable platforms for practice and assessment. What they failed to accomplish was the implied goal: on their own, they do not promote *training* because practice alone does not promote the development of expertise (Ericsson, 1993, 1996; Dede, 2007). Rather, these systems require input from a skilled instructor to support training. Thus, efficiency and effectiveness of training was not supported at an expected level. In other words, simply providing a new platform for teaching does not ensure that training will improve. In response to this newly identified issue, the military has begun to fund research efforts focused on the implementation of instructional strategies and guidance to promote automated instructional support, leading to more effective and efficient training experiences for trainees.

One way to answer this need is to apply strategies derived from the current prevailing learning efficiency theory in the educational literature, Cognitive Load Theory (CLT) (Sweller, 1988) and to consider specifically the application of those strategies within a multi-media system (Multi-Media Theory (MMT), Mayer, 2005). CLT, and by extension, MMT, have demonstrated great success in providing recommendations on how to improve the delivery of declarative knowledge and procedural skills to learners. They have also demonstrated that their strategies can better focus the learner's attention, reduce the impact on working memory capacity, and result in more efficient acquisition of knowledge. It remains unclear, however, if they will improve the efficiency of the application of conceptual knowledge.

Cognitive Load Theory (CLT)

In CLT, learning is achieved when new information is stored in long-term memory (LTM), an unlimited storage space (Sweller, 1988). However, before being stored in LTM, information has to be processed by working memory (WM), a limited storage space (Mayer, 2005). Therefore, the main focus of CLT is to manage working memory's constrained capabilities to ensure adequate resources are available to process all information requiring storage in LTM. Cognitive load, or the amount and complexity of the information being processed in WM, is divided into three categories: intrinsic, germane, and extraneous. Intrinsic cognitive load is that imposed by the complexity inherent in the content being taught and, therefore, cannot be controlled. Germane cognitive load is imposed by tasks that lead to better understanding of the target content and, therefore, makes good use of working memory's limited resources. Extraneous cognitive load is imposed by tasks unrelated to the target content and, therefore, wastes the already limited capacity of working memory. Since intrinsic cognitive load cannot be managed, CLT turns its main attention to maximizing germane and minimizing extraneous cognitive load (Clark, Nguyen & Sweller, 2006).

Implications of CLT for Multimedia Theory

MMT considers CLT as it applies to multi-media systems. This theory purports that working memory consists of two, at least, partially separate channels: visual and auditory. Each channel can process only a limited amount of information at a time. However, because they are partially separate, more information can be processed by working memory if both channels are used instead of only one (Mayer, 2005).

Many principles in Multimedia Theory focus on reducing extraneous cognitive load, including, but not limited to, coherence, signaling, redundancy, spatial contiguity, and temporal contiguity (Mayer, 2005). For this study, the authors consider the coherence principle: learning is improved when extraneous information is excluded rather than included. Thus, based on this principle, the question arises: Does the way in which information is presented in Simulation Based Training (SBT) impose extra cognitive load. If so, is that extra cognitive load extraneous or germane?

Presentation strategies are of great concern in SBT because as technological capabilities increase, so does the complexity of the simulation environment, likely resulting in increased cognitive load. The way in which information is presented can either promote or detract from the learning process, based on whether or not the information increases extraneous or germane cognitive load in WM. In this paper the authors target the prevailing presentation mode in SBT: animations. Animations are defined by the authors as sequential illustrations or images that are presented to the user to represent movement or relationships. People and objects can move in either a two-dimensional or three-dimensional space. Static images, in contrast, are provided to users in a serial pattern but without movement shown. Relationships among and between objects and people are not explicit. Rather, users must infer interconnected pieces based on narrative information or the proximity of the items. Animations are commonly used in simulation-based training, even though their cost is high and their actual benefits to learning are quite unclear. Ambiguous theoretical support and empirical results make it difficult to discern the true nature of their impact on learning. As such, the authors seek to better understand the impact of animations on the learning process.

