

A Haptics Experiment in Assistive Technology for Undergraduate HCI Students

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Abstract

While many Human-Computer Interaction (HCI) courses mention the concept of assistive technology (AT) for the disabled, they seldom do more than give a brief overview of the subject – there are few suggestions for assignments in common HCI textbooks related to assistive technology. In addition, in computer science we seldom get an opportunity to conduct real experiments, as they do in the physical sciences, i.e. form an hypothesis, test the hypothesis, and evaluate the test results. Within HCI we do occasionally get to test innovative input or output devices or techniques, but most frequently this occurs as a usability study, which is not the same as a scientific experiment. This paper describes the development of a scientific experiment using a SensAble Phantom force-feedback device as a potential device for the visually impaired.

1 Introduction

As part of the National Science Foundation grant project "Integrating Haptics into an Undergraduate Computer Science Curriculum" (Webster, Liffick & Hutchens, 1999), we acquired a SensAble Phantom haptics device. The uniqueness of this device provided an opportunity to devise a student project that was (1) introductory to the concept of assistive technology, (2) a true experiment in the classic sense of the sciences, (3) was of small enough scope that it could mostly be constructed and conducted by undergraduate students in a one-semester HCI course, and (4) was sufficiently complex and outside of the students' typical experience such that they could not anticipate the outcome.

There have been a number of projects that have attempted to show the usefulness of haptics as an interaction method for blind users. The Moose project {O'Modhrain and Gillespie, 1997} developed a force-feedback mouse that would present unique haptic feedback for graphical objects such as windows, icons, and checkboxes. Spatial maps have been suggested as a way for blind users to learn new environments they wish to traverse (Schneider and Strothotte, 2000). A combination of audio feedback and haptics was used to help blind students understand line graphs better (Ramloll *et al.*, 2000). The most ambitious projects are being conducted by the Certec group at Lund University (Sjöström, 2001). Several projects have explored issues of navigation, finding objects, and understanding objects using haptic devices such as the SensAble Phantom.

All of these instances, however, rely almost exclusively on anecdotal testing, in a "discount usability study" sort of way (Nielsen, 1994). While this technique is certainly useful, I wanted to

demonstrate to my HCI students that sometimes formal experiments are desirable, even necessary, and to demonstrate the required steps that are important for a successful experiment.

Finally, for me one of the troubling aspects of teaching HCI over the past several years has been that students appear to have a warped sense of what “usable” means. It appears that many CS majors believe that a usable system is any that they can figure out how to use, regardless of how long it took or how difficult it was for them to learn. They then apply this internal view of what is usable when personally evaluating any new system, with little regard for the “typical” or special needs user. I felt it was important, then, that this project involve a technology that they had not themselves mastered, as a way of helping them appreciate the trials and tribulations of other novice users. The focus of this project on the factor of visual disability is an intentional means to force students outside of their usual egocentric perspectives.

2 The Project

The project was broken down into several key tasks:

- Defining the experimental question (i.e. forming the hypothesis)
- Selecting an experiment to test the hypothesis
- Becoming familiar with the equipment and software to be used in the experiment
- Developing software that supports the experiment’s activities and data collection needs
- Defining constraints related to choosing test subjects, subject training, and the design of unbiased testing protocols
- Defining factors related to the design of the experiment, such as what data is to be collected, what virtual objects will be displayed, and the nature of these objects (e.g. size, texture, position, orientation)
- Conducting the experiment with human subjects, including the necessary steps for getting permission to conduct the experiment, collecting consistent data across multiple student teams, and creating an aggregate database of test results
- Analyzing the collected data.

2.1 The Hypothesis

The experimental question for this project was based on the notion that persons who are blind might be able to use the touch capability of the Phantom device to identify geometric objects within a virtual space. This might ultimately allow blind users to successfully access a typical graphical computer display using such a device. The formal hypothesis of this experiment attempts to reduce this idea to a form that was within the scope of ability and time for a typical undergraduate HCI course:

Hypothesis: Blind users are more adept at recognizing basic geometric shapes using the Phantom haptics device than sighted users when the shapes are not visible to the user.

2.2 Designing the Experiment

The first surprise for the students was to learn that this hypothesis might be tested with a variety of different experiments. Our first discussion, then, centered around the nature of potential experiments, and what needs to be done to ensure that the experiment is not accidentally biased. Furthermore, it was necessary to discuss the issues related to constructing a valid scientific

experiment instead of an informal anecdotal study. The constraints of a formal experiment was a relatively new idea to these students, even though they had all completed many hours of physical science courses. In these other science courses, the experiments they conducted were already designed – they only had to conduct the experiment and analyze the data.

The initial task was to ensure that the selected experiment actually tests the given hypothesis. During brainstorming sessions conducted in teams, students identified a number of experiments that, while valid in their own way, did not really address the hypothesis. What did come out of these discussions, however, was basic ideas about how an experiment of this sort should be conducted, e.g. using timed results, counting errors, identifying initial and final states for the experiment, multiple test trials, ensuring uniformity in testing over multiple subjects and testers, avoiding biases in the tests, training subjects to use the testing device, etc.

