Impacts of Effective Temperature on Sectional View Drawing Ability and Implications for Engineering and Technology Education Students

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Intro

While vision offers distinctive information for the representation of the surroundings, and is crucial for the development of spatial ability, evidence suggests that the lack of visual experience may have limited effects on the perception and mental representation of space (Cattaneo, Vecchi, Coroldi, Mammarella, Bonino, & Ricciardi, 2008; Ricciardi, Renzi, Bonino, Kupers, & Pietrini, 2010). Bonino, Ricciardi, Sanì, Gentili, Vanello, Guazzelli, Vecchi, & Pietrini (2008) have all stated that visual experience is not a necessary pre-requisite for a functional neural system within the parietal cortex, which is crucial in processing spatial information. Congenitally blind individuals, for example, recruit intraparietal and superior parietal regions during non-visual spatial processing and localization (Weeks, Horwitz, Aziz-Sultan, Tian, Wessinger, Cohen, Hallett, & Rauschecker, 2000), spatial imagery (Vanlister, De Volder, Wanet-Defalque, Verar, 2003), orientation discrimination (Ptito, 2005), spatial attention, and memory (Bonino et al., 2008). Individuals could develop their cognitive mechanisms through touch and hearing, which only allows for a sequential processing of information. The Greek philosopher Aristotle, in his thesis On the Soul, states that the sense of touch is the most important sense (Bremer, 2008).

The organ of touch is unique among the senses. In the other senses, the material is neutral with respect to the range in question: the eye jelly, for example, is colorless, the air in the ear silent. Touch, in contrast, inevitably possesses some of the qualities along its own range. (Caston, 2005).

Reid (1764) noted:

...by touch we perceive not one quality only, but many, and those of different kinds. The chief of them are heat and cold, hardness and softness, roughness and smoothness, figure, solidity, motion and extension (p.99).

There are two kinds of temperature: ambient temperature and effective temperature. Ambient temperature relates to the surrounding environment and effective temperature to an individual’s perception of the ambient temperature (McAndrew, 1993). Temperature can influence thermal comfort, working performance, and social behavior. In a classroom that is slightly cool, an assumption can be made that learning could be affected in a negative way. The purpose of the current study is to identify whether the effective temperature, as related to the sense of touch, can increase or decrease spatial ability performance for engineering technology and technology education students.

The following were the primary research questions:

Does the difference of effective temperature have an effect on students’ spatial visualization ability as measured by the MCT?

Does the difference of effective temperature have an effect on students’ ability to sketch a sectional view drawing?

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

H0: There is no significant effect on students’ sketching ability as measured by the MCT due to a difference of effective temperature.

H1: There is no significant effect on students’ spatial visualization ability due to a difference of effective temperature.

H01: There is significant effect on students’ sketching ability as measured by the MCT due to a difference of effective temperature.

H02: There is significant effect on students’ spatial visualization ability due to a difference of effective temperature.

Review of Literature

Spatial ability

Spatial ability can be described as the collection of cognitive skills that permit learners to relate with their environment (Hegarty & Waller, 2005). Spatial cognition acts are the foundation that allow the learner to form and retain mental interpretations of a mental model, or stimulus, in order to rotate or manipulate the object successfully (Carroll, 1993; Höfler, 2010). According to McGee (1979), spatial abilities consist of five distinct areas: spatial perception, spatial visualization, mental rotations, spatial relations, and spatial orientation.

Spatial abilities have long been known as a critical skill for student achievement in STEM-related curriculum and coursework (Pedrosa, Barbero, & Miguel, 2014; Sorby, Nevin, Mageean, Sheridan, & Behan, 2014; Kell & Lubinski, 2013; Cohen & Hegarty, 2012; Metz, Sorby. Berry, Conner, Dixon, Allam, Merrill, Peters, Pfister-Altschul, Zhang, & Leach, 2011; Cohen & Hegarty, 2012; Hegarty & Kozhevnikov, 1999). Barke (1993) determined that well-developed spatial skills are critical in the understanding of foundations in chemistry. In addition, Gutiérrez, Domínguez, & González (2015) write that student success depends on well-developed spatial ability in science and engineering. Decades of research have called for a heightened focus on the importance of spatial visualization ability in engineering education (Marunic & Glaza, 2013; Miller & Bertoline, 1991).

Spatial Visualization

A formal definition from McGee (1979) states spatial visualization is “the ability to mentally manipulate, rotate, twist, or invert a pictorially presented stimulus object” (p. 893). Educational research studies conducted in spatial visualization have determined that there may be as many as 84 different career fields where spatial abilities play a critical role in success (Smith, 1964). Maier (1994) found that spatial visualization and mental rotation abilities are particularly important for success in technical professions like engineering. Improving these skills is a key factor in student success and retention in engineering and technology coursework (Ferguson, et al., 2008). In particular, Brus, Zhoa, & Jessop (2004) and Sorby (2001) have produced studies suggesting that there is a positive correlation between spatial visualization ability and the retention and completion of degree requirements for engineering and technology students.

