Table of Contents

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Immediate Impact of Dynamic Graphics Instruction on Learners of Varied Levels of Spatial Ability

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ABSTRACT

Spatial ability is a skill set that has shown to be vital to success in a variety of academic disciplines and professional careers, particularly in engineering- and technology-related fields. Various instructional mediums such as animation, video, and static graphics are utilized by educators as a means to help develop and promote spatial ability. The effort to produce some of these instructional tools can be considerable. The impact of each form of media used can also impact retention and application in learners of varying levels of spatial ability. This study investigated the immediate impact of static graphics, animation, and video on mental rotation abilities of non-engineering university students with varying levels of spatial ability at a midwestern university. Statistical significance was not found between each of the groups, but multiple interactions were observed that posit that a single form media may not be the solution for all learners. Educators should weigh the cognitive task and the abilities of learners prior to selecting the media. Where possible multiple forms of instructional tools should be made available to cater to the classroom.

Keywords: *Multimedia learning, spatial ability, mental rotation, video, animation, static graphics*

INTRODUCTION

Spatial ability is the ability to recognize the orientation of an object from different angles or position (Gorska & Sorby, 2008). It has been shown to be critical in the success of learners in the fields of medicine, science, engineering, and mathematics (Sorby, 2009). In spite of this, there has been a de-emphasis on spatial ability training, especially in engineering curricula (Pleck, McGrath, Bertoline, Bowers, & Sadowski, 1990). Some engineering disciplines, such as electrical and chemical, have opted out of graphics training entirely (Nozaki, Study, Steinhauer, Sorby, & Sadowski, 2016). The American education system has instead focused on verbal and mathematical learning (Webb, Lubinski, & Benbow, 2007). The learning environment and educational materials that are used in today's curricula are increasingly visually based, but learners have little to no knowledge or skill in conceptualizing graphics (Sorby, 2009). As a result, learners may have difficulty in understanding concepts and course materials.

The reduced emphasis in graphics and visualization training should also be of concern to several areas outside of engineering and technology as well. Non-technical professions in history and archaeology may use 3D visualizations to reconstruct historical sites. Healthcare managers may use 3D visualizations when determining location of facilities. GIS professionals have often used robust graphics for resources and planning. Perhaps the latest trend is the use of interactive graphical representations of data for enhanced usability of information through augmented reality and virtual reality applications. Even common citizens make decisions about retirement, finances, and healthcare treatment from graphics represented in print, web sources, and video (Rushmeier, Dykes, Dill, Yoon, & Peter, 2007). In a world where more information and tasks are becoming increasingly graphics oriented, demonstrated spatial skills serve not only engineers and technologists but the common person as well.

Spatial ability, according to Linn and Peterson (1985), has three categories: spatial perception, mental rotation, and spatial visualization. Common strategies in teaching spatial ability such as sketching and utilization of static graphics are often the first applied in spatial learning (Sorby, 1999). With the continued advances in multimedia, the efficacy of these mediums is called into question leading educators to ask, "how does multimedia based instruction impact spatial ability?" Parts to this question have already been examined. There have been documented gains of increased learning from animation mediums (Korakakis, Pavlatou, Palyvos, & Spyrellis, 2009; Mayer, Heiser, & Lonn, 2001; Mayer & Sims, 1994; Moreno & Mayer, 1999). Studies in video have shown the ability to improve attention (Tiernan, 2013), recall (Yadav, Phillips, Lundeberg, Koehler, Hilden, & Dirkin, 2011), and motivation (Choi & Johnson, 2010). Research on comparing the cognitive impacts of animation and video as compared to traditional approaches remains a particular void.

