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

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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
 1. Haptics-Augmented tools designed for K12 education (2003)
 - ✗ 2-6 grades elementary school students' opinions (N=56)
 - ✗ Simple machines concepts: i.e. Lever, Pulley, Inclined Plane
 2. Haptics-Augmented tools designed for undergraduate engineering education (2007)
 - ✗ 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

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

DESIGN PHASES II

Phase	Task	Notes	Timeline
3	Evaluation Protocol Development	on-going revision	Fall 2011-12
3	Formative Evaluation II (user test/small-group evaluation II)	2 nd user test with 2 students, revisions made	Fall 2011-12
4	Formative Evaluation III (to test the effectiveness of the software in enhancing students' understanding of abstract haptic concepts)	with two classes of Engineering –major students	Winter 2011-12 Spring 2011-12
5	Analyzing results		Summer 2011-12

THE INTERFACE

Training Suite for Undergraduate Mechanics

File Edit View Help

WELCOME (USER name)! You can use this button to change your preferences. Preferences...

Course View

- Undergraduate Mechanics
 - Dynamics
 - Interactive Free-Body Diag
 - Particle Dynamics
 - Rigid Body Dynamics
 - Conservation of Energy
 - Statics
 - Vector Addition
 - Concurrent Forces
 - Goes on...
 - and on...
 - and on...

Variables View

Mass (kg) : 5 15 10

Ramp Angle (deg) : 0 60 30

Force Angle (deg) : 0 30 15

Dynamic Friction Coeff. : 0.00 0.50 0.25

Static Friction Coeff. : 0.35 1.00 0.67

Applied Force (N) : 0.00 103.01 51.51

Reset Variables...

I would like to:

☐ Answer the questions...

ACTIVATE

CANCEL

Results and Messages

>> Training Suite for Undergraduate Mechanics, Version 1.0
>> © Copyright Ohio University 2011
>> WELCOME!

Check this section regularly for results and any other relevant system messages!

Ready

CAP NUM SCRL

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.

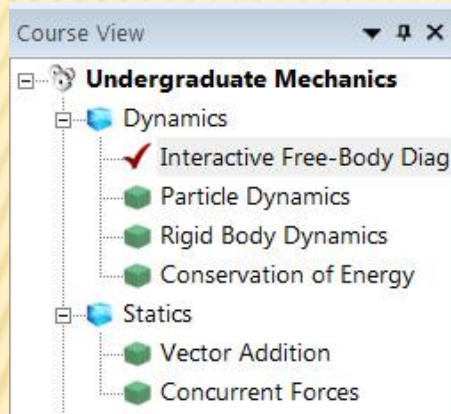


THE TUTORIAL

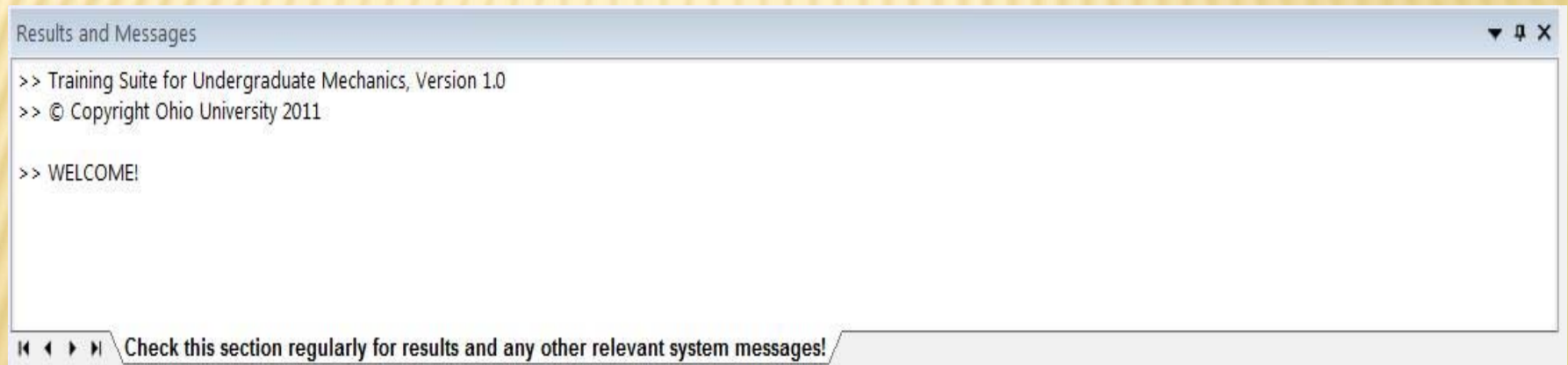
An Instructional Tutorial of Haptics-Augmented Training Suite for Undergraduate Mechanics

