Iowa Dental SURGICAL SIMULATOR

Virtual Dentistry: The Forces Behind the Pain

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Honors Project Presentation

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- Background
- Experiment One:
  - Formative Evaluation Design
  - Results
- Experiment Two:
  - Signal Detection Test Design
  - Results
- Now What?

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Background

Challenge of Dental Education

- Teach biomedical sciences
- Teach irreversible surgical procedures
- Integrate science with application
- Produce safe practitioner within four years

Further Complications

- Diminishing patient pool
- Increasing costs for patient care

Challenge

- Must decrease the number of procedures performed on human subjects strictly for educational purposes

Project Goal

- Teach and test dental students the subtle tactile and surgical skills required of the dental profession.
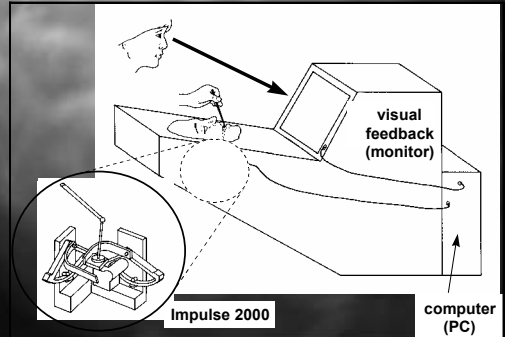
Solution -- IDSS

- Use force feedback (haptics) to teach and assess the tactile skills of dentistry
- Begin with the detection of dentin caries
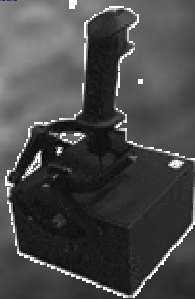- Collaboration between Colleges of Dentistry and Engineering

Initial Research

Nigel Gomez -- College of Engineering

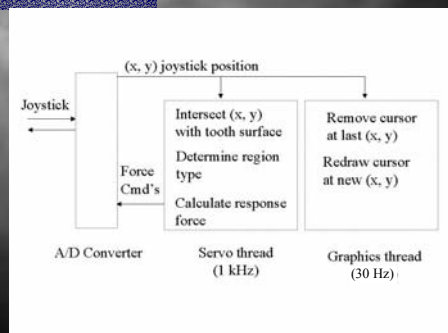- Great variability in the forces expert dentists exerted during probing
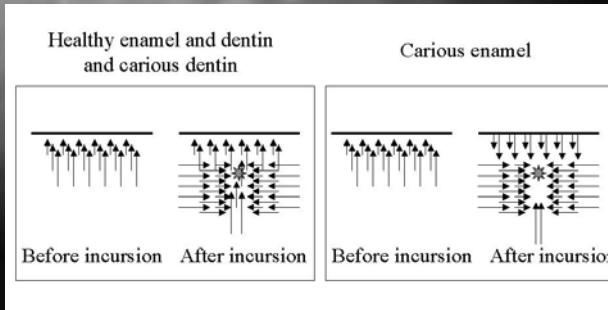
Original Conception

Haptic Device (IE 2000)

Behind the Scenes

The Force Models

Healthy enamel and dentin
and carious dentin

Carious enamel

Before incursion   After incursion

Before incursion   After incursion

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Experiment One:

Formative Evaluation

Evaluation Questions

- Are the forces realistic?
- What _design_ improvements are required?
  - Hand position natural and comfortable?
  - Able to concentrate on probing versus on operating the simulator?
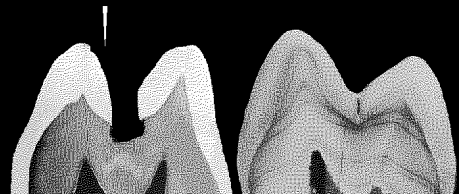 - Are the graphics of sufficient quality?

Probing Tasks
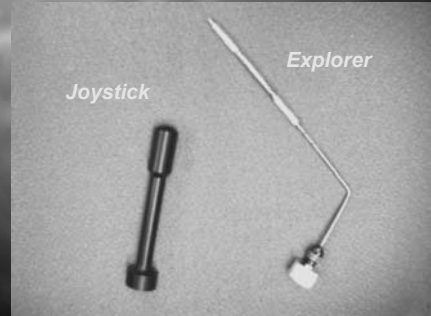
Time: 15:42:58

X: 204
Y: 318

Preparation   Carious Lesion

Prototype System

Probing "Instruments"

Joystick   *Explorer*

Evaluation Design

Group / Probing	Practice	First Experience; Questions	Second Experience; Questions
Group A1 (N = 3)		Joystick - Carious lesion	Explorer - Preparation
Group A2 (N = 3)		Joystick - Preparation	Explorer - Carious lesion
Group B1 (N = 3)		Explorer - Preparation	Joystick - Carious lesion
Group B2 (N = 3)		Explorer - Carious lesion	Joystick - Preparation

Common Questions

- "Feel" of the healthy tooth tissues?
- User's comfort with the simulator?
- Graphics quality?
- Hand position?
  Improvements needed for teaching tactile sensitivity?
- Improvements to the realism?
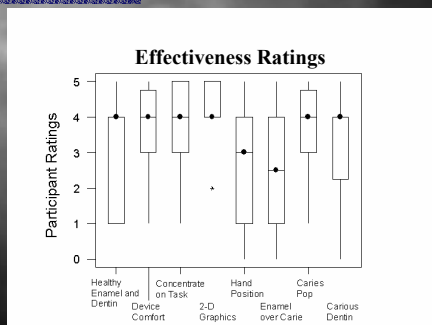
Task Specific Questions

