Design, Development And Evaluation of An Interactive Virtual Haptics-augmented Training System for Undergraduate Engineering

Robert L. Williams II, Ernur Karadogan, David. R. Moore, and Tian Luo
Mechanical Engineering and Instructional Technology
Ohio University

2013 TUES/CCLI PI Conference
January 23-25, 2013
THE BIG PICTURE

- NSF-funded project
- The Precursors
- 2-6 grades elementary school students' opinions (N=56)
- Simple machines concepts: i.e. Lever, Pulley, Inclined Plane
- Physics, Statics, and Dynamics
- Freshman and sophomore students at Ohio University,
- Products with physics (N=64), statics (N=15), and dynamics
- (N=21) classes
TWO CONFLICTING THEORIES

- Pavio’s (1986) dual-coding theory
  Haptics as an additional sensory channel might be encoded beyond verbal information, which could improve and reinforce learning.

- Cognitive load theory (Sweller, 1994)
  One’s working memory is limited in scope and thus any activity that overloads that scope, such as haptics, will be ineffective.
## DESIGN PHASES I

<table>
<thead>
<tr>
<th>Phase</th>
<th>Task</th>
<th>Notes</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Interface Design</td>
<td>on-going revision</td>
<td>Winter 2010-11</td>
</tr>
<tr>
<td>1</td>
<td>First Module Design</td>
<td>Interactive Free Body Diagram</td>
<td>Winter 2010-11</td>
</tr>
<tr>
<td>1</td>
<td>Tutorial Development</td>
<td>on-going revision</td>
<td>Winter 2010-11</td>
</tr>
<tr>
<td>1</td>
<td>Documentation</td>
<td>on-going</td>
<td>Winter 2010-11</td>
</tr>
<tr>
<td>2</td>
<td>Test Questions Development</td>
<td>on-going revision</td>
<td>Spring 2010-11</td>
</tr>
<tr>
<td>2</td>
<td>Formative Evaluation I (one-to-one evaluation)</td>
<td>with Dr. Bob</td>
<td>Spring 2010-11</td>
</tr>
<tr>
<td>2</td>
<td>Formative Evaluation II (small-group evaluation I)</td>
<td>Initial user test with 6 students, revisions made</td>
<td>Spring 2010-11</td>
</tr>
<tr>
<td>2</td>
<td>Second Module Design</td>
<td>Rigid Body Diagram</td>
<td>Summer 2010-11</td>
</tr>
</tbody>
</table>
# DESIGN PHASES II

<table>
<thead>
<tr>
<th>Phase</th>
<th>Task</th>
<th>Notes</th>
<th>Timeline</th>
</tr>
</thead>
<tbody>
<tr>
<td>3</td>
<td>Evaluation Protocol Development</td>
<td>on-going revision</td>
<td>Fall 2011-12</td>
</tr>
<tr>
<td>3</td>
<td>Formative Evaluation II (user test/small-group evaluation II)</td>
<td>2&lt;sup&gt;nd&lt;/sup&gt; user test with 2 students, revisions made</td>
<td>Fall 2011-12</td>
</tr>
<tr>
<td>4</td>
<td>Formative Evaluation III (to test the effectiveness of the software in enhancing students’ understanding of abstract haptic concepts)</td>
<td>with two classes of Engineering –major students</td>
<td>Winter 2011-12</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Spring 2011-12</td>
</tr>
<tr>
<td>5</td>
<td>Analyzing results</td>
<td></td>
<td>Summer 2011-12</td>
</tr>
</tbody>
</table>
THE INTERFACE
SOFTWARE IMPLEMENTATION

- It is programmed on a PC with Visual C++, OpenGL for graphics, and DirectX for haptic interaction (position input and force output), using a Logitech Force 3D Pro haptic joystick.
An Instructional Tutorial
of Haptics-Augmented
Training Suite for
Undergraduate Mechanics
Haptics-Augmented Software Choice Menu

Haptics-Augmented Software Results and Messages Window
Interactive FBD Variables Window