Information Presentation in Simulation Based Training

While simulation based training is likely the most appropriate platform for military training, due to its applied focus, interventions for increasing efficiency and effectiveness of these systems is necessary. Furthermore, cost effectiveness is important. Technology will continue to progress at a rate faster than research can assess its effectiveness. Therefore, researchers reside in a situation where they can create and develop many technologically interesting systems, but research needs to focus on those areas where technology can be most effective. In other words, testing and validation of various technological capabilities need to occur in order to determine their impact on training and help guide training and development decisions.

For this paper, the authors chose to investigate one intervention strategy that is commonly used, but rarely investigated: using animated versus static imagery to train skills in SBT. The financial cost and development time differential between these two types of information presentation styles and how they affect training for different types of skills were considered. While several studies have been conducted in this area (for a review, see Höffler & Leutner, 2007), finding, overall, a mid-sized advantage when using animated imagery over static imagery. More specifically, when moderator variables were considered, several trends were found. Representational animations were superior over decorative animations. Additionally, animations representing highly realistic or procedural-motor knowledge also positively affected learning. Unfortunately, these findings have not yet addressed our areas of concern. First, the majority of studies have focused on the representation of mechanical systems, demonstrating how the parts interact and affect each other. Second, the type of knowledge measured has been predominately declarative or procedural in nature. Our goals, however, deal with human systems, not mechanical ones, and focus on conceptual knowledge in addition to procedural skills. More specifically, the military has begun to require that all personnel, regardless of level, be able to adequately access situations in the field and make decisions effectively, efficiently, and with an understanding of the consequences of these decisions. This requires personnel to not only know the roles and skills of teammates to more conceptually comprehend how each individual's job affects another's and how the team's actions affect other teams and situations. As such, the authors seek to replicate the finding that animating mechanical systems leads to more efficient and effective knowledge about how the system interacts (Höffler & Leutner, 2007) and extend it by applying the same processes to human systems.

Static vs. Animated Imagery

There has been some controversy in the discussion about the possible superiority of animation over static pictures in instructional video presentations. Research results about the impact of animation on learning are diverse and ambiguous, ranging from extremely valuable to detrimental (for a full review see Mayer, 2005; Mayer & Moreno, 2002). Both static and animated presentations seem to have reasonable empirical evidence and theoretical foundations, especially based on cognitive load theory.

For instance, supporters of the superiority of animation over static pictures may argue that animation decreases cognitive load by providing an external visualization of a process or a procedure that would have to be otherwise mentally reconstructed and visualized by the learner from a series of static pictures. In other words, animation may have an enabling function, beneficial to those who cannot mentally reconstruct or visualize a certain process or procedure from a series of static pictures (Schnotz, 2002). This may be of particular benefit to pre-deployed military personnel who may lack the experience to complete this process. Additionally, static pictures require signaling cues to convey motion. These cues have to be integrated into the pictures by the user, increasing cognitive load and jeopardizing learning efficiency (Lewalter, 1997). On the other hand, since an animation is composed by several static pictures displayed in sequence and each frame is only available for a short period of time (Hegarty, 2004), one may argue that processing animated information imposes higher cognitive load due to the temporal limits of working memory. Indeed, although they seem to have greater overall advantage (Höffler & Leutner, 2007), animated instructional presentations do not seem to improve efficiency over static ones (Tversky, Morrison & Betrancourt, 2002). Hence, the key point is to investigate in which contexts animation improves learning effectiveness and learning efficiency.

The target learner is believed to be an important factor when determining the impact of animation on learning efficiency. When dealing with novice learners, who cannot mentally visualize the process or can do so only by expending significant cognitive effort, simulation has been found to be a useful tool. However, when learners are able to mentally visualize the process with an acceptable level of cognitive effort, the simulation may prevent them from visualizing the process on their own. As a result, learners may lack the opportunity to process valuable information and, consequently, lack the opportunity to acquire and assimilate deeper knowledge. In other words, animation may not only be irrelevant in this case but can even have an inhibiting function, leading to superficial learning (Schnotz, 2002). In novice learners, it is expected that the intensity and demanding nature of the battlefield, as well as its complexity, would be difficult to imagine and may hinder the process at several points. More advanced learners, with higher prior knowledge, have to invest less mental effort into learning a given topic and thus, have more cognitive capacity available to comprehend motion at a very detailed level (ChanLin, 2001; Höffler, 2003 and Nerdel, 2003 in Hoffler & Leutner, 2007; Szabo & Poohkay, 1996). Thus, while more advanced learners are better able to process animation with lower cognitive effort, learners with lower prior knowledge are the ones who would most likely benefit from animations (Boucheix, & Guignard, 2005).