Mayer (2009) reported that individuals could learn from words and pictures better than by learning from words alone. Learning from multimedia is still limited by some key constraints. Relevance is one key consideration in the cognitive processing of multimedia presentations. Information from a multimedia presentation is immediately received and processed by sensory memory, but given the short store of the sensory memory the full message of the multimedia presentation is lost. Should the message remain relevant, the working memory of the brain is able to interact with the message and encode it into existing knowledge structures for later retrieval (Schunk, 2012). In addition to relevance is the consideration of cognitive load. The difficulty in processing multimedia messages for learners is that the intrinsic cognitive load is high. Where static media typically presents information in a pictorial model, multimedia presents multiple graphics, in the form of animation and video, sometimes with audio channels. The increased information on the visual and auditory channels can increase cognitive load (Mayer, 2008). Multimedia designed for learning must balance the relevance and cognitive load issue. Finally, the utilization of multimedia must also follow practical applications of instructional design. When instructional learning mediums in animation or video are properly segmented, concise, relevant, and integrated appropriately, they can produce learning in a variety of subject areas (Lai & Newby, 2012; Moreno & Mayer, 1999; Salina et al., (2012); Yadav et al., 2011).

The malleability of spatial ability has been well documented (Sorby, 2005; Sorby, 2007; Sorby, 2009; Terlecki, Newcomber, & Little, 2008). Strategies used have been heavy information processing tasks such as sketching, multimedia software, and training workbooks with exercises that require learners to infer begin and end states from static graphics (Sorby, 2007). These are admittedly difficult and time consuming for novice learners to master. Animation has been researched regarding knowledge and/or task performance studies (Fong, 2012; Koch, 2011; Rafi, Samsudin, & Ismail, 2006; Stull, Hegarty, & Mayer, 2009) but the lack of research on spatial ability and learning from video provides new for avenues in study. In the age of advancing multimedia and graphics technology, appropriate strategies and techniques should be revisited.

For the given study, two questions were examined:

RQ1: Are there statistically significant differences in participants' mental rotation abilities between participants that receive static graphic and text instruction versus those that receive animated instruction and those that received video instruction?

RQ2: Are there statistically significant differences in participants' mental rotation abilities between participants of high spatial ability, medium spatial ability, and low spatial ability?

Experimental Treatments & Content

This study utilized a true experimental design with stratified random sampling. A 3 X 3 factorial design was used for this experiment. Each participant was randomly assigned to one of three experimental conditions: static graphics and text (SGT), interactive 3D animation (I3D) or video (V). Participants in SGT received instructional treatment consisting of text and static graphics from a textbook chapter on mental rotation of 3D objects. Participants in I3DA received the same instructional content but delivery consisted of text and interactive 3D animation. Participants in V received the same instructional content as the other two groups but delivery of content consisted of text and video.

Each group received instruction on mental rotation of 3D objects about two or more axes. Specifically, participants reviewed material demonstrating the rotation of an object about the X, Y, and Z axes in positive or negative directions in three-dimensional space. Text information described various possible rotations of objects in three-dimensional space. Supporting isometric graphics of simple objects demonstrated the rotation described in the text. All groups with three types of instructional mediums received the same models, and text information demonstrated. All instructional mediums were designed to be self-paced and self-instructional. Participants were free to review the models and instruction in each of the mediums as many times as comfortable. The content for the instruction came from the text, *Introduction to 3D Spatial Visualization: An Active Approach* (Sorby, Wysocki, & Baartmans, 2003). The selected chapter from the textbook is titled "Rotation of a 3D Object About Two or More Axes."

Spatial Ability Stratifying Test

The Mental Rotation Test (MRT) was used as stratifying test to measure spatial ability for participants that were included in the study. The MRT is an appropriate assessment for spatial ability given the high internal consistency and test-retest reliability of the instrument (Vandenberg & Kuse, 1978). The MRT is a four-page test that consists of 24 items, six items on each page. An item consists of one reference 3D figure and four target 3D figures. Target figures are shown to the right of the reference figure. Participants must select two correct target figures that match the reference item (Hoyek, Collet, Fargier, & Guillot, 2012). Credit was given for selecting both appropriate target orientations to the reference. The scores for each individual fell in between 0 and 24. Once all scores were collected, participants were classified in low, medium, and high spatial ability categories. The ranges for each category were determined after data was collected. Participants for this study were designated as high spatial ability (HSA) if a score between 20 and 24 was attained. Participants were designated as medium spatial ability (MSA) if a score between 11 and 19 was attained. Participants were designated as low spatial ability (LSA) if a score between 0 and 10 was attained. The ranges for each category were selected so that each instructional group would contain equal numbers of participants.

