The Impact of Haptic and Visual Feedback on Teaching

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Abstract

Haptic feedback, an important aspect of learning in virtual reality, has been demonstrated in contexts such as surgical training. However, deploying haptic feedback in other educational practices remains understudied. Haptically-enabled science simulations enable students to experience abstract scientific concepts through concrete and observable lessons in which students can physically experience the concepts being taught through haptic feedback. The present study aims to investigate the effect of an educational simulation on the understanding of basic physics concepts related to buoyancy. Specifically, we hypothesize that a simulation with visual and haptic feedback will improve participant learning transfer.

Index Terms: Human computer interaction (HCI)—Interaction paradigms—Virtual reality; Education—Interactive learning environments

1 Introduction

Virtual reality (VR) systems are commonly used for training and education in numerous disciplines including medical [3] and K-16 education [2]. A common reason for using VR in these training and education scenarios is due to the VR enabling users to experience situations that "cannot be accessed physically" including traveling back in time, visiting outer space, or training in life-threatening situations such as fire fighting or surgical training simulations [2].

The effectiveness of VR training and education systems is paramount to their application for future use. Even though it is accepted that VR is beneficial for education, the impact of visual feedback and haptic feedback on comprehension is less well understood. The importance of haptic feedback has been demonstrated for surgical training [1], however it has remained understudied in science, technology, engineering, and mathematics (STEM) learning environments [5].

2 Background

Haptically-Enabled Science Simulations (HESSs) Elementary school teachers often have limited opportunities for their students to practice complex mechanistic reasoning - including about the concepts and laws of physics. These complex and abstract ideas are often thought to be beyond students' grasp, and thus not tied directly to a concrete and directly observable lesson. Because of this, these lessons are usually postponed until higher grade levels [4]. This limits student opportunities to reason about the hidden mechanisms such as the "how," "when," and "why" of observed phenomena.

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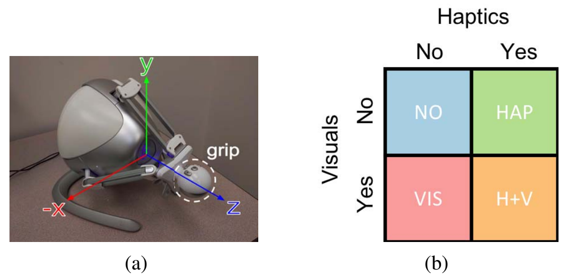

Figure 1: (a) A photo of the Novint Falcon used in our experiments. The device can track user movement of the grip and apply forces in 3D. (b) The abbreviations for each of the four between-participant conditions. NO - No haptics and no visuals (blue), HAP - haptics and no visuals (green), VIS - no haptics with visuals (pink), and H+V - haptics and visuals (orange).

Including HESSs into these instructors' teaching materials could aid in an earlier introduction of these ideas and, in return, encourage more exploration of said concepts as an earlier age. We address these missing areas of elementary science curricula by suggesting the use of haptic force-feedback technology. Use of HESSs could also be used to help preservice teachers, students training to become teachers, construct consistent models regarding physics content. Improving the teaching of basic physics with their students early on will help lay the groundwork for future STEM learning.

Specific Aims This preliminary study aims to better understand how people learn phycis concepts and how the use of STEM knowledge matched with an additional resource can make this learning more effective. Its intertwined project goals are to:

(1) Add foundational human-computer interaction (HCI) knowledge to guide the design, development, and testing of haptically-enabled learning environments (HESSs).

(2) Isolate and document the haptic influences on the development of teachers' specialized content knowledge of forces as interactions.

(3) Study the pedagogical impact of HESSs on elementary preservice teachers.

3 System Design

3.1 Equipment

The haptic device used in this study was a Novint Falcon force-feedback device (Fig. 1 (a)). The Falcon supports 3 degrees of freedom (DoF) position tracking of its grip: left and right (x-axis), up and down (y-axis), and forward and backwards (z-axis). The Falcon is capable of rendering haptic forces along these three axes. The details on rendering haptic forces in our study are described in Sect. 3.2.

