AN EXPLORATION OF MULTITOUCH TECHNOLOGY:

A COMPARISON OF A SPLIT ANGLE KEYBOARD WITH MULTITOUCH AND CURRENT INPUT TECHNOLOGIES

Jenna Shanis, Alan Hedge

October, 2003

Shanis, J. and Hedge, A. (2003) Comparison of mouse, touchpad and multitouch input technologies. Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting, Oct. 13-17, Denver, CO, 746-750.

Current Input Interface Issues

- Conventional computer input is inefficient (Westerman, Elias, and Hedge, 2001) :
  - Hand must switch between typing and pointing activities
  - Separate devices require different skill sets: typing movements for keyboards, mostly point-and-click operations for other input devices.
  - Most input devices can only be operated with one hand.
  - Physical arrangement can be a risk factor in the development of musculoskeletal disorders
  - Physical area required for a keyboard and a mouse or other input device is an inefficient use of workspace.

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Input Devices

- Mouse uses x-y position and buttons for:
  - Keyboard input (1 button)
  - Cursor positioning (x-y hand/arm movements)
- Touchpad uses a sensor grid for:
  - Cursor positioning (1 finger)
- MultiTouch uses a touch-matrix surface for:
  - Keyboard input (1 finger)
  - Cursor positioning (2-fingers)
  - Gesture input (2+ fingers & movements)

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Research Questions

- The following questions were explored:
  - Is keying input faster and more comfortable for a MultiTouch surface than for a conventional keyboard numberpad ?
  - Is cursor positioning faster, more comfortable, and “safer” for a Multitouch surface than for a touch pad or a mouse?
  - Is text editing faster and more comfortable using MultiTouch gesture commands than using a mouse or touchpad?

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Experimental Design

- Repeated measures design with 3 conditions:
  - Keyboard + mouse
  - Keyboard + integrated touchpad
  - Keyboard + integrated Multitouch
- 12 right-handed subjects (6 men and 6 women)
- 18 to 22 years old, Cornell recruits via e-mail
- 3 tasks:
  - Number Entry
  - Cursor Positioning
  - Text editing
- Hand posture (right hand side video)
- Comfort & Preference (Pre-post questionnaires)

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Environment & Apparatus

- Chair (Herman Miller Aeron) Keyboard tray (Steelcase Stella)
- Dell 20” (51cm) monitor.
- Overhead, fluorescent lights
- VHS camcorder (Hitachi 7300x)
- Each subject personally positioned the keyboard and sat at a comfortable distance from the monitor and keyboard.

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Keyboard A: Microsoft Natural Keyboard

- Split angle of 25 degrees
- Keyswitch make force 0.60-0.82 N
- 7degree slope from front of keyboard to the back
- External 2 button mouse with scroll wheel (Dell/Microsoft Intellimouse)

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Keyboard B: Cirque Wave Keyboard with numberpad & touchpad

- Split angle of 22 degrees
- Keyswitch make force 0.46-0.52 N
- 7 degrees slope from front of keyboard to the back
- Integrated Touchpad
  - 2 buttons located below touchpad
  - 4.75 x 6 cm pad

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Keyboard C: FingerWorks Retro Keyboard with MultiTouch pad

- Split angle of 23 degrees
- 16 degrees angle at the front of the keyboard and then, evens at 3.5cm from the keyboard tray
- Integrated MultiTouch pad
  - Surface to the right of keyboard
  - 14.5 x 12.5 cm pad
  - Keyswitch make force 0 N

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Tasks: Number Entry

- Data entry of 250 numbers from a hardcopy random number table
- Different number groupings were used each session/condition
- Total input time recorded
- Numberpad on two of the keyboards were compared with the keyless, sensory MultiTouch number pad