Each participant was randomly assigned to one of three experimental conditions: SGT, I3DA, and V. Table 1 illustrates the nine groups.

Dependent Variable

The dependent variable for this study was performance on The Purdue Spatial Visualization Test: Visualization of Rotations (PSVT:R). Participants in all control and experimental groups received this assessment immediately after completing the instruction. The results of the immediate posttest were used to examine the effectiveness of all SGT, I3DA, and V instruction on participants' recall and application of instructional content.

The PSVT:R consists of 30 items of 3D objects. One example rotation is shown with a corresponding rotation. Then one reference figure is shown and five target figures. The participant is asked to select one of the five target figures that correspond to the rotation of the example rotation (Sorby, 1999). Credit was given for selecting the single appropriate target orientation that demonstrates the rotation in the example. The scores for each individual fell in between 0 and 30. The PSVT:R is an appropriate assessment for spatial ability given the prolific current research and the high validity and reliability of the instrument (Maeda & Yoon, 2013).

Both the MRT and PSVT:R measure an individual's 3D spatial visualization ability and there exists a strong correlation between the two (Branoff, 1999). Using the MRT as a stratifying test limited threats to external validity. While using the same pretest and posttest could have influenced the outcome on posttests, using the MRT as a stratifying test provided reliable insight into the spatial ability of the participants while allowing the PSVT:R to be a reliable measure of instructional outcomes and retention as an immediate and delayed posttest.

Subjects

Undergraduate students (272) from a midwestern university participated in this study. Participants were non-engineering majors with no prior coursework in engineering, 3D computer animation, computer-aided drafting, 3D modeling, or 3D studio art. In this study, 156 women and 116 men participated. This sample of students was selected to limit the impact of prior knowledge or skill and generalizability of results.

RESULTS

All statistics were computed in SPSS. A box plot of the immediate posttest by instructional group, SGT, I3D, and V, is presented in Figure 1. Table 2 reports the mean scores and standard deviations on the content related immediate posttest. Table 3 reports the results of the one-way analysis of variance.

The scores on the content-related posttest were compared using a one-way analysis of variance for independent samples (= .05). The results indicated that there was no significant difference with regard to the received instruction between groups, $F(2,271) = .223$, $p = .801$. The participants in the I3D group scored higher ($M = 15.511$, $SD = 6.410$) than those in the SGT ($M = 15.122$, $SD = 6.677$) and V ($M = 14.891$, $SD = 5.879$) groups.

Table 1. Design Groups

Independent Variable 2: Level of Spatial Ability	**Independent Variable 1: Type of Instructional Medium**		
	SGT	I3D	V
HSA	SGT-HSA	I3D-HSA	V-HSA
MSA	SGT-MSA	I3D-MSA	V-MSA
LSA	SGT-LSA	I3D-LSA	V-LSA