The nature of the system being animated may also have an impact on learning efficiency. In some cases, dynamic systems consist of a series of discrete steps where learners are able to mentally simulate the functioning of that system from static images. If this is the case, animated images are not expected to facilitate comprehension any better than a series of static images representing those discrete steps (Mayer, 2005). In fact, if learners are able to mentally animate the functioning of that system from static images, adding animation is expected to be disadvantageous to learning, as it would not induce deep processing of the material (Schnotz, Bockheler, and Gzrondziel, 1999 in Hoffler & Leutner, 2007; Schnotz & Lowe, 2003, in Mayer, 2005).

Another factor that may mediate the relationship between animation and learning efficiency seems to be the instructional role of the animation. Animations are significantly better than static presentations when they are representational, that is, the information to be learned relates to the motion, trajectory or change over time depicted by the animation (Höffler & Leutner, 2007). This is especially true if learners are not able to mentally animate the functioning of the system from static images of the discrete steps that compose that process (Mayer, 2005). For instance, animation has been found to be more efficient than static pictures when teaching how gears function (Boucheix & Guignard, 2005), how to bandage a hand (Michas & Berry, 2000), and how electrons move inside a flashlight (Yang, Andre, & Greenbowe, 2003). In these cases, the animation is being used to convey germane information.

When animation is merely decorative, that is, it is not crucial to understanding the topic, extraneous cognitive load is being imposed (Höffler & Leutner, 2007). If animation is used when the information to be learned does not relate to the motion, trajectory, or change over time or when the dynamic process consists of discrete steps that learners are able to mentally animate from a sequence of static images representing those steps, then learners will be required to process more complex information that is not directly beneficial for comprehending the process or concept. In this case, by adding animation, non-relevant material is being added, i.e., extraneous cognitive load is being imposed, which has been shown to impair leaning (Mayer, Heiser, & Lonn, 2001 in Mayer, 2005). It may be suggested that animation increases learners' motivation (Levin, Anglin, & Carney, 1987; Harp & Mayer, 1998; Weiss, Knowlton, & Morrison, 2002) and this motivation may, to a certain point, compensate for the disadvantage of placing unnecessary burdens on the learner's limited working memory. However, the overall effect of decorative animation does not appear to positively contribute to learning, yet it is widely used in SBT, regardless of the type of information it represents.

Thus, the true nature of the impact of animating human systems requires investigation to better understand how it can be used as an information presentation strategy pre-, during, or post-training. In this study, the authors seek to determine if it can be used to demonstrate human relationships rather than mechanical processes. Can the same principles demonstrated to be successful with procedural-motor types of information be extended to conceptual knowledge? Is animation more suitable than static images to demonstrate human relationships (conceptual knowledge) while simultaneously teaching procedural knowledge and, therefore, increasing learning efficiency?

Specifically, this study focuses on measuring the impact of animation on acquisition of procedural information, comprehension of conceptual information, application and retention of procedural and conceptual knowledge, and learning efficiency. Animations of team interactions of the Fire Support Teams (FiST) were developed to teach the processes of these teams while also teaching how inter-and intra-team interactions impact other teams and other situations during battle. This study was conducted in an attempt to analyze the impact of the use of animation versus static imagery on knowledge acquisition, comprehension, application, retention, and learning efficiency. In this paper, the focus is on Call for Fire (CFF) teams within the military. The authors hypothesize that by animating team interactions, they will be able to train simultaneously both declarative knowledge/procedural skills and conceptual knowledge, resulting in increased learning efficiency.

