Application of Color on 3D Dynamic Visualizations for Engineering Technology Students and Effects on Spatial Visualization Ability: A Quasi-Experimental Study

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Abstract

There are several reasons for exploring the potential of color information and its effects on improving spatial visualization ability. Color is one of the fundamental properties of objects and is detected preattentively with other primary properties like brightness and line orientation (Enns & Rensink, 1991; Treisman, 1986). Even though the role of color in object constancy and depth perception is clear, the value of adding redundant color as spatial stimuli has attracted very little attention (Alington, Leaf & Monaghan, 2001). According to Mehta & Zhu (2009) a large amount of research has been done in this domain; however, the psychological processes through which color operates have not been fully explored.

Introduction

Color theorists believe that color influences cognition and behavior through learned associations (Elliot, Maier, Moller, Friedman, Meinhardt, 2007). However, research provides inconsistent results when using visual cues like color (Seddon & Shubber, 1985). For example the amount of color may have an effect on the results when comparing color versus monochrome. Too much color, however, may have an adverse effect on the subjects when comparing color versus monochrome (Seddon & Shubber, 1985).

As a result, the field has observed certain conflicting results. To add to the related body of knowledge the following study was conducted.

The following was the primary research question:

Is there a difference in spatial visualization ability, as measured through technical drawings, among the impacts of visual cues (adding blue color) on dynamic visualizations for engineering technology students?

The following hypotheses will be analyzed in an attempt to find a solution to the research question:

H_0: There is no difference in spatial visualization ability, as measured through technical drawings, among the impacts of visual cues (adding blue color) on dynamic visualizations for engineering technology students.

H_A: There is an identifiable difference in spatial visualization ability, as measured through technical drawings, among the impacts of visual cues (adding blue color) on dynamic visualizations for engineering technology students.

Methodology

A quasi-experimental study was selected as a means to perform the comparative analysis of spatial visualization ability during the fall of 2014. The study was conducted in an engineering graphics course. The participants from the study are shown in Figure 1. Using a convenience sample, there was a near equal distribution of the participants between the three groups.

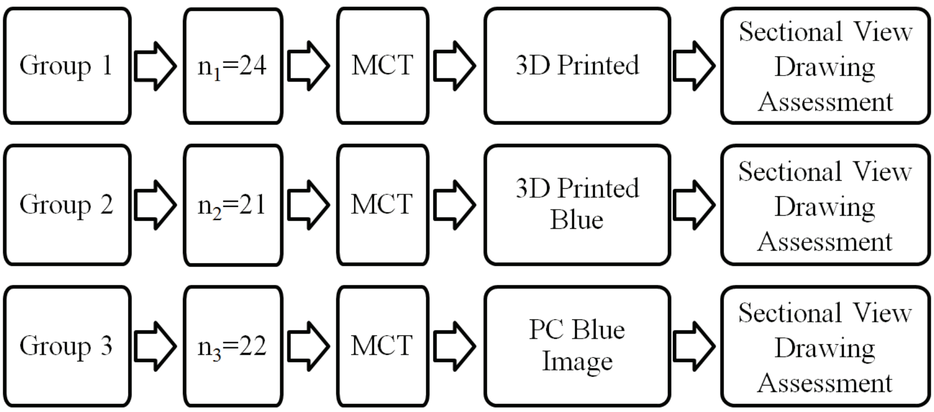

Figure 1. Research Design Methodology

The students attending the course during the Fall semester of 2014 were divided into three groups. The three groups (*n1*=24, *n2*= 21 and *n3*=22, with an overall population of *N* = 67) were presented with a visual representation of an object (visualization) and were asked to create a sectional view. The first group (*n1*) received a dynamic 3D printed dodecahedron visualization, self rotated at 360 degrees on the top of a motorized base at about 4 rounds per minute (slow rotation was used to prevent optical illusion and distortion of the original shape) during the creation of the sectional view (see Figure 2). The second group (*n2*) received the same dynamic 3D printed dodecahedron visualization, also self rotated at about 4 rounds per minute at 360 degrees on the top a motorized base at about 4 rounds per minute with students wearing blue glasses; thus, it created a blue background around the visualization during the creation of the sectional view (see Figure 4). The third group (*n3*) received a blue, shaded PC developed, dynamic 3D dodecahedron visualization, also self rotated at about 4 rounds per minute at 360 degrees at about 4 rounds per minute (see Figure 3). A color test was also implemented and no students were identified as color blind since everyone stated the correct colors.

