Haptic Abilities of Freshman Engineers as Measured by the Haptic Visual Discrimination Test

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Abstract

The Haptic Visual Discrimination Test (HVDT) is a standardized and quantitative test that requires skills in tactile sensitivity, spatial synthesis and the ability to integrate partial information about an object into a whole. In this test, the subject manipulates an object in one hand without seeing it, and then selects a corresponding object on an identification chart with their free hand. The test was developed of a period of eight years and tested on both normal and disability subjects, with test-retest reliability of the HVDT between .91 and .93. The HVDT was administered to a large sample of engineering students and the mean of the resulting scores was one standard deviation above the mean of the normal population. The high instance of haptic ability in these students, who also showed high visualization ability, suggests a potential need for haptic and tactile related instruction in addition to lectures and computer-based or virtual formats.

Introduction

Visualization ability has traditionally been assessed with tests such as Lowenfeld's Successive Perception Test I, the Purdue Spatial Visualization Test, and Vandenberg's Mental Rotation Test among others. These tests measure different aspects of the subjects' ability to integrate partial visual information into a whole object with the information presented to the subjects in a 2-dimensional format by either paper and pencil or computer based tests. Results of these tests are often used to determine whether students need remediation in order to be successful in engineering design related courses or to assess the results of instruction in visualization. With the increase of computer-based instruction and the future of CAD trending toward 3-D modeling and incorporating aspects of virtual reality, other ways of measuring visualization ability and instructing students in improving their visualization skills need to be considered along with the traditional methodologies.

Research has shown that tactile interaction enhances visualization of scientific data in people with visual impairments, along with those having normal vision (Fritz & Barker, 2002). A recent study (Study, 2001) has also shown that the haptic tendencies, measured by the Haptic Visual Discrimination Test (HVDT), of a large sample of engineering students were one standard deviation above the mean of the normal population. To neglect the haptic abilities of these students by focusing primarily on visual and verbal instruction and traditional testing formats would be ignoring one of their primary ways of interacting with their surroundings. This paper discusses the results of the HVDT in that study and the effect the haptic tendencies of these students could have on their instruction in CAD and visualization.

Haptic Visual Discrimination Test

The Haptic Visual Discrimination Test (HVDT) was designed as a standardized and quantitative test that would require skills in tactile sensitivity, spatial synthesis and the ability to integrate partial information about an object into a whole. The test was developed over an eight-year period where the selection and refinement of the assessment procedure was investigated meticulously. Each revision of the test was administered to representative samples which included a distribution of "normal" children and adults and disability samples which included mentally retarded, deaf, visually impaired, schizophrenic and other impaired subjects. Test-retest reliability was between .91 and .93 with coefficients of determination between .83 and .87 indicating that between 83 and 87 percent of the variance could be accounted for by haptic-visual discrimination skills. There is a standardized and quantitative procedure of test administration and scoring and the same scoring procedure is used for all age groups which allows for interpretation of results based on normative data (McCarron & Dial, 1979).

The HVDT is an individually administered test. The subject sits across from the examiner at a testing table that contains only the materials necessary for the administration of the HVDT. A book of photographic plates, the identification chart, is placed in front of the subject along with a visual screen. The visual screen is a frame with a cloth screen suspended from the top section. The subject may adjust the position of the identification chart and the visual screen to make themselves more comfortable. A case containing the test objects is placed in a position con-