Hypotheses

It is expected that novice learners will struggle to acquire conceptual knowledge in this area because they must understand the organization and duties of the CFF team *and* envision how the team would interact to most effectively execute the task. Due to a lack of experience, the ability to envision these interactions is expected to be very limited. However, despite the increased cognitive load burden it may place on learners, animations are hypothesized to assist novice learners in acquiring declarative knowledge/procedural skills and conceptual knowledge by illustrating intra-team interactions. Increased learning efficiency is hypothesized to be the result. More specifically, animations are hypothesized to assist learners in learning how to execute a Call for Fire (CFF) task and understanding the relationships between team members and other teams.

Specifically, the hypotheses include:

1. Cognitive Load will be higher in the animated group compared to the static group during training but lower during assessment.
2. Procedural Knowledge Acquisition will be higher for the animated group than for the static group.
3. Conceptual Knowledge Comprehension will be higher for the animated group than for the static group.
4. Conceptual Knowledge Application will be higher for the animated group than for the static group.
5. Learning Efficiency will be higher for the animated group than for the static group.
6. Knowledge Retention will be higher for the animated group than for the static group.

Method

In this experiment, two versions of a training video illustrating the relationships among members of a Fire Support Team (FiST) and the procedures a Forward Observer – Artillery (one of the members of the FiST) should follow during a Call For Fire (CFF) task are compared. Both versions present identical audio narration. However, two different visual representations of the material were presented. In the static version, still images were provided to learners in sequential order. No movement was depicted in these pictures. In the animated version, the same illustrations were used except in this version, they were represented in a movie-like fashion. They demonstrated movement of objects and people and displayed the associations between these individuals. For example, interactions among team members were demonstrated by illustrating how communication in one part of the battlefield must travel to another member of the team in order to execute a target destruction sequence. In contrast, the static version simply showed a picture of the various members and their relative locations.

The goal is to understand the influence of animated or static images on knowledge retention and learning efficiency. The measure for *application* of conceptual knowledge is the Conceptual Knowledge Application Test while *acquisition* of conceptual knowledge is tested using the Conceptual Knowledge Test. Acquisition of procedural knowledge is measured by the Procedural Knowledge Test and perceived cognitive load is measured using the Cognitive Load Questionnaire (CLQ). Because this is a two-part study, with participants answering the same tests and questionnaires seven days after their first session, comparisons of the results from the two parts of the study were used to estimate learning efficiency (a function of conceptual knowledge and cognitive load scores compared between the two parts of the study), and knowledge retention (scores on knowledge tests compared between the two parts of the study). All parts of this study were online.

Apparatus

Introductory Questionnaires

- *Biographical Questionnaire* This questionnaire addressed personal identifiers such as age, race, gender, military experience, degree of comfort with and frequency of use of computers, etc.
- *Prior Knowledge Questionnaire* - Participants answered free-entry questions regarding their prior knowledge of or experience with the FiST, Forward Observers, CFF tasks, and military simulators. This questionnaire was developed by our team.

Cognitive Load Questionnaire

- *Cognitive Load Questionnaire* (Paas, Tuovinen, Tabbers, & VanGerven, 2003) - Participants rated their perceived cognitive load during a task or set of tasks ranging from "very, very low mental effort" to "very, very high mental effort."

Knowledge Acquisition

- *Procedural Knowledge Test* - Participants answered lab-developed multiple-choice questions regarding how to execute a CFF task and how to use the DVTE simulator. Questions included the order of steps that should be followed to complete a certain task and the pieces of equipment that should be used to accomplish a certain step in the procedure. Test-retest reliability showed a 90% agreement between pilot participants and construct validity evaluations by experts showed an average rating of 4.0 (out of a possible 4 points).
- *Conceptual Knowledge Test* - Participants answered lab-developed multiple-choice questions regarding the relationships among members of the FiST, such as which support team each FiST member communicates with and how the tasks are divided among the different members of the FiST. Test-retest reliability showed a 90% agreement between pilot participants and construct validity evaluations by experts showed an average rating of 3.73 (out of a possible 4 points).