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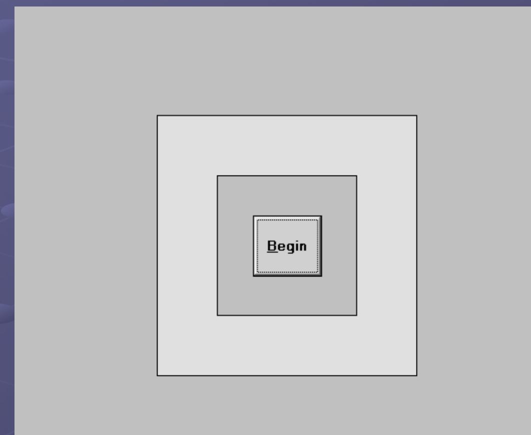
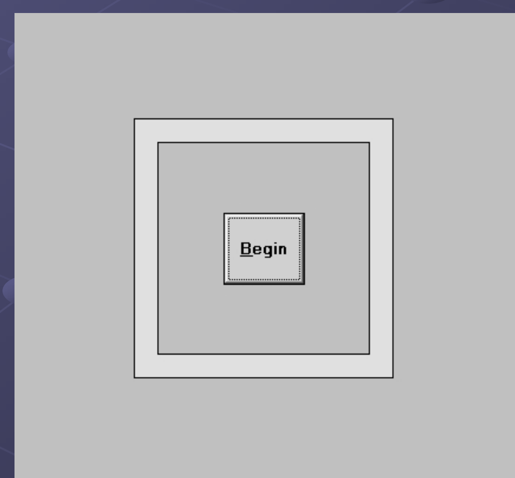
Tasks: Cursor Positioning

- Utilized Custom Tracking software
- As many laps as possible in the 30-second time period, while staying within the track boundaries
- Wide and narrow tracks tested
- Crossing the boundaries registered as error
- Mouse was compared with the touchpad and MultiTouch pad



1.5 cm wide with a 6 cm perimeter



0.5 cm wide with a 5.5 cm perimeter

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Tasks: Text Editing

- 3 separate, but comparable, ones were used
  - approximately 1,000 words
  - 10-12 grade level using a Felsch-Kincaid index
  - approximately same number of each editing task
- Editing time recorded
- Combination of Keyboard & MultiTouch Gestures were compared with Keyboard & Mouse and Keyboard & Touchpad

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Questionnaires: Pre & Post-Trial

- On a linear rating scale, Ss marked fatigue after each keyboard condition for the following:
  - Right hand
  - Right wrist
  - Right Forearm
  - Right Upper Arm
  - Right Shoulder
  - Neck
  - Upper back
  - Lower back

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Questionnaires: Post-Trial

- Measured:
  - Enjoyment and comfort of each of the input devices
  - Ease of learning and performing the 2D gestures
  - Frequency with which split and conventional keyboards
  - Use of different types of input devices

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Procedure

- Completely crossed, repeated measures design
- Three conditions containing each of three tasks
- Subjects were tested in each of the three conditions in the same room within one visit
- Condition order and tasks within each were counter-balanced and randomly assigned to the subjects

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Procedure

- Subject entered the laboratory and made him/herself comfortable at station
- Fatigue questionnaire
- MultiTouch was briefly described, demonstrated, and practiced (3 to 5 minutes long)
- Video-recording began
- Subject participated in each of three tasks (random order) with each of the following keyboards (random order)

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Procedure (cont.)

- Between each keyboard condition, fatigue questionnaire was completed
- Video-recording ended
- Post-trial questionnaire was given
- Subject was paid and left

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Data Collection and Analysis

- Speed (for the text editing and number input tasks)
- Number of laps completed (cursor positioning task)
- Accuracy, in percent error (cursor positioning task)
- Video recordings of the subjects' right arm and wrist (cursor positioning data was used)

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Video-motion analysis

- Peak Performance 2D system
- Collect a 10-second sample
- Digitized a random sample of 12 still images (per subject per condition)
- Points were chosen on the middle of the forearm, the wrist pivot, and on the fourth knuckle and then connected, creating an angle