- Carious Lesion
  - "Feel" of the enamel
  - " Feel" of the "pop" of the carious lesion
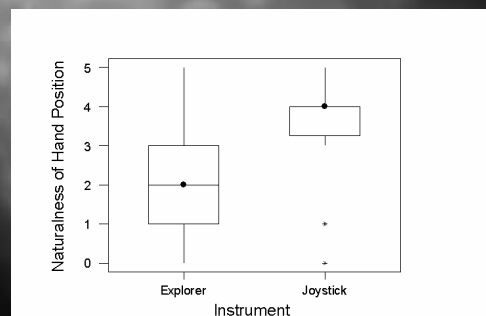- Preparation
  - "Feel" of carious dentin

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Experiment One:

Results -- Questionnaire

General Response

Effectiveness Ratings

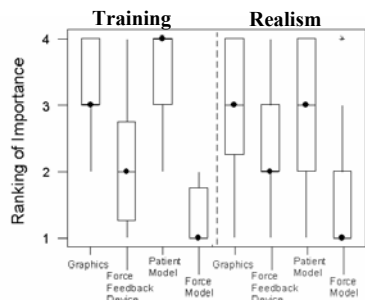## Naturalness of Hand Position

Relative Importance of Components

Overall Findings

• Vibration bothered the dentists

• Work on hand device - add more degrees of freedom

• Understand tradeoff between graphics and vibration

• Led to second experiment

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Experiment Two:

Signal Detection Test

Introduction

■ Previous work with Dental Simulator indicates vibration as a potential problem

■ Amount of vibration is a function of update rate and output force

❑ Previous work indicates a servo rate of 1000HZ is needed for stable environments

Objective

- To measure whether the vibration limited the dentist's ability to perceive small features
- To determine which enhancements would remove the vibration

Methodology

- Signal Detection Test
  – Signal + Noise => Vibration and step present
  – Noise => Vibration only
- Task: slide the cursor across a virtual surface perceive a small step amidst vibration
- 1 = definitely yes, 6 = definitely no

What the subject viewed...
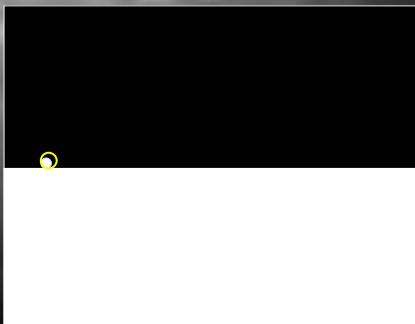
Methodology

- 4 conditions on the surface
  – 2 Update rates (1630 HZ and 468 HZ)
  – 2 Output forces (4.88 N and 1.63 N)
- Randomly presented signal, levels of vibration
- Six participants
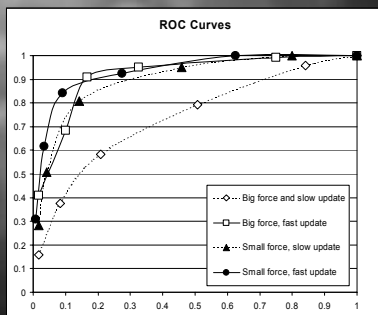- 20 repetitions, fully crossed, 2^3 full factorial (160 total trials)

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Experiment Two:

Results -- ROC Curves

Results

- Response Operator Characteristic (ROC) curves across conditions and confidence level
- Separation in performance levels for one condition (Strong force, slow servo rate)
- 69% accuracy versus 86% accuracy $t(2.73)p<0.05$

Results - ROC curves

ROC Curves

- Big force and slow update
- Big force, fast update
- Small force, slow update
- Small force, fast update

Averaged across subjects

Results

- Also recorded force and position in 30 ms increments
- During trials with weak force the vibrations ceased when the user entered the step
- May have two discriminating factors
  - kinesthetic movement due to step
  - momentary lapse of vibration

Results - Position and output force
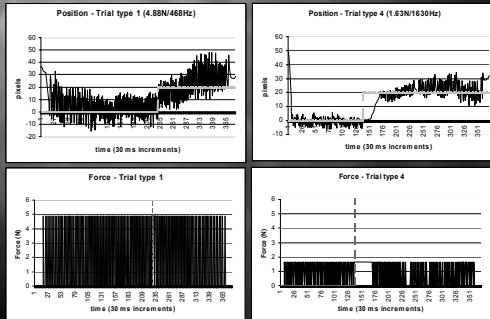
Conclusions

- Slow update rate and strong force results in poor performance
- Momentary lapse of vibration may have added a cue for detecting the step signal
- Replicated experiment, but eliminated the effect of the lapse of vibration -> Results similar
- Increase update rate for better performance

Future Work

- Must consider specifications in haptic interfaces:
  - level of touch detail needed
  - importance of touch
  - importance of graphics
- Currently working on the second generation of the Dental Simulator with new device

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Now What?

Phantom