Knowledge Application

- *Conceptual Knowledge Application Test* - Participants answered lab-developed free-entry questions that required inferences about and deeper knowledge of the FiST. The questions presented situations a member of the FiST might face that were not mentioned in the training presentations, requiring participants to apply their conceptual knowledge to novel situations in order to properly answer the questions. Test-retest reliability showed an 60% agreement between pilot participants and construct validity evaluations by experts showed an average rating of 3.33 (out of a possible 4 points).

Participants

There were initially 391 total participations. Because this study was conducted fully online, a significant number of participants had to be cut from the analyses due to the following reasons: multiple participations (6), early withdrawal (161), not enough time between administrations (65), completed the study too quickly to have adequately completed all the tasks (25), and prior knowledge (6). Among the remaining 115 participants analyzed, 39 were males and 76 were females. The ages ranged from 18 to 31.

Procedure

After providing informed consent online, participants were presented, and allowed unlimited time to complete, computer-based versions of the Biographical and Prior Knowledge Questionnaires. Participants who reported having any knowledge of the Call for Fire task were excluded. This acted to ensure that no participants had access to, or knowledge of, the training prior to the beginning of the study. The remaining participants were not asked to complete pretests on the knowledge tests regarding the Call for Fire task since they reported having no prior knowledge of the subject and therefore would be unable to answer questions regarding this subject.

Next, participants were asked to click on a web link randomly assigning them to watch one of the two versions of the training video: animated or static. Following the video, participants were asked if they were able to watch the video as instructed. Next, they answered a computer-based version of the CLQ based on the amount of cognitive load required to attend to the training presentation.

After that, participants completed computer-based versions of the knowledge tests, administered in ascending knowledge level order in order to access participants' knowledge from information acquisition, to assimilation, and finally to application (Procedural Knowledge Test, Conceptual Knowledge Test, and Conceptual Knowledge Application Test). Participants were allowed unlimited time to complete the knowedge tests. Next, they once again answered the computer-based versions of the CLQ based on the cognitive load required to complete the procedural, conceptual acquisition, and conceptual application tests. Finally, participants were asked to create a password to link their data from the first part of the study to the data from the second part.

Seven days after the first part (Part A), participants signed up for the second part (Part B) of the study. This time margin was maintained by only allowing participants access to part B on the seventh day. After providing informed consent, participants were presented the same computer-based versions of the Procedural Knowledge Test, Conceptual Knowledge Test, and Conceptual Knowledge Application Test. Next, they answered the computer-based versions of the CLQ reporting the amount of cognitive load utilized to complete the knowledge tests. Finally, participants were asked to enter the password they had created in the first part of the study to confirm that the same person participated in both parts.

Results

Preliminary Data Analyses

Data were analyzed using SPSS 17.0 for Windows. Missing data were deleted listwise from analyses. Means and standard deviations for variables of interest are provided in Table 1.

Results by Hypothesis

Cognitive Load will be higher in the animated group compared to the static group during training but lower during assessment.

An analysis of variance (ANOVA) using cognitive load as the dependent variable (DV) and group as the independent variable (IV) was conducted. There were no significant between-group differences during training or assessment (Part A ($F(1,113)=3.03$, $p=.09$ and Part B ($F(1,113)=.06$, $p=.81$)).

Procedural Knowledge Acquisition will be higher for the animated group than for the static group.

An analysis of variance (ANOVA) using procedural knowledge acquisition as the dependent variable (DV) and group as the independent variable (IV) was conducted. Contrary to the hypotheses, procedural knowledge acquisition was significantly lower for the animated group (see table 1).

Conceptual Knowledge Comprehension will be higher for the animated group than for the static group.

An analysis of variance (ANOVA) using conceptual knowledge comprehension as the dependent variable (DV) and group as the independent variable (IV) was conducted. There were no significant between-group differences.

Conceptual Knowledge Application will be higher for the animated group than for the static group.