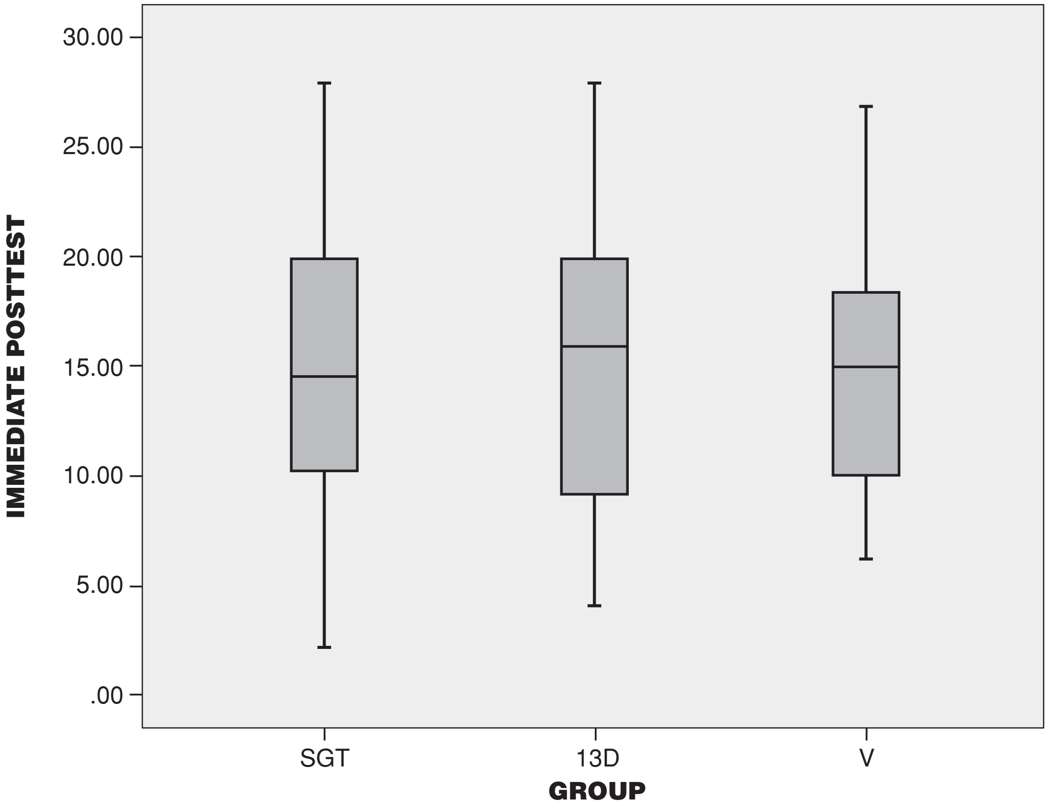

Figure 1. Box plot of immediate posttest scores by group.

Table 2. Mean Scores and Standard Deviations for the Immediate Posttest by Instructional Group

Group	*n*	Mean	Std. Deviation
SGT	90	15.122	6.677
I3D	91	15.511	6.410
V	91	14.891	5.879
Total 272	**15.124**	**6.309**	

Table 3. One-Way Analysis of Variance of Immediate Posttest Score by Instructional Group

Source	*df*	*SS*	*MS*	*F*	*p*
Between Groups	2	17.821	8.911	.223	.801
Within Groups	269	10769.057	40.034		
Total	**271**	**10786.879**			

A box plot of the immediate posttest subdivided by instructional group and spatial ability is presented in Figure 2. Cases 64, 108, 119, and 152 indicated the existence of outliers. Even though the cases were further than 1.5 interquartile ranges, each were still closer than three interquartile ranges from the nearer edge of the box. Therefore, the suspected outliers were reasonable to be kept in the analysis. Table 4 reports the mean scores and standard deviations on the content-related immediate posttest. Table 5 reports the results of the two-way analysis of variance. When analyzing instructional medium subdivided by spatial ability, there was not a statistically significant difference $F(4, 271) = 1.281$, $p = .278$. Participants of high spatial ability in the I3D condition ($M = 21.5$, $SD = 4.329$) scored higher than participants in the SGT ($M = 20.767$, $SD = 4.776$) and V ($M = 19.533$, $SD = 4.848$) high spatial ability groups.