Figure 2. Dodecahedron 3D Printed Dynamic Visualization

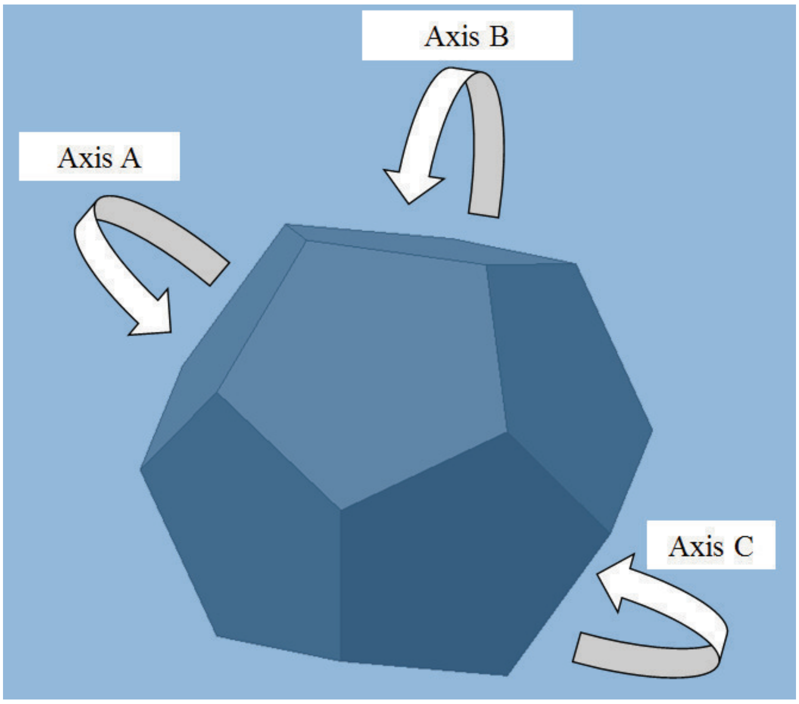

Figure 3. Blue Dodecahedron 3D Dynamic Computer Generated Visualization

Figure 4. Blue glasses treatment used for Group 2

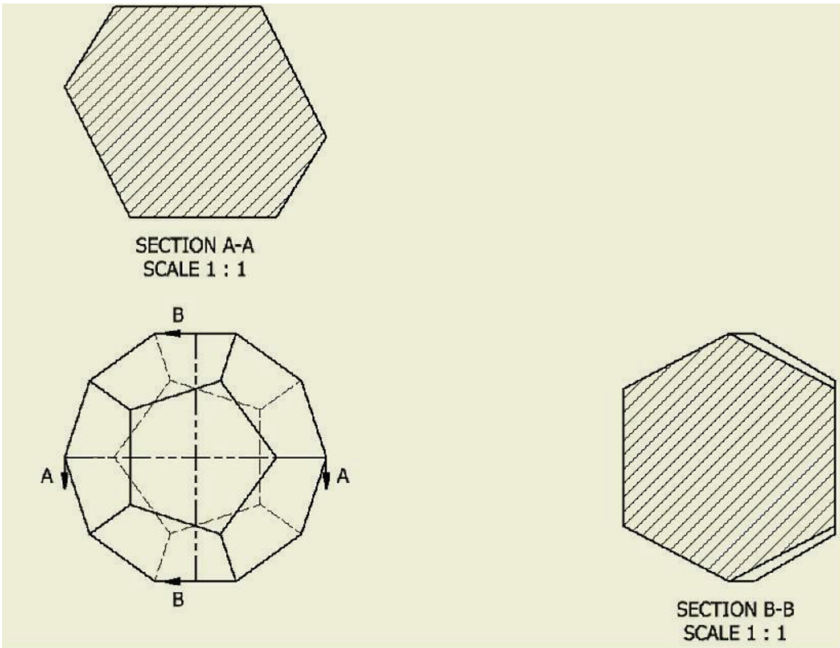

Figure 5. Sectional View of Dodecahedron

Data Analysis

Analysis of MCT Scores

The first method of data collection involved the completion of the MCT instrument prior to the treatment to show equality of spatial ability between the three different groups. The maximum score that could be received on the MCT was 25 and, as it can be seen in Table 1, n1 had a mean of 14.45, n2 had a mean of 12.75, and n3 had a mean of 13.25. A one-way ANOVA was run to compare the mean scores for significant differences, as it related to special skills among the three groups. There was no significant difference between the three groups as far as spatial ability, as measured by the MCT instrument (see Table 2).