Visual Capacity

While vision offers distinct inputs in spatial representation, individuals lacking vision from birth may often show spatial skills similar to those who do not lack visual capacity (Bonino, Ricciardi, Bernardi, Sanì, Gentili, Vecchi,
& Pietrini, 2015). However, these congenitally blind individuals may exhibit impairment in more complex spatial ability tasks as they relate to perspective or angle image. Bonino, et al. (2015) examined the extent to which visual proficiency and sensory modalities affect the functioning of the brain architecture that supports spatial imagery. In the study, both sighted and congenitally blind subjects were measured through brain responses, as it relates to an angle discrimination task using visual, tactile, and auditory stimuli. Both groups did not differ in the tactile stimuli, however, in the blind group performance was impaired in relation to auditory stimuli. These findings suggest that spatial representation relies on a “distributed parietal cortical network that develops and functions independently from visual experience and is able to process non-visual spatial information” (Bonino, et al., 2015, p. 69).

Bonino, et al. (2015) found that blind individuals were less accurate during an auditory task, but during the tactile test these individuals performed similarly to those without visual deficiency. This may be due to a reliance on higher cognitive level processing for non-visual spatial processing (Noordzij, Zuidhoek, & Postma, 2007; Vecchi, 1998). This higher cognitive level processing substantiates that the brain’s architecture is pre-programmed to operate independently of visual experience.

**Sense of Touch**

According to Aristotle, the sense of touch “acts by contact while other senses act from a distance” (cf. On the soul, 423b 1–5). Aristotle rejected touch as a sense due to its inherent ability to require contact in order to experience. In addition, since touch is not localized to one particular organ, it must not be considered a “sense” and therefore does not lead us to the belief of a “sixth sense.” Ross (1931) stated that color is the object of sight, sound the object of hearing, and flavor the object of taste, but that touch “discriminates more than one set of different qualities” (p.418).

Aristotle and his successors relied on their sources of evidence available at the time. This included theory based solely on phenomenology and gross anatomy. They could relate senses to body parts (e.g. sight ceased to exist when the eyes were closed), but the sense of touch remained elusive (Wade, 2003).

**Temperature and Touch**

Reid (1764) noted that it is through touch that we experience many qualities, and those of differing kinds. The most dominant of which would be temperature, the sensation of “heat and cold; hardness and softness; roughness and smoothness; figure, solidity, motion, and extension” (p. 99). Erasmus Darwin (1794) supported the qualities of temperature by observing that heat and touch depend primarily on different sets of nerves. From this he determined that the entire muscular system could be considered one organ of sense.

Bell (1803) stated that the sense of touch was the change that arose “in the mind from external bodies applied to the skin” (p. 472). As technology and scientific inquiry advanced, the revelations of skin as an organ became more realistic. In particular, Blix (1884) found that underlying nerves provided stimulation of separate nerve ‘end-organs in the skin.” In addition, Max von Frey (1895) theorized that the sensations of temperature (warm, cold, pressure, and pain) were the responses of “end organs” in the skin. This marked the beginning of defining skin as an organ and identifying phenomenological differences that would lead to the integration of this area into cutaneous anatomy and physiology.

**Methodology**

A quasi-experimental study was used as a means to perform the comparative analysis of rotational view drawing ability during the Spring of 2016. Using convenience sampling instead of random assignment of the population, made the author believe that a quasi-experimental study was the appropriate methodology to be used. The study compared three groups comprising engineering and technology education students exposed to three different effective temperatures in order to determine whether there is a significant difference in sectional view drawing ability (see Figure 1).

The research protocol was generated and submitted for approval to the College’s Human Subjects Review Committee were it was approved and received exempt status. Data was tested for equality of variances using Levene’s test. Levene’s test indicated equal variances ($F = 3.56, p = .382$), therefore degrees freedom did not have to adjust. Temperature data was analyzed by a 3-way repeated measures analysis of variance (ANOVA), with temperature of the stimulus ($+84.2°F$ vs. $+93.2°F$ vs. $+102.2°F$), and the type of stimulus (warm vs. cold vs. hot) as subject factors. The temperature of $93.2°F$ (temperature of a healthy human’s skin) was used as a baseline for the warm water treatment with a variation of $+9°F$ for the cold treatments, respectively.