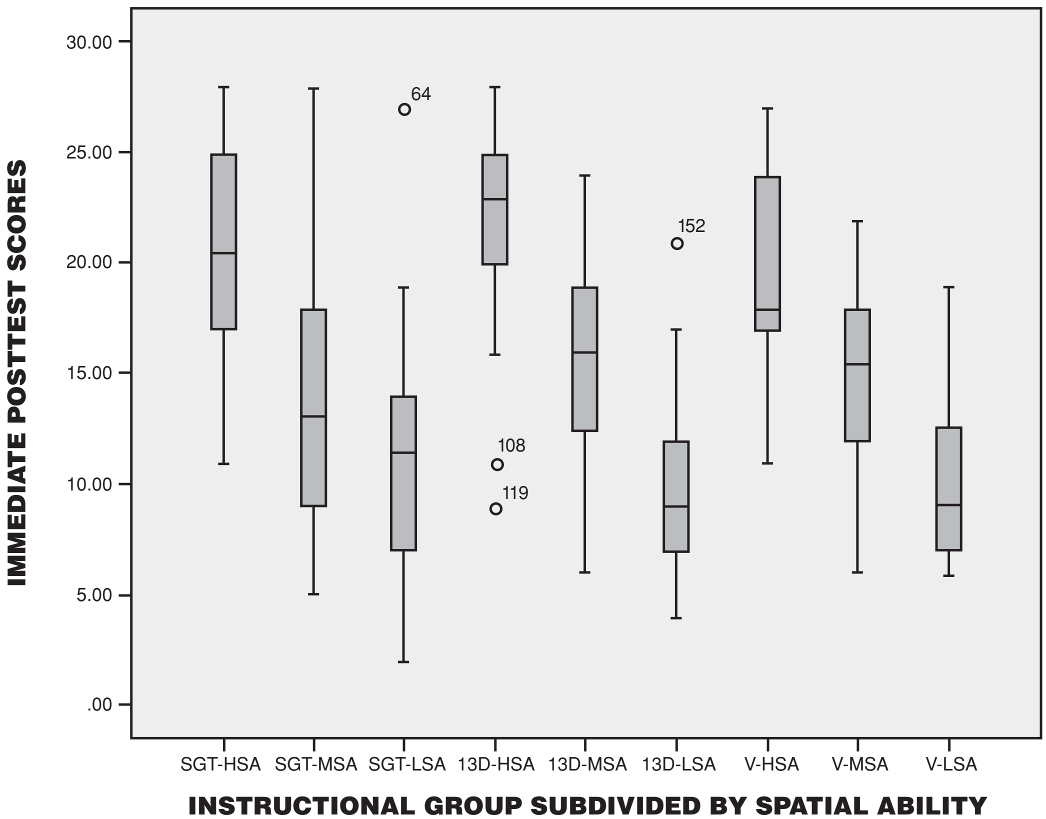

Figure 2. Box plot of immediate posttest scores subdivided by group and spatial ability.

Table 4. Descriptive Statistics for Immediate Posttest by Instructional Group and Spatial Ability

Groups	Mean	Std. Deviation	*N*
SGT-HSA	20.767	4.776	30
SGT-MSA	13.633	5.592	30
SGT-LSA	10.967	5.442	30
(control groups)			
I3D-HSA	21.500	4.329	30
I3D-MSA	15.484	4.434	31
I3D-LSA	9.733	4.017	30
(experimental groups)			
V-HSA	19.533	4.848	30
V-MSA	14.867	4.798	30
V-LSA	10.226	3.853	31
(experimental groups)			

DISCUSSION

The results on both the immediate posttest showed that there was not a statistically significant difference between the SGT, I3D, and V with regard to participants' ability to mentally rotate objects. However, numerous interactions and observations were noticed when the groups were subdivided by spatial ability.