An analysis of variance (ANOVA) using conceptual knowledge application as the dependent variable (DV) and group as the independent variable (IV) was conducted. Contrary to the hypotheses, conceptual knowledge application was lower for the animated group (see table 1).

Learning Efficiency will be higher for the animated group than for the static group.

An analysis of variance (ANOVA) using learning efficiency as the dependent variable (DV) and group as the independent variable (IV) was conducted. Contrary to the hypothesis, learning efficiency was significantly higher for the static group during part A (see table 1). However, no significant differences were observed during part B. A repeated measures analysis of variance (RMANOVA) using the same variables was also conducted. A significant difference between groups in efficiency scores from time 1 to time 2, was found ($F(1,113)=5.07$, $p=.026$). However, despite having retained more of their initially acquired knowledge compared to the static group, the overall score for the animation group was still lower than that of the static group, making this finding not immediately useful. If this trend had continued (animated group continuing to retain more of their initially acquired knowledge while expending increasingly less cognitive load to apply the information) then the finding may be effective for longer term retention and efficiency.

Knowledge Retention will be higher for the animated group than for the static group.

A series of analyses of variance (ANOVA) using procedural knowledge acquisition, conceptual knowledge comprehension, and conceptual knowledge application (part B) as the dependent variables (DVs) and group as the independent variable (IV) were conducted. Contrary to the hypotheses, procedural knowledge acquisition was significantly lower for the animated group (see Table 1). However, no significant between-group differences in conceptual knowledge comprehension or application were found.

Discussion

Aiming to increase learning efficiency, we considered the use of one information presentation strategy to allow us to teach both procedural and conceptual knowledge simultaneously. The use of animation to articulate the relationships between team members of a FiST and to reduce cognitive load was tested. In doing so, the authors aimed to increase learning efficiency by teaching the skills simultaneously. Considering the high fiscal impact of using animations, it is necessary to determine if the return on investment for learning quality justifies the cost. Based on these data, it appears that contrary to the hypotheses, using *static* images, rather than animated ones, depicting human relationships within a team structure, better supports learning of procedural and conceptual knowledge by novices while simultaneously reducing the amount of effort required to apply the knowledge.

The static group was better able to acquire both procedural and conceptual knowledge. Also, even though only the procedural knowledge acquisition was significant, conceptual knowledge acquisition followed the same trend. The static group was also able to apply the conceptual knowledge better, and they were able to do so while expending less cognitive effort. In other words, they were more efficient in their learning. Despite no significant differences in cognitive load being found between the groups, when combined with performance data, significant differences were observed. Together, these data demonstrate that when static images are used for instruction, learners are better able to acquire and apply multiple levels of information, supporting its superiority as an instructional intervention. Why is this important? It will allow researchers and developers to provide additional information or additional learning material to those who are observing static imagery due to the availability of resources to process that information.

However, in contrast, the time two data, or how much knowledge the groups retained after a one-week interval, displayed a different trend. The static group members retained only a portion of the information they initially acquired. Furthermore, they had to expend more cognitive effort to be able to process it and apply it in the assessment phase. The animated group, on the other hand, performed better in time two than they did in time one. They also expended less cognitive effort. This suggests that the static group's learning efficiency scores declined from time one to time two while the animated group's efficiency scores increased. However, even though the static group retained less information than they initially acquired, compared to the animated group, their net knowledge level was still higher than the animated group at time two. And while their cognitive load score decreased from time one to time two, their net score was still lower (better) than the animated group, suggesting that while they did less well relative to their own learning, they still did better than the animated group. This suggests that training with static imagery leads to better knowledge acquisition and initial application as well as short-term retention.

What is unclear is whether or not this trend will continue. In other words, if the static group continues to retain less and less information while simultaneously requiring more and more cognitive effort to apply their knowledge, and the animated group members continue to retain or improve their knowledge scores while simultaneously decreasing the amount of effort required to apply their knowledge, eventually these two groups would cross in efficiency scores. As such, the animated group's long-term retention may exceed that of the static group. Because of the impact this may have on recommendations for learning strategies, further investigation to understand this trend is recommended.