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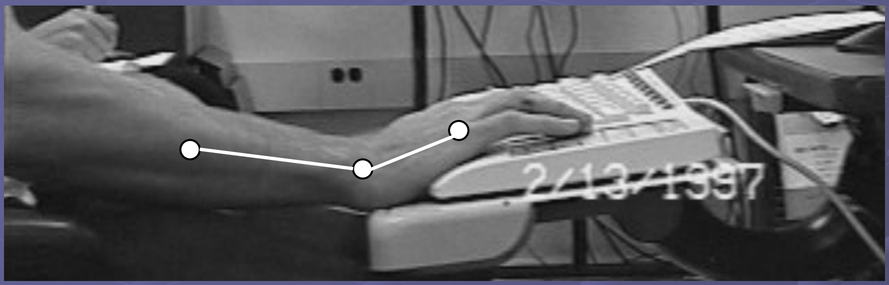
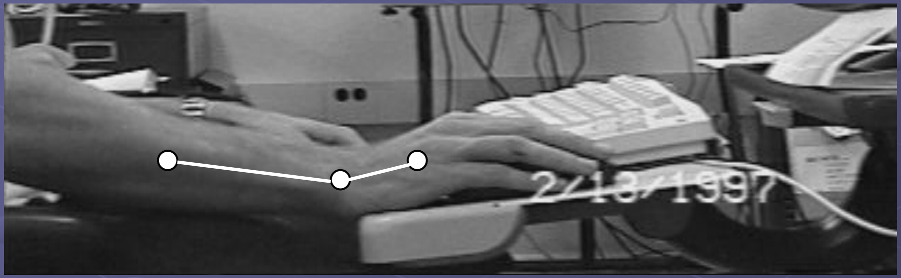
Wrist Extension (Subject 11)



MultiTouch



Mouse

Touchpad

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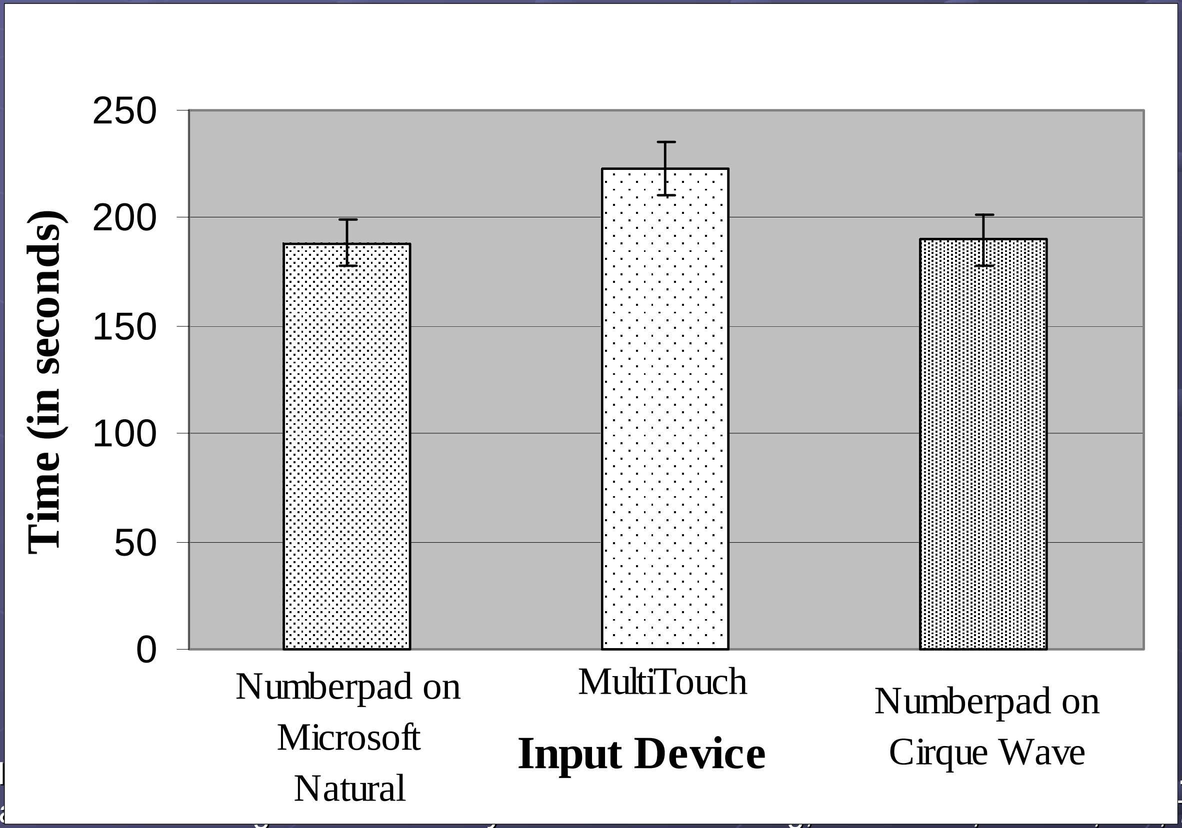
Results: Number Entry