Table 1. MCT Descriptive Results

	N	*Mean*	*SD*	*Std. Error*	*95% Confidence Interval for Mean* *Lower Bound*	*Upper Bound*
3D Printed (n1)	24	14.45	4.564	.847	12.71	16.18
3DPrinted Blue (n2)	21	12.75	4.561	.931	10.82	14.68
PC Blue Image (n3)	22	13.25	4.046	.826	11.54	14.96
Total	67	13.55	4.412	.503	12.54	14.55

Table 2. MCT ANOVA Results

Quiz	*SS*	*df*	*MS*	*F*	*p*
Between Groups	40.918	2	20.459	1.053	0.354
Within Groups	1438.172	65	19.435		
Total	1479.091	67			

* Denotes statistical significance

Analysis of Drawing

The second method of data collection involved the creation of a sectional view drawing. As shown in Table 3, the group that used the 3D Printed Model, and wore the blue glasses as visual aid (n =21), had a mean observation score of 3.26. The groups that used the PC computer generated model, and used no blue glass visual (n = 24), and the PC generated blue shaded image (n = 22), had lower scores of 3.17 and 3.00 respectively. A one-way ANOVA was run to compare the mean scores for significant differences among the three groups. The result of the ANOVA test, as shown in Table 4, was not significant, $F(2, 62) = 6.525$, $p < 0.802$. The data was dissected further, through the use of a post hoc Tukey's honest significant difference (HSD) test. As it can be seen in Table 5, the post hoc analysis shows no statistically significant difference between the 3D printed Blue vs. PC Model ($p < 0.968$, $d = 0.96$) and the 3D Printed Blue vs. PC Blue Image ($p = 0.792$, $d = 0.263$), with PC Blue Image vs. PC Model being equal and higher than the first one in both cases (p=.792, d=*.263).*

Table 3. Sectional View Drawing Descriptive Results

	N	*Mean*	*SD*	*Std. Error*	*95% Confidence Interval for Lower Bound*	*Upper Bound*
3D Printed	24	3.17	1.465	0.299	2.55	3.79
3D Printed Blue	21	3.26	1.046	0.240	2.76	3.77
PC Blue Image	22	3.00	1.272	0.271	2.44	3.56
Total	67	3.14	1.273	0.158	2.82	3.45

Table 4. Sectional View Drawing ANOVA Results

Quiz	*SS*	*df*	*MS*	*F*	*p*
Between Groups	.736	2	.368	.222	.802
Within Groups	103.018	62	1.662		
Total	103.754	64			

* Denotes statistical significance

Table 5. Sectional View Drawing Tukey HSD Results

	Visual Aids (1 vs. 2 vs. 3)	Mean Diff. (1-2)	Std. Error	*p*
2 vs 1	3D Printed Blue vs. 3D Printed	.096	.396	.968
2 vs 3	3D Printed Blue vs. PC Blue Image	.263	.404	.792
3 vs 1	PC Blue Image vs. 3D Printed	.263	.404	.792

* Denotes statistical significance

Discussion

While not statistically significant, the students who received treatment using the 3D printed Dynamic visualization, with the addition of the blue glasses visual cue, outperformed their peers who received treatment from the other two types of visualizations. Previous research supports that the effect of color on those with high spatial ability may result in little benefit, as high spatial ability learners develop mental models on shape alone. Khooshabeh & Hegarty (2008) suggested that color affects the performance of learners with low spatial ability more so than those with high spatial ability.

Due to the findings in this study and the relatively high scores recorded from the MCT given to the participants prior to the treatment, the researchers believe that the population used (engineering technology students) did not demonstrate a statistically significant difference in spatial abilities from the addition of the color, due to the fact that spatial abilities were well developed in this population.

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