Interactive Plots Window
ONCE YOU CLICK ACTIVATE...
RESEARCH QUESTIONS

- RQ1A: Do participants with haptic augmentation achieve more in reference to *conceptual questions* compared to their visual only counterparts?
- RQ1B: Do participants with haptic augmentation achieve more in reference to *factual questions* compared to their visual only counterparts?
- RQ2: Do participants with haptic augmentation spend more *time-on-task* than visual only participants?
- RQ3: Do participants with haptic augmentation *express more confidence* overall compared to their visual only counterparts?
- RQ4: Do participants with haptic augmentation *express more motivation* compared to their visual only counterparts?
PROCEDURES: STAGE I

- Exploration of the Particle Dynamics (box on the ramp) Module
  - Levels randomized

  - 3-minute time limit expired?
    - YES
      - Conceptual and Factual Questions
    - NO
      - Are all four levels completed?
        - Level Change
PROCEDURES: STAGE II

Are all four levels completed?

NO

VISUAL GROUP

Visual Experience Questions (with confidence ratings)

YES

HAPTICS GROUP

Haptic Experience Questions (with confidence ratings)

Ask participants’ comments / experience (Open-ended)
BREAK-DOWN OF EVALUATION QUESTIONS

- Level-specific Test Questions
- Conceptual and factual questions
- Experience Questions (visual vs. haptics)
- Confidence ratings
- Open-ended Questions
- As qualitative data
TWO MAJOR TYPES OF INSTRUMENTS

- Type 1: level-specific conceptual and factual questions are presented to test students’ understanding of critical dynamic concepts.
TWO MAJOR TYPES OF INSTRUMENTS

- Type 2: Haptic-only questions that are only pertinent to their haptics experience rather than general factual and conceptual testing questions are asked.
- These questions were designed to distinguish the effect of the haptics from the visual feedback.
- Confidence ratings were added which required students to rate their confidence level of the question they just answered.
PARTICIPANTS

- 51 student volunteers
- Engineering majors
- From a large, mid-western, public university
- Aged from 20 to 25 years old
- 43 of 51 have taken a course which provided some prior knowledge
## Results

### Achievements

<table>
<thead>
<tr>
<th></th>
<th>Haptic group</th>
<th>Visual group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Conceptual (stage 1)</td>
<td></td>
<td>Higher</td>
</tr>
<tr>
<td>p = .036 &lt; .05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Factual p = .851 &gt; .05</td>
<td>Non-sig</td>
<td></td>
</tr>
<tr>
<td>Experience/Haptic only questions</td>
<td></td>
<td>Higher</td>
</tr>
<tr>
<td>p &lt; .001 &lt; .05</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

- Time-on-task

<table>
<thead>
<tr>
<th>Time spent on the instructional program excluding flash tutorial p = .119 &gt; .05</th>
<th>Haptic group</th>
<th>Visual group</th>
</tr>
</thead>
<tbody>
<tr>
<td>Non-sig</td>
<td>--------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Time spent on the Flash tutorial p = .007 &lt; .05</td>
<td>More time</td>
<td></td>
</tr>
<tr>
<td>Stage 1: Time spent in answering conceptual questions p = .111 &gt; .05</td>
<td>Non-sig</td>
<td></td>
</tr>
<tr>
<td>Factual questions p = .678 &gt; .05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stage 2: Time spent on the experience/haptic-only section p &lt; .001 &lt; .05</td>
<td>More time</td>
<td></td>
</tr>
</tbody>
</table>
RESULTS

- Confidence ratings
  - Visual group is Higher ($p < .001 < .05$)

- Motivation
  - Haptic group is more motivated
CONCLUSION AND RECOMMENDATIONS

- Our findings indicate that haptic augmentation had limited empirical support.
- With experienced students in higher-order engineering and science fields, haptic-augmentation contributes little to the learning of the material and may in fact inhibit learning.
CONCLUSION AND RECOMMENDATIONS

- A positive affective and attitude effect
- Caution: Hawthorne Effect
- Indications: Hapics-augmentation could be put to use for populations of students who are at risk for dropping out or moving away from technical and engineering professions.
Potential reasons

Many of the concepts we chose to teach were too simple for our target population

Learners were being provided with too much context and that context was limiting their interest

Less-experienced learners may be able to profit more from the haptics-augmentation
REFERENCES


REFERENCES