- There was an effect of input device on the time to input a given set of numbers ($F_{2,20}$=22.73, p=0.000)



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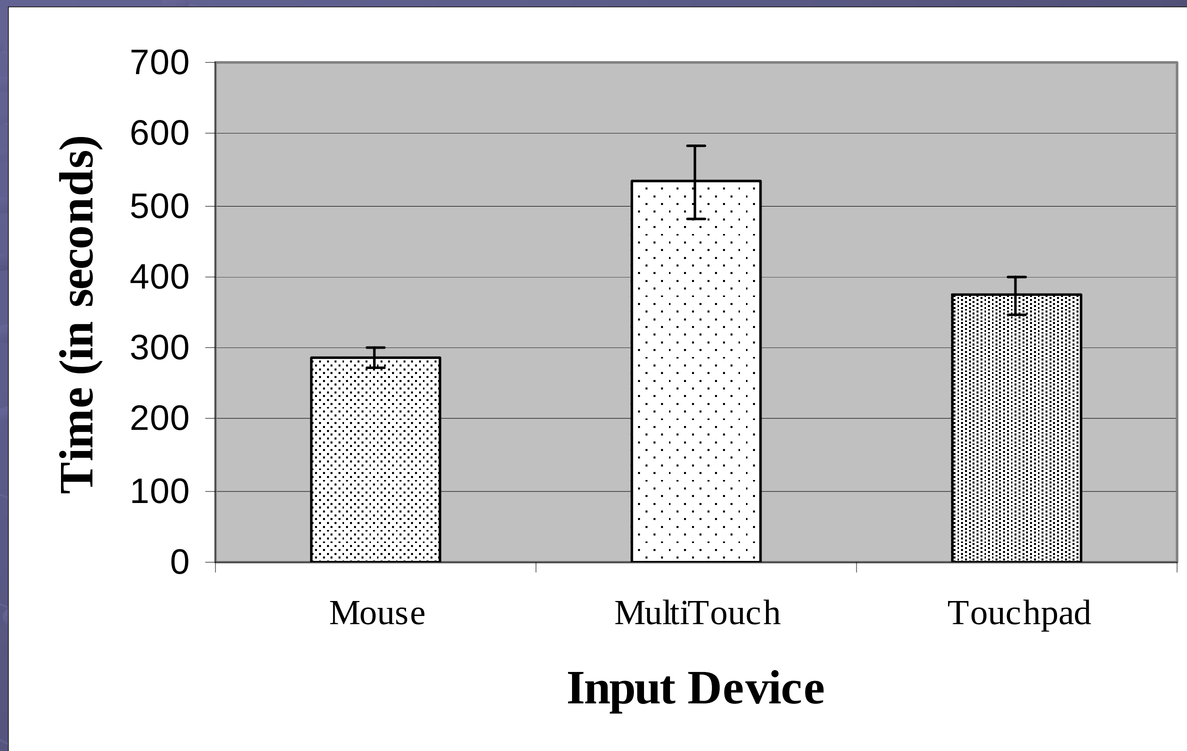
Results: Text Editing



- MultiTouch took longer than the editing with the mouse ($F_{2,20}=17.16$, $p=0.004$) or the touchpad ($F_{2,20}=17.16$, $p=0.012$)
- Touchpad took significantly longer than the mouse ($F_{2,20}=17.16$, $p=0.009$)