After listing their ideas and allowing comments by the rest of the class, I simplified one of the ideas down to a level that I felt was within the scope of time and ability of the class: have four test trials for each subject; for each trial, randomly project basic geometric objects of a specific size into virtual space at a known location one at a time for the subject to identify, with a sufficient number of trials to ensure that all objects were likely to be projected at least once; each subsequent trial would reduce the size of the objects, starting at about 4 inches in size and reducing to about 0.5 inch in size; each identification task would be timed; the subject would have one opportunity to give an identification of the object, and the number of incorrect identifications would be kept. Furthermore, although the Phantom is a 3-D device, for this initial experiment I decided to reduce space to essentially only 2 dimensions. This was done to reduce the amount of training time for the subjects to learn to use the Phantom, and to make the objects to be identified as basic as possible: a square, rectangle, circle, triangle, and diamond shape.

Figure 1 shows the experiment's setup. The board in front of the Phantom is used to reduce the range of motion of the Phantom's arm to 2 dimensions – as long as the user keeps the stylus in contact with the board, any object encountered in the virtual space will be perceived in only the x and y dimensions. Thus, a sphere reduces to a circle, a cube to a square, a box to a rectangle, etc. During actual trials of the experiment, the monitor will be turned away from the user so that they cannot see the object they are attempting to identify. In the center of the board is a small depression marking the "home" position for calibrating the Phantom. About 3 inches to either side of the home position is a "start" position, which is also marked with small depression. Two starting positions were provided to accommodate both right- and left-handed users. Locating the object (not a part of the experiment) is accomplished simply by moving the stylus along the board in line from the start position toward the home position.

2.3 Conducting the Experiment

A formal *training protocol* was developed and incorporated into the experiment, since the expected test subjects were prohibited from having experience with the Phantom device.

Other apparatus issues were discussed, including the positioning of the test subject and the device, the method to be used in limiting the Phantom to 2 dimensions instead of 3, how timing would be accomplished, how the Phantom was to be initialized and "homed," how the user would signal and enter their identification attempt, how the starting and stopping of the experimental trials would be signaled, etc. This led to the development of *testing protocols*, i.e. sets of written instructions for the test subjects and the test conductors to follow, as a way of ensuring that all students conducted



Figure 1: Student Steve Gumphier tests out the experiment's apparatus.

the same experiment without biasing the results. Environmental issues for the test subjects were discussed, e.g. for sighted subjects, would they be blindfolded, or would the monitor simply be turned away from them so that they couldn't see the current test object that was in virtual space.

Finally, the problems of dealing with human test subjects was discussed. Some issues included how test subjects would be selected or rejected (what are the desired or undesired characteristics of subjects), how the subjects would be trained, how long the experiment would last, subject consent forms, and getting permission from the university Human Subjects Committee to conduct the experiment. This was also a good opportunity to discuss the appropriate collection, disposition, security, and confidentiality of personal data of test subjects, and the appropriate limits of what demographic data would be collected for this particular project.

3 The Results

The 22 students of the course worked either as individuals or in teams of 2, resulting in 15 teams. Each team developed its own test program, based on a training program provided by the course instructor. Each team was responsible for conducting its own tests on 5 test subjects for each student experimenter. Although the full experiment called for a comparison between sighted and unsighted test groups, the teams were able to only test the sighted subjects due to time constraints. Four of the 15 teams produced entirely invalid results, caused by improperly defining the range of statements within their code that would be timed. All other teams developed successful tests.

4 Lessons Learned

Although we were unable to complete the entire experiment with two sets of test subjects at this time, the students clearly benefited from the project from several perspectives. First, it gave them an awareness of disabilities issues that had never been addressed within their curriculum before, and did so in a novel and engaging way. Many of the students reported that having to think about the needs of such a specialized group of users (i.e. the unsighted) was highly illuminating for them. It gave me a good opportunity to illustrate how important it is to take user group

characteristics into account when designing systems, not just for disabled users alone. Using a disabled group as a focus of this experiment made it possible to force the students to think outside of themselves and their own experiences for a change. This is a vital lesson for young computer professionals to learn, and I am highly encouraged that using disabled users as focal points for projects and assignments is an effective way of promoting that ability.

The experiment itself also forced test subjects into a role similar to having a disability (i.e. blindness), since they had to rely entirely on the sense of touch in order to perform the task. As the student teams developed their software, they initially struggled with this limitation. This struggle itself gave the students an appreciation for the difficulties of disabled users, and an awareness of the need for universal design issues. Furthermore, it gave them a sense of the possibilities for using input/output devices in novel ways to assist disabled users. The concept of "assistive technology" suddenly had a concrete meaning to them.

Although some of the students, especially those with the least ability, approached the Phantom device with a certain amount of trepidation, all eventually were able to complete the programming of the device sufficiently to conduct tests with real subjects – even those who improperly coded the timing mechanism were still able to run the tests, even though their results were entirely invalid. By using such a unique device, the students' natural curiosity and interest in technology meant that they all found the project to be fun and challenging.

Finally, it was very clear from the beginning of this project that few of the students really understood the nature of a scientific experiment, as opposed to anecdotal study. They were surprised by the amount of formality that had to be built into the experiment. The need for training and testing protocols was clearly new to the students.

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