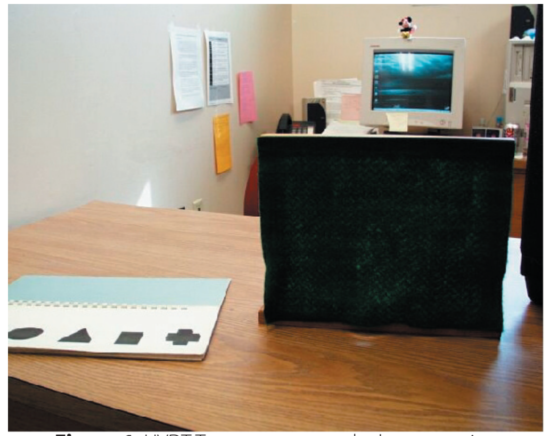

Figure 1 HVDT Test-setup - test taker's perspective

Figure 2 HVDT Test-setup - examiner's perspective

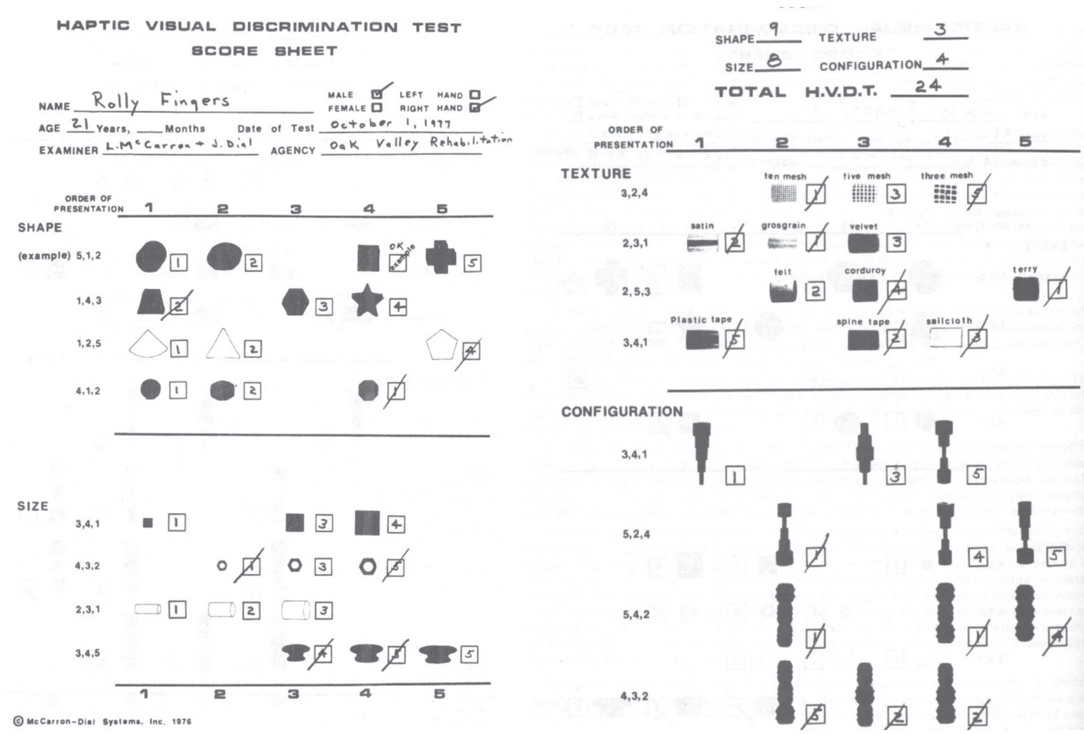

Figure 3 Sample HVDT score sheet

venient to the examiner but out of the view of the subject (Figures 1 and 2). The subject places their preferred hand through the opening in the visual screen and the examiner places an object in their hand. The subject is allowed to manipulate the object in their hand without seeing it, and then is asked to point to the corresponding object on the identification chart with their free hand (McCarron & Dial, 1979).

There are four different components of the HVDT; shape, size, texture, and configuration. Shapes include plastic blocks from a children's toy shaped like rectangles, ovals, squares, triangles and other geometric shapes; sizes are differently sized cubes, cylinders, nuts, and wooden drawer pulls; texture includes cloth samples such as sailcloth, corduroy and velvet; configuration is measured with different wooden dowel rods which range in diameter and are similar to stacked cylinders or dowels which have been turned on a lathe. Scores are recorded on a standardized score sheet which allows the examiner to note which object the subject is holding and whether they answered correctly. A sample score sheet is shown in Figure 3. Administration of the typically takes between 10 and 20 minutes, although there is no time limit (McCarron & Dial, 1979).