First, participants of high spatial ability scored higher than participants of medium and low spatial ability on the immediate posttest in each of the respective instructional mediums. This is not surprising as participants of higher spatial ability typically have to allocate fewer cognitive resources than those with lower spatial ability and are therefore able to build the referential connections (Mayer & Sims, 1994). Rochford (1985) found in a study of learning anatomy that students who struggle to mentally operate or perceive three-dimensional objects often scored lower on practical anatomical tests. Extending this rationale to this study, it is possible that the participants that scored lower on the mental rotations tests appear to have had to provide greater cognitive effort than those of higher spatial ability. Multiple studies including those by Chang (2014), Fong (2012), and Stull et al. (2009) acknowledged the cognitive disadvantage that participants of low levels of spatial ability have. This provides further evidence for spatial ability as an important factor in instructional medium effectiveness. The other issue as to why the participants of high, medium, and low spatial ability did not score higher or lower than others in their respective groups has roots in cognitive load theory (CLT) by Sweller (1988). Schemas are a critical component in CLT (Van Merrienboer & Sweller, 2005). Sweller (1994) stated that "a schema is a cognitive construct that organizes the elements of information according to the manner with which they will be dealt" (p. 296). Unless an individual had in place firm understanding of X, Y, Z space, positive and negative rotation, isometric views, and 3D space, an individual would not be able to retrieve the necessary information from their long- term memory storage. Therefore, the cognitive processing of participants of high, medium, and low spatial ability was limited to the schemas that they had in place from other prior experiences. For comparison purposes, the high spatial ability groups likely had a firm development of the necessary information schemas to begin with, so it was unlikely that they would have regressed and scored lower than those of medium spatial ability. As a contrast, the low spatial ability groups likely had weak or none of the necessary information schemas to begin with so it was unlikely that they would have improved or scored higher than those of medium spatial ability as they would still need to have developed and integrated the needed information schemas further. Without the basic units of knowledge that schemas provide and their operation, it is unlikely that there would have been significant knowledge acquisition for spatial ability groups to have scored significantly higher or lower.

Second, there was not a statistically significant difference between participants in the I3D instructional medium and those in the SGT medium on the immediate posttest. When subdividing the groups by spatial ability, the I3D-HSA and I3D-MSA groups scored higher than the SGT-HSA and SGT-MSA groups on the immediate posttest. In the last pairing,

Table 5. ANOVA Results for Immediate Posttest by Instructional Group and Spatial Ability

Source	*SS*	*df*	*MS*	*F*	Sig.	η2
Corrected Model	4964.117	8	620.515	28.027	.000	.460
Intercept	62748.261	1	62748.261	2834.187	.000	.915
Instructional Medium	22.729	2	11.365	.513	.599	.004
Spatial Ability	4827.291	2	2413.646	109.019	.000	.453
Instructional Medium * Spatial Ability	113.412	4	28.353	1.281	.278	.019
Error	5822.761	263	22.140			
Total	73405.000	272				
Corrected Total	10786.879	271				

Note. R Squared = .460 (Adjusted R Squared = .444).

however, SGT-LSA participants scored higher on the immediate posttest than the I3D-LSA participants. Although research by Hasler, Kernsten, & Sweller (2007), Lai and Newby (2012), Korakakis et al. (2009), Mahdjoubi & A-Rahman (2012), and Moreno and Mayer (1999) found that animations could be more effective than static graphics with certain instructional material, for the immediate posttest part of this study I3D was not superior to SGT in all cases. Why did this occur? Much of the interaction again is related to CLT (Sweller, 1988). Participants in the I3D-HSA and I3D-MSA groups may have found the presented multimedia to be more effective immediately to rehearse in their working memory, encode, retrieve, and apply than the SGT-HSA and SGT-MSA groups. The I3D-LSA group may not have been immediately prepared to apply the information. As a result, when asked to retrieve and apply information, the intrinsic cognitive load may have been so much that the I3D-LSA group actually performed much more poorly than the SGT-LSA group. The SGT-LSA group may not have been as cognitively challenged as the material could have been more familiar in the form of static graphics and text, and therefore experienced much more germane cognitive processing. This automated schema appears to have worked well for the SGT-LSA group as their working memory was unaffected and had more information processing resources available in retrieval and application. Looking to Sweller's (1994) CLT, it could also be anticipated that the schema that would have helped the I3D-LSA group was not yet fully developed. Sorden (2012) elaborated on the importance of schemas by stating:

> *Schemas organize simpler elements that can then act as elements in higher order schemas. As learning occurs, increasingly sophisticated schemas are developed and learned procedures are transferred from controlled to automatic processing. (p. 4)*