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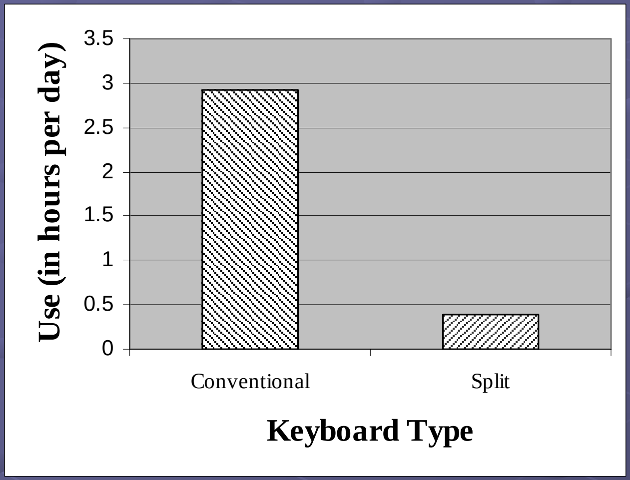
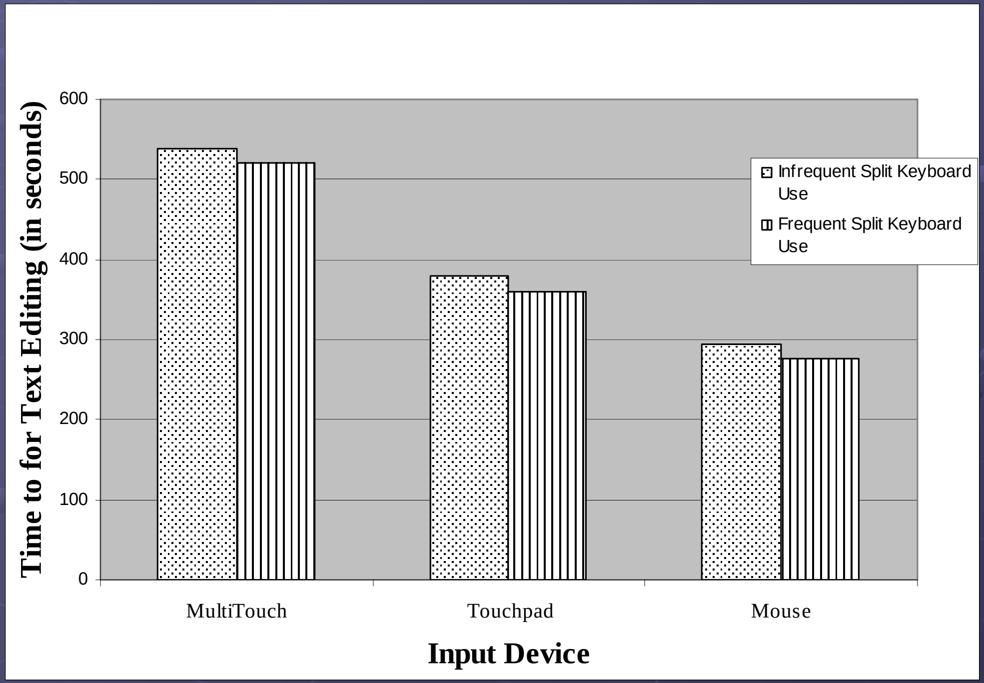
Results: Text Editing & Keyboard Use





No text editing x previous split keyboard use interaction

Subjects with frequent use of a split keyboard fared better on all three input devices

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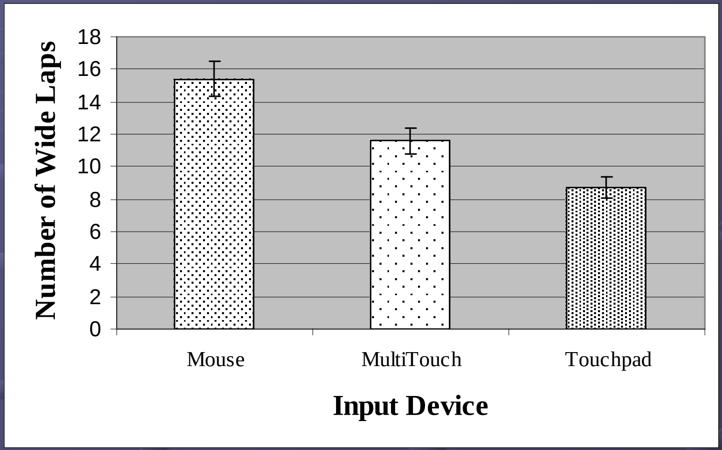
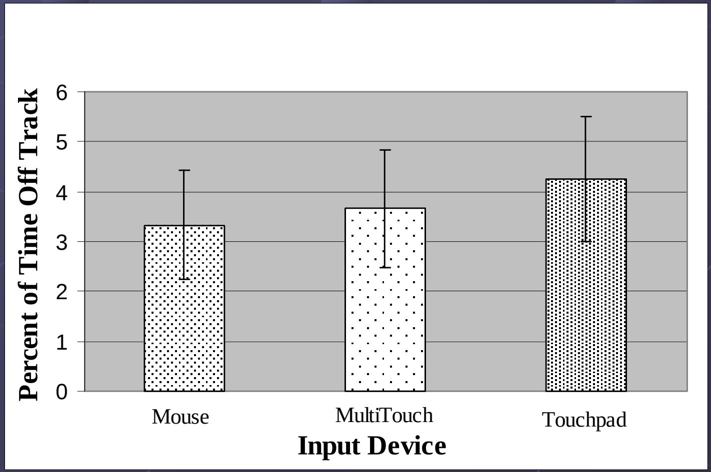
Results: Cursor Positioning – Wide Track