Begin

CLOSE-UP



Haptics-Augmented Software Choice Menu



Haptics-Augmented Software Results and Messages Window

Variables View

Mass (kg) :

Ramp Angle (deg) :

Force Angle (deg) :

Dynamic Friction Coeff. :

Static Friction Coeff. :

Applied Force (N) :

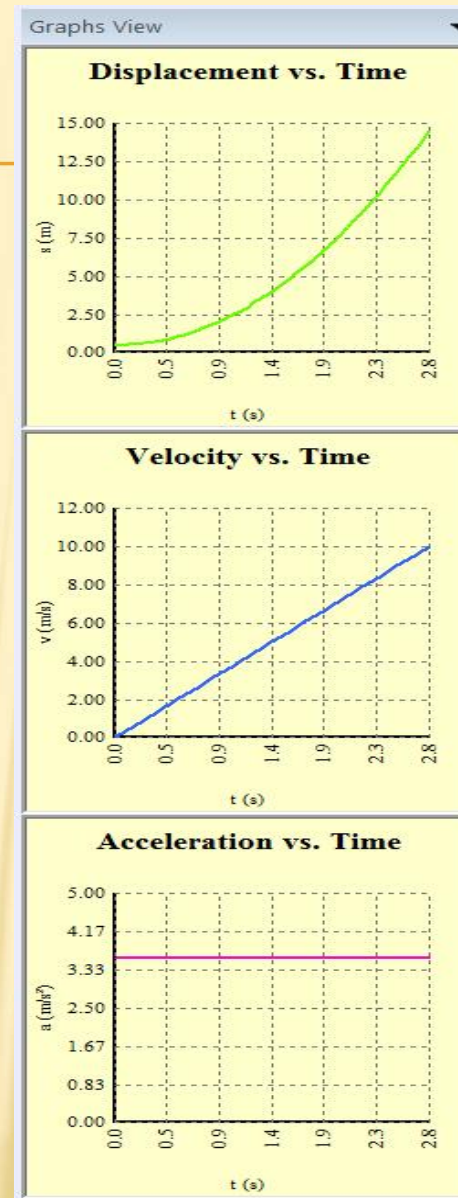
I would like to:

☐ Answer the questions...

ACTIVATE

CANCEL

Interactive FBD Variables Window



Interactive Plots Window

ONCE YOU CLICK ACTIVATE...

Training Suite for Undergraduate Mechanics

File Edit View Help

WELCOME (USER name)! You can use this button to change your preferences. Preferences...

Graphs View

Displacement vs. Time

Velocity vs. Time

Acceleration vs. Time

Variables View

Mass (kg): 5 15 10

Ramp Angle (deg): 0 60 30

Force Angle (deg): 0 30 15

Dynamic Friction Coeff.: 0.00 0.50 0.25

Static Friction Coeff.: 0.35 1.00 0.67

Applied Force (N): 0.00 103.01 51.51

Reset Variables...

I would like to:

☐ Answer the questions...

ACTIVATE

CANCEL

Results and Messages

Mass	10.0 (kg)
Ramp Angle	30.0 (deg)
Force Angle	15.0 (deg)
Dynamic Friction Coeff.	0.25
Static Friction Coeff.	0.67
Applied Force	51.51 (N)
Ramp Length	15.00 (m)
Cube Side Length	1.00 (m)

Check this section regularly for results and any other relevant system messages!

