Examining the Haptic Object Recognition Behaviors of Pre-Service Technology Teachers

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Abstract

If touch and vision share common mechanisms in forming visual mental images, we hypothesize that observed hand movements during blind haptic manipulations should vary according to the clarity of the image created in the mind's eye. An experiment was conducted to establish the physical behaviors of students hand movements during haptic object exploration. The Haptic Visual Discrimination Test (HVDT) was administered to a group of thirteen undergraduate Initial Technology Teacher Education students. A discreet visual recording of each student completing the test was conducted enabling retrospective analysis of physical behaviors during manipulation episodes. The purpose of the study was to explore the possible merits in capturing real-time visual footage of hand-movement during the HVDT in order to establish if we can learn more about the tacit nature of physical behaviors and responses during haptic manipulations. Detailed analysis of data for two participants provides clear evidence of both similarities and differences in behaviors and approaches to examining physical objects. We believe that further investigations are merited and we hope that discussions at the conference will help us in further refining the method and stimulate discussion around possibilities for this research within engineering graphics education.

Introduction

Our everyday environment is experienced through various sensory modalities working together. Although the visual system plays an important role in sensory perception, visual mental images of objects can be created by haptic exploration alone (Norman et al., 2004). Objects can be quickly and accurately defined using our sensory system by extracting basic features and their spatial arrangement (Pensky et al., 2008).

In order to visually communicate design ideas and solve graphical problems engineers need to be able to create, manipulate and synthesize visual mental images. The clarity of these images is very much based on the ability to interpret physical and visual information through our senses.

Lederman & Klatzky (1987, p. 342) describe the study of hand movements during haptic manipulations as providing a *"window through which it is possible to learn about the underlying representation of objects in memory and the processes by which such representations are derived and utilized".* While the physical manipulation of objects has been promoted as important in the early stages of spatial skill development (Piaget & Inhelder1967), a limited amount of research has been conducted in examining the behaviors of expert haptic manipulators. This was the main focus of this study.

Method

Thirteen students on an Initial Technology Teacher Education program at University of Limerick volunteered to take part in the study. The participants were recruited after responding to an email sent to their class group by the researcher. All participants were male with an age range from 18-36 with a mean age of 20.6 years.

The Haptic Visual Discrimination Test (HVDT) was used to obtain a measure of students' haptic object recognition abilities. The HVDT consists of four sections; shape, size, texture and configuration. The test was administered using the standard protocol described in the guidelines for the test. The basic procedure was for each participant to haptically explore 48 individual items and select the object they believe they are manipulating from a chart with multiple items displayed. The haptic manipulation was conducted in a blind fashion using a screen that the participants' placed both hands through. A discreet camera was set up to record the physical hand movements of the students as they completed each of the forty-eight tasks in the test. This enabled us to analyze psychomotor behaviors and reaction times subsequent to the completion of the test.

The experiment was approved by the University of Limerick, Faculty of Science and Engineering Ethics Review Board.

Results and commentary

The overall scores in the Haptic Visual Discrimination Test (HVDT) are shown in Table 1.

Table 1. Overall Scores in the Haptic Visual Discrimination Test (HVDT)

Number of Students	13
Mean Score	39.92
Standard Deviation	2.98
Variance	8.22
Minimum	34
Maximum	44

The scores in this study are very similar to those reported by Study (2003) where they reported a mean score of 39.54 (N = 218) with a group of freshman engineering students at Purdue University. Interestingly, Lane and Sorby (2015) have reported that Irish students typically have lower spatial skills than their international counterparts on entry to third level education. However, their spatial skills have been found to have significantly improved after undertaking a special spatial skills and sketching class integrated into the first year Initial Technology Teacher Education (ITTE) program at University of Limerick. The use of haptic activities when teaching students who traditionally underperformed on tests of spatial ability has been shown to improve visualization test scores more than relying solely on traditional methods of instruction (Study, 2006). All students who took part in this study had already completed this spatial skills and sketching class before taking the HVDT.

The HVDT is composed of four sections; Shape, Size, Texture and Configurations. There are 12 elements in each section with one mark awarded for each correct answer. The overall scores for each of these sections are shown in Table 2.