- Subjects completed more laps with the mouse than with MultiTouch ($F_{2,20}=34.54$, $p=0.003$) or with the touchpad ($F_{2,20}=34.54$, $p=0.000$). MultiTouch fared better than the touchpad in the number of laps completed on a wide track ($F_{2,20}=34.54$, $p=0.000$)



- No significant differences in error were seen



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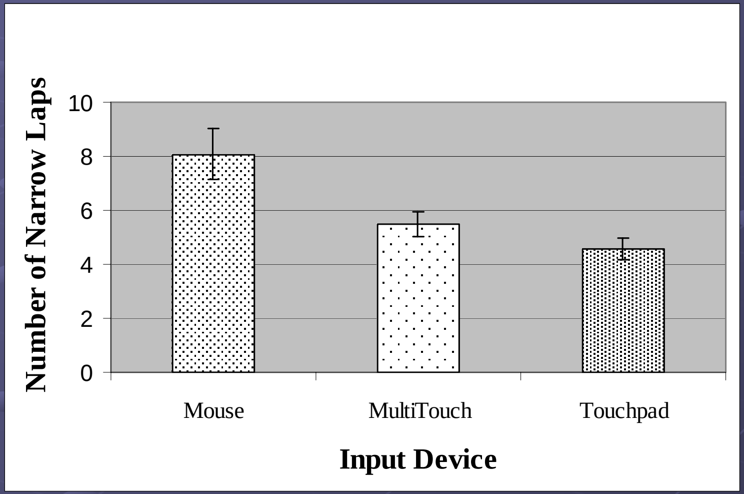
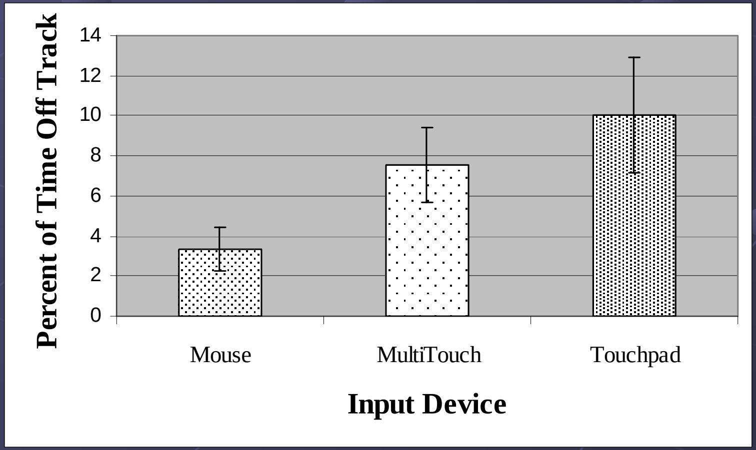
Results: Cursor Positioning – Narrow Track

- Significantly more laps with the mouse in the allotted thirty seconds than with MultiTouch ($F_{2,20}=16.74$, $p=0.006$) or with a standard touchpad ($F_{2,20}=16.74$, $p=0.003$)

- When using a mouse, subjects made significantly fewer errors than with MultiTouch ($F_{2,20}=7.30$, $p=0.011$) or with a standard touchpad ($F_{2,20}=7.30$, $p=0.044$)