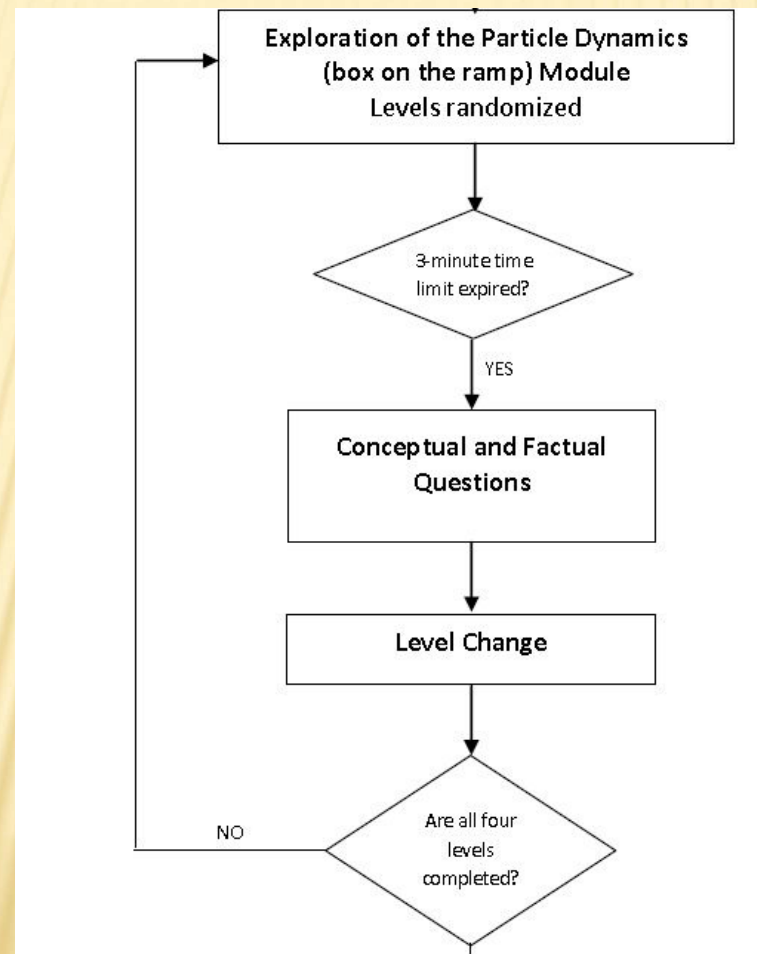
Ready

CAP NUM SCRL

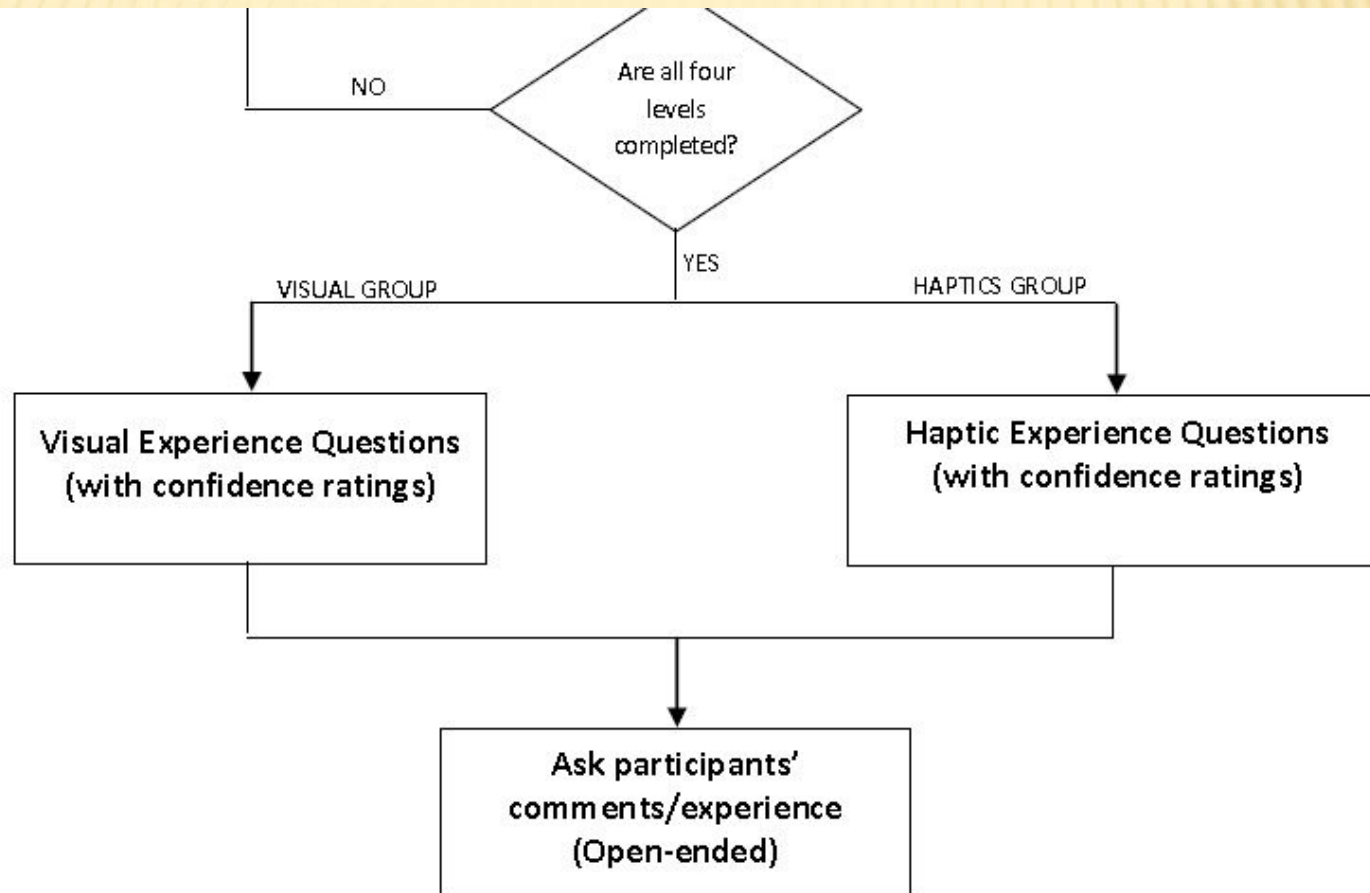
RESEARCH QUESTIONS

- ✗ 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



PROCEDURES: STAGE II



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

- ✗ Type1: level-specific conceptual and factual questions are presented to test students' understanding of critical dynamic concepts

The screenshot displays the 'Training Suite for Undergraduate Mechanics' software. The main window is titled 'Interactive FBD - Numerical Questions'. It features a 'FIGURE 1 Schematic View' showing a block of mass m on an inclined plane at angle θ . Forces acting on the block are gravity g , normal force N , friction force F_f , and an applied force F at an angle ϕ . A coordinate system with x and y axes is shown.

To the right of the schematic is a 'TABLE 1 List of Variables' with the following values:

Variable	Value
F_{app} (N)	-1
Mass (kg)	-1
theta (deg)	-1
phi (deg)	-1
μ_k	-1
μ_s	-1
g (m/s^2)	-1
Ramp Length (m)	-1
Box Side Length (m)	-1

Below the table, two questions are presented:

Q1) Given numerical values for ... $a = 0$ (static case, no acceleration, but impending motion up) what is the minimum force F_{minUP} to hold the box in place? What are the associated numerical values for the magnitudes of the W , N , and F_f vectors?

Q2) Given numerical values for ... $a = 0$ (static case, no acceleration, but impending motion down) what is the minimum force $F_{minDOWN}$ to hold the box in place? What are the associated numerical values for the magnitudes of the W , N , and F_f vectors?