At this point, we conclude that initial knowledge acquisition and application as well as short-term retention are better supported by static imagery compared to animated imagery when teaching human system interactions. Furthermore, because static images are less time-consuming as well as less financially costly, the return on investment of using static imagery clearly exceeds the same when using animated imagery. Why might this occur? The authors hypothesized that by illustrating how the team interacts, they would be able to help learners focus their attention, retain information, and create better mental models. Contrary to the hypothesis however, it was found that those learners left to mentally construct the system better acquired, assimilated, applied, and retained the information being taught. Potentially, the learner that must make the effort to process the inter-and intra-relationships of the teams creates his or her own mental model of the learning experience. In doing so, learners may be better able to assimilate that information in long-term memory, resulting in easier extraction and application of the information. Constructivist learning approaches support this finding in that they suggest that when learners construct their own mental models of learning situations, they are better able to organize the information, connect it to existing schema in long-term memory, and thus more easily extract, apply, and retain that information (Loyens & Gijbels, 2008). Thus, concepts supported by constructivist theories for efficiency with this type of knowledge may need to be considered. It appears that the extra effort placed into the learning timeframe allowed the group members that had to create their own mental models to apply the knowledge better.

What can be done with this information? One possible application of this information is in scenario-based training. The military is now expending a significant amount of resources investigating the impact of scenario-based training to teach complex decision-making skills. In scenario-based training we consider the entire training cycle. In other words, we consider pre-, during, and post-training interventions to aid learning efficiency. One of the goals in research from scenario-based training is to identify strategies from the educational literature that may apply to this environment. Specifically, easily generalizable, reconfigurable, and replicable strategies are needed for use pre-, during, and post-training. Finding that static imagery not only has a high return on investment, but particularly promotes learning and, more specifically, learning efficiency, it may be useful to provide instructors with stock photos or stock imagery that can be reconfigured to support pre-training story or context manipulations during training instructional pieces or post-training after action review discussions. In doing so, we may be able to illustrate concepts in a cost-efficient manner. It is expensive and difficult to replicate or generalize animated photos. Furthermore, they require a high level of skill to build. However, with static images pre-stored, instructors who are novice level computer programmers could create pre-, during, and post-training strategies beneficial to trainees.

Table 1. Results.

Measure	Method	Results	Mean	Std. Dev.
Procedural Knowledge Acquisition*	Procedural Knowledge Test	Part A, p<.02		
		Animated	64.38	21.53
		Static	74.07	17.47
		Part B, p<.01		
		Animated	60.76	24.43
		Static	72.21	18.75
Conceptual Knowledge Comprehension	Conceptual Knowledge Test	Part A		
		Animated	65.61	21.01
		Static	71.26	21.69
		Part B		
		Animated	61.50	22.43
		Static	66.34	21.44
Conceptual Knowledge Application*	Conceptual Knowledge Application Test	Part A, p<.03		
		Animated	15.00	6.73
		Static	17.97	7.10
		Part B		
		Animated	15.94	6.80
		Static	17.80	7.47
Perceived Cognitive Load	Cognitive Load Questionnaire	Part A training		
		Animated	5.61	1.40
		Static	5.44	1.94
		Part A tests		
		Animated	6.25	1.52
		Static	5.67	2.01
		Part B tests		
		Animated	5.78	1.59
		Static	5.70	1.85
Learning Efficiency	Comparison of a combination of conceptual knowledge application and perceived cognitive load between Parts A and B	Part A* p<.01		
		Animated	-0.2	0.92
		Static	0.33	1.05
		Part B		
		Animated Time 2	-0.08	0.97
		Static Time 2	0.14	0.94

*p < .05

It was found that the use of static imagery to illustrate inter-and intra-team coordination in an applied battlefield setting better supports learning acquisition, application, and short-term retention. Thus, it has a better return on investment compared to animated imagery, and it may be useful for scenario-based training due to its generalizability, reconfigurability, and replicability at little cost to instructors.

Recommended areas of consideration include long-term retention and constructivist approaches for applied learning efficiency.

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