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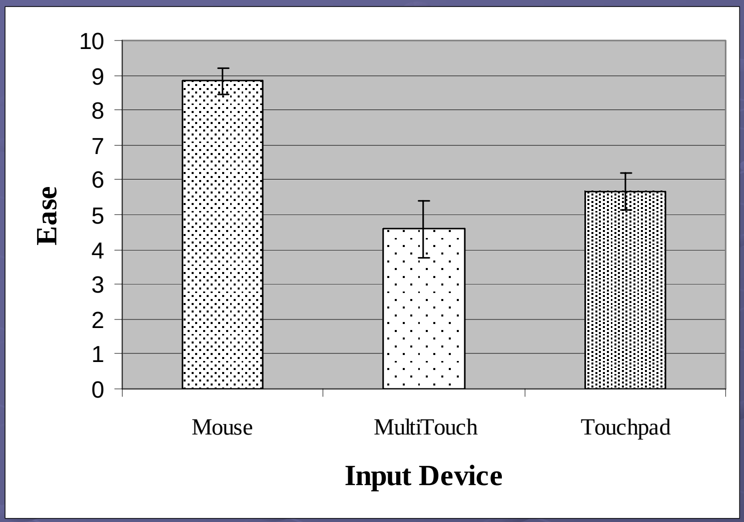
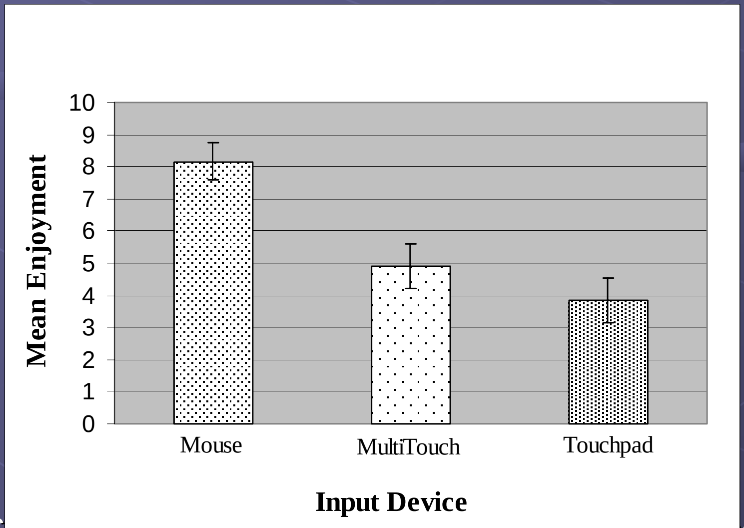
Results: Enjoyment & Ease





- Easier to use mousing technology rather than MultiTouch (F2,22=12.59, p=.006) or a Touchpad (F2,22=12.59, p=.006), but no significant difference between MultiTouch and the Touchpad
- Most enjoy using a mouse over MultiTouch (F2,20=14.27, p=.018) or a touchpad (F2,20=14.27, p=.005)

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Results: Fatigue

- There were no significant effects of input device on physical body fatigue.

- There was a trend, however, that when using a touchpad, more fatigue was reported in the right hand.

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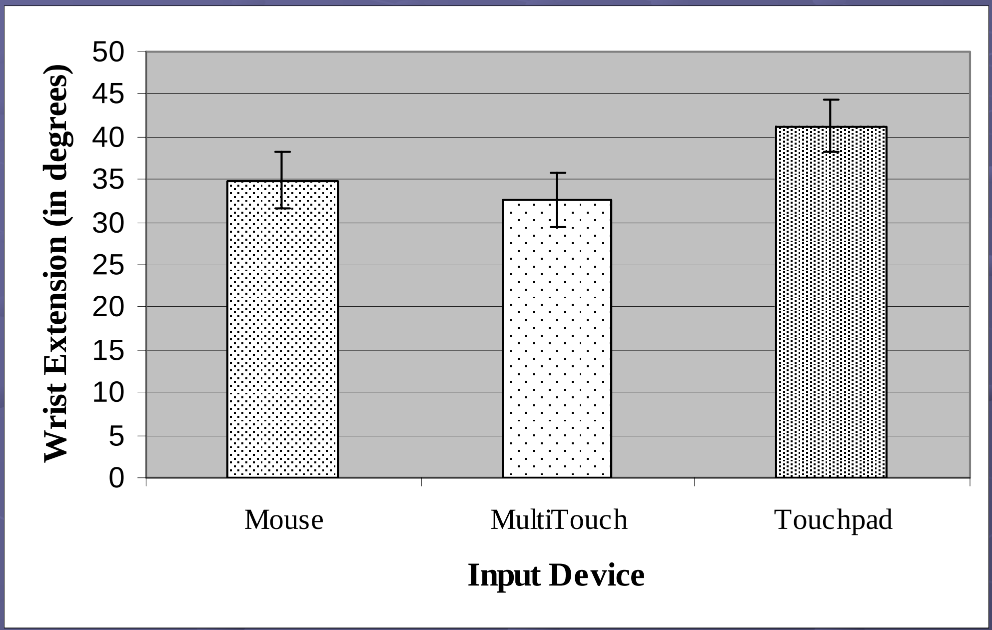
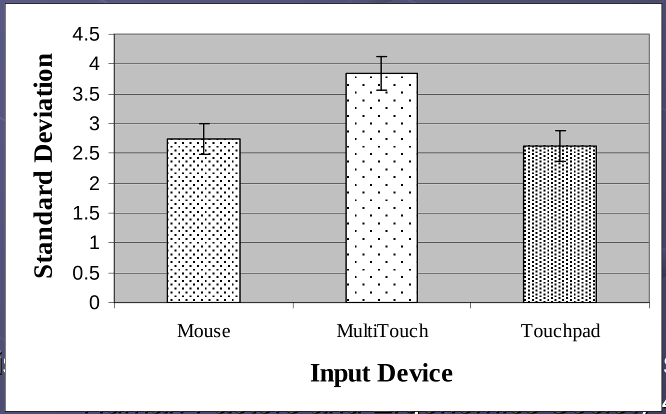
Results: Video Motion Analysis of Wrist Extension