Third, there was not a statistically significant difference between participants in the V instructional medium and those in the SGT medium on the immediate posttest. When subdividing the groups by spatial ability, the V-MSA group scored higher than the SGT-MSA groups on the immediate posttest. The V-HSA group actually scored lower than the SGT-HSA group on the immediate posttest. Further, the V-LSA group actually scored lower than the SGT-LSA group on the immediate posttest. Why is it that researchers (Salina et al., 2012; Choi & Johnson, 2010; Choi & Yang 2011) found success with video-based instructional medium, but the V medium in this study on the immediate posttest did not show superior results? Once again CLT (Sweller, 1988) may provide some insight into these results. The V-HSA and V-LSA groups' lower scores could be attributed to extraneous cognitive load provided by the complexity of the video showing the demonstrated rotations of the objects. Immediately following the instruction, participants of these two groups could have been still attempting to make sense through rehearsal and attempted encoding of information, so much in fact that performance on the posttest was impacted. To further add to this discussion, Reed (2009) stated that recall of observed actions is different from performed actions because different systems are involved in encoding information. The observance of the hand rotating an object in the video is inherently different than interpolating the movements of static graphics. The mind in static graphics is freer to flip and rotate, whereas a demonstration shows a canonical movement that participants may inherently be trying to include as exact movements into their processing schema. As a result, when asked to recall information for the posttest, the video groups could have potentially been using an entirely different problem-solving protocol that was not yet refined as compared to the static graphic groups. A new, unrehearsed problem-solving medium therefore could explain the lower scores. Sorden (2012) stated that "proper encoding requires rehearsal and since rehearsal takes time, the multimedia lesson must allow an adequate period for incubation or it can be ineffective" (p. 6). The sum time after the learning session and before assessment was less than a few minutes. It is questionable to say that this was an adequate amount of time for the V-HSA and V-LSA groups.

Fourth, there was not a statistically significant difference between participants in the V instructional medium and those in the I3D medium on the immediate posttest. The I3D group scored higher than the V group on the immediate posttest. When subdividing the groups by spatial ability, the V-HSA group scored lower than the I3D-HSA groups on the immediate posttest. The V-MSA group scored lower than the I3D-MSA group on the immediate posttest. Intriguingly, the V-LSA group scored higher than the I3D-LSA group on the immediate posttest. The findings here are consistent with what Rafi et al., (2006) found in their study where video did not produce as significant gains in achievement as animation-based resources. The potential explanations for the results can be found by returning to CLT (Sweller, 1988). As mentioned previously, the V-HSA and V-MSA groups' lower scores could be attributed to extraneous cognitive load provided by the complexity of the video showing the demonstrated rotations of the objects. Immediately following the instruction, participants of these two groups still could have been attempting to make sense through rehearsal and attempted encoding of information, so much in fact that performance on the posttest was impeded. The animations, simpler in form, contained less visual information to process, and therefore may not have produced extraneous cognitive load. Another possible explanation for the lower scores of the V-HSA and V-MSA groups has roots in Mayer's (2009) multimedia instructional principles, specifically the coherence principle. The coherence principle is the premise that people learn better when extraneous material is excluded rather than included. One of the primary differences between the I3D and V instruction was that a hand was present in the V instruction that was responsible for moving the object. The hand could have been perceived as being extraneous to the participants, thereby leading to extraneous cognitive processing and resulting in difficulty in encoding the information into long-term memory.