Table 2. Section breakdown in the Haptic Visual Discrimination Test (HVDT)

	Shape	Size	Texture	Configurations
Mean Score (N = 13)	11.77	8.69	8.38	10.69
Standard Deviation	0.44	1.84	1.26	1.32
Minimum	11	7	6	8
Maximum	12	12	10	12

In total we analyzed 624 manipulation episodes where each of the 13 students completed 48 independent tasks. We conducted a correlation analysis to determine if there was any relationship between reaction time and scores for each of the four sections of the test. No significant correlations were observed. It should be noted that as per the HVDT protocol, participants were not given a time limit for the test and the absence of a correlation is not surprising. We believe that this could possibly be different if testing conditions were changed and students were given a time limit, similar to the approach taken in studies by Pensky et al. (2008) and Norman et al. (2004).

A video recording of each test was taken in order to facilitate retrospective analysis of behaviors and reaction times. Lederman & Klatzky (1987) describe eight distinct procedural hand movements that can be reliably observed during physical manipulation of 3D objects. These distinctly different movements (shown in Figure 1) were used to classify the type of procedure used by each student for each object in the HVDT.

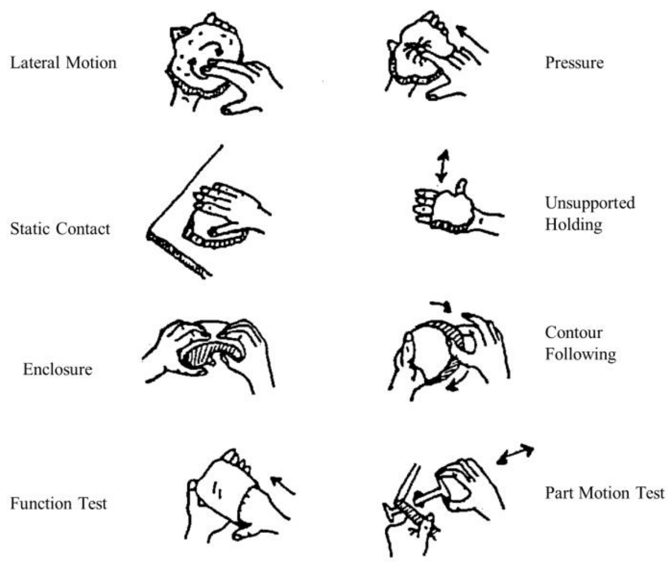

Figure 1. Typical movement pattern for exploratory procedures (Lederman & Klatzky, 1987)

In order to examine the behaviors observed during the physical manipulations we closely analyzed the 'best' and 'worst' students based on the overall scores for the purposes of this digest.

Table 3. Analysis of video recording data

	Participant 9 'worst'	Participant 10 'best'
Overall Score	34	44
Total Time Manipulating	606 seconds	637 seconds
***'Lateral Motion'* instances**	40	44
***'Pressure'* instances**	44	38
***'Static'* instances**	0	3
***'Unsupported Holding'* instances**	0	0
***'Enclosure'* instances**	26	14
***'Contour Following'* instances**	15	16

While there are no notable differences in time, the analysis of the applied procedures yields some interesting observations. Both participants were observed to have used a similar amount of procedures, but there was a notable difference in the number of times that the ‘enclosure’ procedure was used by Participant 9. This suggests that they were unable to definitively create a visual mental image of the objects using procedures such as ‘lateral motion’ and ‘contour following’. Enclosure does not support any detailed examination of intricate details of objects. Lane & Carty (2014) previously reported a similar observation when students sketched objects that were haptically manipulated. They reported that poor visualizers tended to rest / place their hands on objects and did not manipulate the objects in any great detail were applied by weak visualizers.

Conclusions

This research study highlights the importance of examining the haptic tendencies of students when forming visual mental imagery. The role of touch in supporting the development of 3D objects is particularly important and this has been widely supported in contemporary research. If both vision and touch share common mechanisms, engineering graphics educators should develop classroom based activities to ensure that all students have the option of both and that we do solely rely on virtual, digital imagery. We hope our future research will lead to a refinement and validation of the method trialed in this study, eventually leading to a large scale international study across different disciplines of engineering education. Through this we hope that we can gain a more detailed understanding of the tacit nature of haptic manipulation skills and the relationships (if any) with other aspects of cognition such as problem solving, spatial skills and creativity.

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