The experiment was run on the Unity 5.6.7 engine on an Alienware Aurora R6 desktop computer. The computer had four Intel Core i7-7700 cores (3.60 GHz), 16.0 GB of RAM, an NVIDIA

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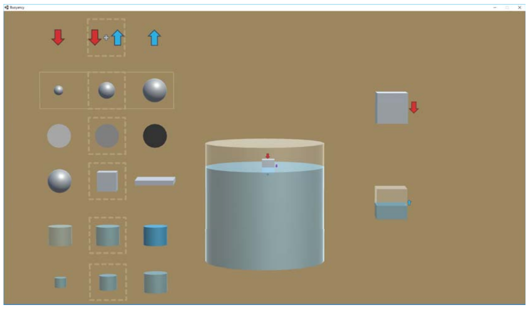

Figure 2: A screenshot of the simulation used in our experiment. The property selection menu is shown on the left side of the screen. In the center is the container, liquid, and buoyancy object. In this image, the object is set to a cube and is floating near the center of the container. On the right side of the screen is a visualization of the buoyancy object (top) and the volume of the displaced liquid (bottom).

GeForce GTX 1080 GPU, and 64-bit Windows 10. The experiment was displayed on a Dell monitor with a 1680 × 1050 resolution.

3.2 Buoyancy Simulation

We created a desktop virtual environment to simulate and visualize different properties of a buoyancy simulation in real time. A screenshot of the environment is shown in Fig. 2. The environment includes a container of liquid and an object that interacts with the liquid. The system models Archimedes' principle, calculating the object weight from the object density and volume, and the buoyant force from the liquid density and how much the object is submerged in the liquid. The user can manually move the object into and out of the liquid, or let go of the object, enabling it to sink or float.

4 Methods

To determine the effect of haptics and visual feedback on user-learning of buoyancy we performed a 2 (haptics: yes, no) × 2 (visuals: yes, no) between-participant user study approved by the Davidson College institutional review board. The experimental design, color coding, and abbreviations used for the four conditions are depicted in Fig. 1 (b). The visuals comprised force arrows indicating the object weight, buoyant force, and net weight + buoyant force. Participants in the NO and HAP conditions did not see the arrows on the selected object or objects on the right side of the scene. The haptic feedback for the Novint Falcon was turned off for participants in the NO and VIS conditions, however participants still used the Novint Falcon to move the object.

4.1 Measures

Buoyancy Questionnaire. An assessment was administered pre- and post-experiment to assess buoyancy knowledge. The questionnaire included yes-or-no questions to determine if a described object will float or sink, followed by a free response option that prompts participants to justify their answer. Additional short response questions require calculations about buoyancy.

4.2 Participants

A total of 41 participants were recruited from Davidson College, faculty, and general public via email and flyer solicitation and snowball recruitment (age = 20 ± 6, 24 women). Participants were compensated with $10 (USA) gift card for participation. Participants were at least 18 years of age, fluent in written and spoken English, did not major in physics.

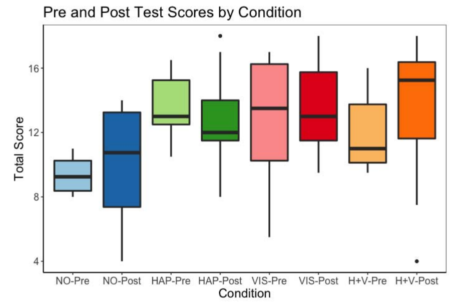

Figure 3: The pre and post test scores for each condition. The pre-test scores are in light colors and the post-test scores are in dark colors.

5 Results

Test scores were graded by two independent graders using the same rubric. Any questions that received conflicting grades were graded by a third grader.

Analysis of participants pre and post-test total scores was performed with a 3 (Condition: HAP, VIS, H+V) × 2 (Test: pre, post) ANOVA with condition as a between-participant measure and test as a within-participant measure. The assumption of homogeneity of variance was checked using Levene's test. Planned post-hoc comparisons looking at changes between pre and post test scores by condition were performed using least-squares means with Tukey adjustments.

A distribution of the total pre-test and post-test scores can seen in Figure 3. A significant main effect pre and post test scores was found, $F(1,35) = 4.21$, $p = .05$, $\eta^2 = .02$. A significant performance improvement was found in the H+V condition, $t(35) = -2.46$, $p = .02$ from the pre-test ($M = 13.42$, $SE = 1.00$) to the post-test ($M = 15.21$, $SE = 1.00$). No other significant changes from pre to post test scores were found. See Figure 3.

6 Conclusion

These preliminary results highlight that participants significantly improved their understanding of buoyancy, as measured by a pre and post-test assessment, when aided by both visual and haptics. The same increase in performance was not seen when participants were given haptics alone or visuals alone.

Acknowledgments

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