Fifth, there was not a statistically significant difference between levels of spatial ability and instructional medium on mental rotation ability. There was no crossover between groups of high spatial ability, medium spatial ability, and low spatial ability participants in immediate posttest scores. Figure 2 shows a variety of interactions with the instructional mediums subdivided by spatial ability. For the high spatial ability groups, the I3D group scored higher than the SGT and V groups respectively. In the medium spatial ability comparison however, the I3D group remained the highest score, followed by the V and SGT groups. In the low spatial ability comparison, the SGT group actually scored highest followed by the V and I3D groups. In addition to the earlier discussion of CLT by Sweller (1988) that would explain these results, some discussion of element interactivity and its impact on cognitive load would provide a good deal of insight into what was observed in these comparisons. Sweller and Chandler (1994) stated that information that can be learned without reference to other information or prior knowledge are relatively low in their element interactivity. Consequently, information that must be learned with reference to other information or prior knowledge is high in their element interactivity. Heavy cognitive load is imposed when dealing with information that has a high level of element interactivity. It was observed in the LSA groups that the SGT group scored higher than both multimedia mediums. It was explained in previous paragraphs that the cause of SGT's performance likely had to deal with extraneous cognitive processing caused by the difficulty of the imagery shown. A further explanation could be that, in addition to the imagery, participants in the LSA groups would also have had to acquire knowledge of 3 X, Y, Z space, positive and negative rotation, isometric views, and 3D space. To paraphrase Sweller and Chandler (1994) these elements cannot be easily learned in isolation, because they interact with each other. With very little prior knowledge on the subject and more complicated imagery, the only participants in the LSA groups that would have had the lowest element interactivity would have been the SGT group. In the HSA groups, the SGT medium scores are higher given the higher element interactivity of the V medium. In the MSA groups however, element interactivity appears to be a negated factor. It seems that MSA participants in both the I3D and V mediums had developed schemas that limited extraneous cognitive processing that would have been caused by the element interactivity and therefore allowed them to score higher than the SGT-MSA participants.

Implications for Practice

Instructional designers may take some suggestions from the findings of this study and apply them to various instructional mediums. Should instructional designers be tasked with preparing lessons with material that is spatially demanding, they are obliged to consider the spatial ability of the target learners. According to Smith and Ragan (2005), "the most important factor for a designer to consider about the audience is specific prior learning" (p. 69). As spatial ability would be considered prior knowledge, it should be accounted for, and if possible, measured utilizing any number of the available instruments (Sorby, 2009). The participants in this study more than demonstrated that at varying levels of spatial ability, each instructional medium seemed to work differently.

Reflection of how to properly manage cognitive load should enter into the mind of the practitioner. Wong, Marcus, and Sweller

(2011) stated, “although new technologies show immense promise, it is important to understand learners have limited working memories” (p. 555). In addition to abiding by Mayer’s (2005) principles for reducing cognitive processing, managing essential processing, and fostering generative processing, practitioners must also recognize that these may not be applicable for all levels of learners. Paas, Renkl, & Sweller (2004) stated:

> *A cognitive load that is germane for a novice may be extraneous for an expert. In other words, information that is relevant to the process of schema construction for a beginning learner may hinder this process for a more advanced learner (p. 3).*

Even with advanced learners, this study showed some evidence with high spatial ability participants that the instructional medium used may have caused germane load for those that received instruction 3D animations and extraneous load for those with video instruction. Therefore, it is reasonable to suggest that designers should try target groups’ analysis along with learning task analysis so that the information can be communicated at the correct size for effective cognitive processing (Van Merrienboer, 1997).

The last point that should be made for instructional designers is which media would be most appropriate for a classroom of learners. The learning goal for this particular study was for participants to be able to solve problems on a mental rotations assessment. Smith and Ragan (2005) make several suggestions for learning medium assistance but perhaps the most critical is that multiple forms should be utilized to represent instructional content. Although time consuming to produce instructional videos and animations, an instructional designer should provide learners with ample instructional mediums to help them attain designated learning outcomes. Just as learners have various prior knowledge, they also have various interests, motivations to learn, attitudes toward subject matter, attitudes toward learning, perceptions of and experience with specific forms of mediation, anxiety levels, and attributions of success (Smith & Ragan, 2005). The variety of these affective characteristics may impact a learner’s perception of the media utilized in instruction and consequently affect performance. Therefore, it may be worth the time and effort necessary to create multiple mediums for a learner’s utilization.

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