Input fields for F_{minUP} , $Weight$, $Normal$, and $Friction$ are provided for both questions. The 'Results and Messages' pane at the bottom shows a message: 'INTERACTIVE FBD: Simulation has been cancelled by the user!'.

On the right side of the interface, a 'Variables View' panel allows users to adjust various parameters using sliders and input fields:

- Mass (kg): 5 to 15 (set to 13)
- Ramp Angle (deg): 0 to 60 (set to 10)
- Force Angle (deg): 0 to 30 (set to 25)
- Dynamic Friction Coeff.: 0.00 to 0.50 (set to 0.11)
- Static Friction Coeff.: 0.21 to 1.00 (set to 0.85)
- Applied Force (N): 0.00 to 111.85 (set to 51.51)

Buttons for 'Reset Variables...', 'I would like to:', 'Answer the questions...', 'ACTIVATE', and 'CANCEL' are also present.

TWO MAJOR TYPES OF INSTRUMENTS

- ✖ Type2: 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

	Haptic group	Visual group
Conceptual (stage 1) $p = .036 < .05$		Higher
Factual $p = .851 > .05$	Non-sig	
Experience/Hapitcs- only questions $p < .001 < .05$		Higher

RESULTS

× Time-on-task

	Haptic group	Visual group
Time spent on the instructional program excluding flash tutorial $p = .119 > .05$	Non -sig	
Time spent on the Flash tutorial $p = .007 < .05$	More time	
Stage 1: Time spent in answering conceptual questions $p = .111 > .05$ Factual questions $p = .678 > .05$	Non -sig	
Stage 2: Time spent on the experience /haptics-only section $p < .001 < .05$	More time	

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: Haptics-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.

CONCLUSION AND RECOMMENDATIONS

- ✖ 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

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