Tukey’s post hoc analyses were performed to account for multiple comparisons and sample size effect. All data was analyzed using SPSS (IBM, Armonk, NY, USA). For the analyses, $p < 0.01$ was used to establish significant differences.

The study was conducted in an engineering graphics course, as part of the Engineering Technology program. The engineering graphics course emphasized hands on practice using 3D drafting software in the computer lab, along with the various methods of editing, manipulation, visualization, and presentation of technical drawings. In addition, the course included the basic principles of engineering drawing/hand sketching, dimensions, and tolerance principles. The participants from the study are shown in Table 1. Using a convenience sample, there was a near equal distribution of the participants between the three groups. The students attending the course during the Spring semester of 2016 were divided into three groups. The three groups ($n_1=42$, $n_2=39$ and $n_3=44$) had the same academic background related to engineering graphics coursework (freshman engineering technology and technology education students had to complete the same intro to engineering graphics course the previous semester) were presented with a 3D printed visual representation of an octagonal pyramid (see Figure 2) and were asked to create a sectional view drawing of it.

To generate the three distinct temperature environments, the 3D printed model used for all groups was...
The use of water did not affect the data collection in any way. This was determined through Filingeri, Redortier, Hodder, & Havenith’s 2015 study conducted to identify whether skin wetness is considered a somatosensory experience, resulting from the integration of temperature (particularly cold) and mechanical inputs. It was found that dry and wet stimuli resulted in similar relative increases in local skin temperature. In addition, to eliminate the sense of vision and focus on the sense of touch, the container with water was enclosed in an opaque box. The independent variable in this study was the temperature of the water: 84.2°F, 93.2°F and 102.2°F for the cold, warm, and hot treatments, respectively. Each group member received 60 seconds to “feel” the model in the water. Using only the sense of touch to receive mental data, each student had to create a sectional view of the water. Using only the sense of touch to receive mental data, each student had to create a sectional view of the water.

Figure 3. Octagonal Pyramid Sectional View

### 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 researchers graded the MCT instrument, as described in the guidelines by the MCT creators. A standard paper-pencil MCT pre and post was conducted, in which the subjects were instructed to draw intersecting lines on the surface of a test solid with a green pencil before selecting alternatives. The maximum score that could be received on the MCT was 25. The pre-test results can be seen in Table 1: n₁ = 23.812, n₂ = 23.637, and n₃ = 23.351. As far as the post-test, overall means were higher: n₁ = 23.899, n₂ = 23.620, and n₃ = 23.620. No noticeable difference was seen for any of the groups that completed the treatment.

In addition, a one-way ANOVA was run to compare group mean and whether they were statistically significantly different during the pre and post treatment, as measured by the MCT. There was no significant difference between the means of the three groups’ level of sectional view drawing ability between pre and post treatment, as measured by the MCT instrument F (2, 98) = 3.492, p = .0310 (see Table 2).

The second method of data collection involved the creation of a sectional view drawing (see Figure 2). As shown in Table 3, the group that used warm water as part of their treatment (n = 39) had a mean observation score of 5.739. The groups that used cold water (n = 42) and warm water (n = 41) had similar mean scores of 5.694 and 5.701, respectively. The group that used hot water as part of their treatment (n = 42) had a lower mean score of 5.489. A one-way ANOVA was run to compare group mean and whether they were statistically significantly different during the pre and post treatment, as measured by the MCT. There was a significant difference between the means of the three groups’ level of sectional view drawing ability between pre and post treatment, as measured by the MCT instrument F (2, 98) = 3.492, p = .0310 (see Table 2).

The third method of data collection involved the completion of the MCT instrument after the treatment to show equality of spatial ability between the three different groups. The researchers graded the MCT instrument, as described in the guidelines by the MCT creators. A standard paper-pencil MCT pre and post was conducted, in which the subjects were instructed to draw intersecting lines on the surface of a test solid with a green pencil before selecting alternatives. The maximum score that could be received on the MCT was 25. The pre-test results can be seen in Table 1: n₁ = 23.812, n₂ = 23.637, and n₃ = 23.351. As far as the post-test, overall means were higher: n₁ = 23.899, n₂ = 23.620, and n₃ = 23.620. No noticeable difference was seen for any of the groups that completed the treatment.