Test Results

Students enrolled in Computer Graphics Technology (CGT) 163, Introduction to Graphics for Manufacturing at Purdue University were the subjects used in this study. The demographics of students in this course were as follows; 81percent male, 89percent enrolled in the Freshman Engineering program, 61percent in their first semester, and a mean age of 18.6 years. Over a 5-week period, 218 subjects completed the test. To assess the affect of history as a threat to internal validity of the HVDT scores, an ANOVA was run on the groups of scores categorized by the week in which the subjects took the test over a five-week time span and no significant difference was found (Study, 2001).

The descriptive statistics for the 218 subjects who took the HVDT are shown in Table 1. The study group as a whole, showed higher haptic tendency than the general population. The mean score of 39.54 was one standard deviation above the mean score of 35-36 which is expected for the general

Statistics	
N	218
Mean	39.54
Std. Deviation	3.29
Variance	10.84
Minimum	29
Maximum	47

Table 1 HVDT descriptive statistics

Table of Norms

Scaled Score	Age (17- Adult)
20	
19	47-48
18	46
17	45
16	43-44
15	42
14	41
13	39-40
12	38
11	37
10	35-36
9	34
8	33
7	31-32
6	30
5	29
4	27-28
3	26
2	25
1	23-24

Table 2 HVDT table of norms

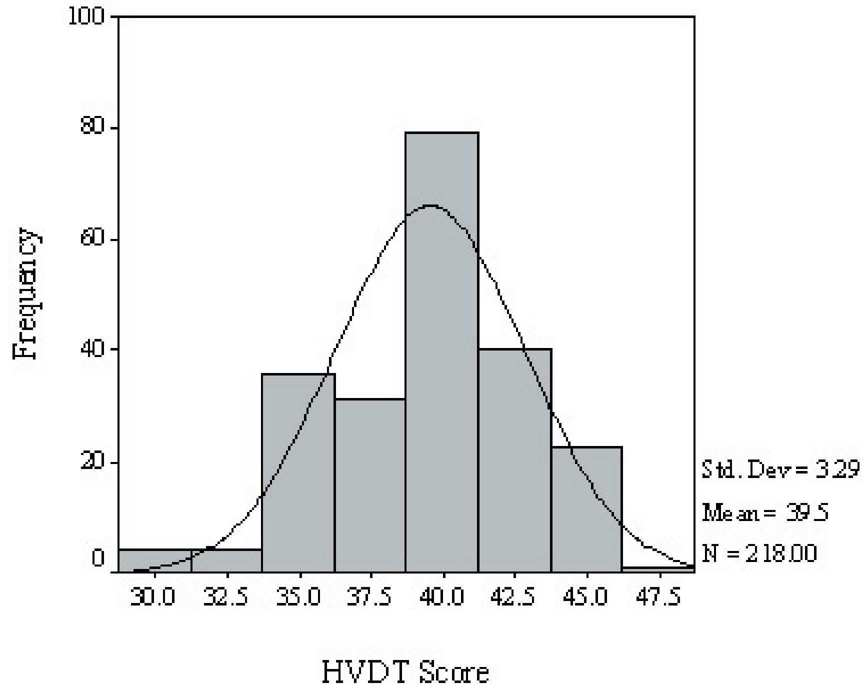

Figure 4 HVDT normal distribution

population of 17 to adult based on norms established by McCarron and Dial shown in Table 2. A scaled score deviation of three is equivalent to one standard deviation. The maximum score of 47 achieved by one subject in the study was two standard deviations above the expected mean. The minimum score of 29 was one and a half standard deviations below the expected mean for the given population. Scores were normally distributed within the study sample (Figure 4).

Discussion

The subjects in this study were not only above average in their haptic tendencies, they also showed a tendency toward possessing high visual abilities according to their test scores on the Successive Perception Test I and the Purdue Spatial Visualization Test: Visualization of Rotations (Study, 2001).