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Water Temp. Groups | N  | Mean  | SD  | Std. Error | 95% Confidence Interval for Mean
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<td>Cold</td>
<td>42</td>
<td>4.893</td>
<td>1.912</td>
<td>.323</td>
</tr>
<tr>
<td>Warm</td>
<td>39</td>
<td>5.739</td>
<td>1.728</td>
<td>.242</td>
</tr>
<tr>
<td>Hot</td>
<td>44</td>
<td>4.319</td>
<td>1.382</td>
<td>.342</td>
</tr>
<tr>
<td>Total</td>
<td>125</td>
<td>4.983</td>
<td>1.674</td>
<td>.302</td>
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Table 3. Sectional View Drawing Descriptive Results

Quiz | SS  | df  | MS  | F   | p   |
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<tr>
<td>Between Groups</td>
<td>1.253</td>
<td>2</td>
<td>0.928</td>
<td>0.349</td>
<td>*0.042</td>
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<tr>
<td>Within Groups</td>
<td>229.592</td>
<td>98</td>
<td>2.342</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>230.845</td>
<td>100</td>
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* Denotes statistical significance

Table 4. Sectional View Drawing ANOVA Results* Denotes statistical significance

Visual Aids (1 vs. 2 vs. 3) | Mean Diff. (1-2) | Std. Error | p   |
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<tbody>
<tr>
<td>2 vs 1</td>
<td>Warm Vs. Cold</td>
<td>-.372</td>
<td>.456</td>
</tr>
<tr>
<td>2 vs 3</td>
<td>Warm Vs. Hot</td>
<td>.0518</td>
<td>.612</td>
</tr>
<tr>
<td>3 vs 1</td>
<td>Cold Vs. Hot</td>
<td>-.354</td>
<td>.439</td>
</tr>
</tbody>
</table>

* Denotes statistical significance

Table 5. Sectional View Drawing Tukey HSD Results* Denotes statistical significance

The null hypothesis that there is no significant effect on students’ spatial visualization ability, as measured by the MCT was accepted. However, the second null hypothesis that there is no effect on students’ spatial visualization ability to sketch a sectional view drawing due to the difference of effective temperature was rejected due to statistically significant evidence. Students that received treatment using warm water outperformed their peers who received treatment using cold and hot water temperatures, respectively. In a study conducted by Filingeri, et al. (2015), the researchers tried to identify whether the absence of humidity receptors in human skin (the sensitivity of skin wetness) is considered an output resulting from the integration of temperature (warm, hot) and mechanical inputs. It was found that warm temperature stimuli have been shown to suppress the perception of skin wetness during initial contact with a wet surface (Filingeri et al., 2015, p.13). This finding suggests that the temperature of warm water, versus hot and cold, allows the absence of skin wetness perception that could lead to a more direct focus. Based on these findings, it can be assumed that the absence of the skin wetness perception could increase the amount of sensitivity data transferred to the brain that can then be translated into spatial visualization data.

According to Bell (1803/2000), the qualities that we perceive from the sense of touch include hardness, softness, figure, solidity, motion, extension, heat and cold. However, even though heat is a quality, cold is the privation of that quality; therefore, in relation to the body, heat and cold are distinct sensations. An experiment conducted by Johann Wilhelm Ritter (1801) showed that different organs experience heat or cold in a different way. If one brings into contact a zinc pole on the tongue and silver on the gums the sensation was different, as that on the tongue feels very warm and the one on the gums felt cold (p. 458). Based on these findings, an assumption can be made that the sensation received when students were touching the 3D printed model in cold, warm, and hot water was completely different. A different signal for each temperature was received through the sensory qualities that could potentially provide a different message as it relates to spatial visualization abilities. Pfaff (1801) concluded that: “one must consider the sense of temperature (for warmth and cold) as essentially different from the common sense, and as special sense” (p. 10).

Evaluating results in Table 4, the ANOVA test did show a significant difference between the three groups F (2, 98) = 0.349, p < 0.05 when measuring the sectional view drawing results. A positive difference in the mean of the warm water treatment was observed, and was statistically significant enough to promote a stronger positive correlation. In addition, evaluating results in Table 5, showed statistically significant difference for the Warm Vs. Hot (p = .049, d = .612) group. As previous studies have suggested the long-term exposure to different temperatures could affect the sensitivity of the skin in a negative way and is likely to affect cognitive abilities. Since cold and hot water temperatures are both reaching more extreme temperatures, it could be suggested that the warm water temperature prolongs the loss of sensitivity and allows for sensitivity of the skin. Due to the fact that the groups in this study were relatively small the results need to be seen with caution and used as the base for additional feature studies. The current paper contributes to understanding the effects of temperature as an instructional tool that can enhance learning.

Limitations and Future Plans

In order to have a more thorough understanding of the effects of temperature, as it relates to spatial visualization ability for engineering technology students, and to add additional information in the body of knowledge, it is imperative to consider further research. Future plans include, but are not limited to:

- Repeating the study to verify the results by using additional types of temperature treatments.
- Repeating the study using a different population,
such as technology education, science, or mathematics students.

- Repeating the study by comparing male versus female engineering technology students.

References


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