Although these subjects did show high visual tendencies, to neglect their haptic tendencies in instruction and evaluation would be neglecting one of their principal ways of interacting with their environment. Individuals who are haptic learners often prefer to orient themselves to the world of experience through touch, bodily feelings, muscular sensations and kinesthetic fusions (Lowenfeld, 1945).

Using the sense of touch to interact in a haptic fashion with the environment is a principal contributor to high level, integrated perceptual functions including the creation of mental models for “invisible parts of a system” (MacLean, 2000). In addition, research has found that while people are used to experiencing the 3D world and are adept at manipulating spatial relationships between real-world objects, they possess little natural comprehension of 3D space in an abstract computer-based or virtual environment (Hinckley, Pausch, Goble, & Kassell, 1994). The lack of any physical interaction with a virtual environment can sometimes lead to sensory cue conflicts. The addition of haptic elements in adjunct with visual elements enhances perception and performance of simple motor tasks in a virtual environment and has great potential to aid in models where subjects have encountered difficulty with optical visualization (Brooks, Ouh-Young, Batter, & Kilpatrick, 1990).

As early as 1965, Ivan Sutherland in his work titled "The Ultimate Display" noted the potential for incorporating other methods of sensory input, including tactile, to create a display that serves as many senses as possible, thus making the virtual world more real. At this point, interacting with virtual or computer-based models does not create the same experience as interacting with physical models because the properties of physical models are difficult to mimic in virtual environments (Clark & Bailey, 2002). The most common interactive graphics systems still often rely upon mouse-based 2D interfaces for the manipulation of 3D data and the creation of geometric models. Any direct or physical operation on these objects using a 2D mouse is both unnatural and counter-intuitive (Dachille, Qin, Kaufman, & El-Sana, 1999). Therefore, testing and teaching visualization in a primarily visual manner using computer based materials, animations and simulations, may not be fully realizing the visualization abilities of the subjects, especially those with identified difficulties in visualization, because most subjects are able to understand haptic language, communication through touch, in an intuitive and relatively effortless manner as it is learned while they are young, at the same time as they learn other languages (MacLean, 2000).

Conclusions

According to Lowenfeld's (1945) theory, subjects are visual, haptic, or indefinite. Those subjects classified as visual, tend to orient themselves to the world through visual perception, and have the ability to integrate partial visual impressions into a whole object. Haptic individuals tend to orient themselves to the world through touch/tactile input, and are not able to integrate the partial visual impressions into whole objects. An indefinite subject is neither strongly visual nor haptic.

There are many identified intellectual abilities for visualization such as spatial orientation, spatial visualization, visual memory, pattern recognition and mental rotation. There are also many categories of tests that measure different aspects of subjects' spatial abilities including recognition, manipulation, and two and three-dimensional transformation. Traditionally, visualization ability has been measured with solely visual tests that do not include a haptic component. With the HVDT results in this study indicating a higher than normal haptic visualization ability in the test subjects, testing and teaching visualization in a primarily verbal and visual manner may not fully realize the visualization abilities of these subjects. A low score on a traditional non-haptic test of visualization would not necessarily mean low visualization ability, perhaps just different visualization ability. And low performance in an engineering design graphics course may occur if information is presented primarily in a paper or web-based format without interaction with physical models.

Currently in most classroom situations 3D models with X,Y, and Z coordinates are created and manipulated with a mouse that operates in a 2D XY plane. This could lead to a type of sensory distortion that users may experience because of the differences of motion between the virtual 3D objects they are interacting with and the motion of real world physical objects such as the mouse. The resultant sensory cue conflicts are caused by the scene motion not typically being accompanied by appropriate physical sensation. Since the haptic tendencies of these test subjects were not to the exclusion of high visual tendencies, and with research showing that the sense of touch contributes significantly to the creation of mental models, despite the trend toward the use of animations and simulations, the use of physical objects as examples and other methods of haptic interaction should be considered in ordinary classroom environments to supplement instruction and testing in visualization.

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