MultiTouch caused significantly less wrist extension than the touchpad (F2,20=3.390 p=0.038) and although not significant, seemed to cause less than with the mouse as well



With MultiTouch, however, there was a higher standard deviation (F2,20=5.442, p=0.023)

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Discussion

- Mean wrist extension was reduced to 32.57° compared with 34.82° when using a mouse and 41.29° with the touchpad
- Due to differences in keyboard slope
- Feedback: visual, auditory, and haptic

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Discussion

- Data entry and text editing took longer with MultiTouch, but MultiTouch was better than the touchpad for cursor positioning speed and accuracy on a narrow track and better for speed on the wide track
- Control of accuracy necessary: wide vs. narrow
- Task Axis Crossing and registered error

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Discussion

- Difference in technologies: MultiTouch vs. Touchpad
- One-handed interface inferior to a two-handed - splits the compound task into subtasks that can be performed in parallel by both hands
- MultiTouch can be used non-dominant hand or possibly bimanually

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Discussion: Learning curve

- Devices such as MultiTouch "allow an input device to express an enhanced vocabulary of explicit actions, but the user must first learn these new ways of touching or using the input device to fully benefit from them." (Hinckley & Sinclair, 1999)
- Detwiler et al. (2000) - task completion times with the MultiTouch keyboard were significantly slower than those with the keyboard and external mouse, but those using the MultiTouch technology after the keyboard, fared significantly better than those exposed to the MultiTouch technology first.

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Follow-up: Learning Curve

- A follow-up study was done by Hedge (2002)
- Four of the twelve subjects were used
- Completed the text passages, ending on the same one that they had previously done with the MultiTouch keyboard in the main study
- An average time decrease of
- 38.2% (ranging from 6.7-64.5%)
- Practice may play a large role in the differences observed!

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Future of Input Devices

- 3D: recognition-based - such as speech, gesture, eye tracking, and camera-based
  - Problems: toolkits for application, lag

- Will have multiple input devices and will have to determine which to use given the task or use simultaneously
  - requires a deeper knowledge about how the device works

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Further development of MultiTouch

- Positive aspects:
  - Sensors in MultiTouch require no mechanical intermediary, allows for a quicker response time and direct manipulation
  - Amount of feedback provided can be controlled
  - Flexible form
  - Unobtrusive, does not look complex and has no buttons which can easily become damaged
  - Elimination of force in order to input data

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Further development of MultiTouch

- Skill level and learning required: motor skills, memory, and perceptual skills
- Interactive setting, whether the user is sitting, has both hands available, and can look and focus her attention on the task at hand

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Thank You

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Input Devices

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- Mouse:
  - Advantages: can be used by either hand, causes relatively little fatigue, is physically robust, and has convenient finger selection buttons, and can position in different locations
  - Disadvantages: associated with substantial wrist extension postures (25-30°) and carpal tunnel pressures (up to 18.7 ± 3.8 mmHg) (Keir et al., 1999), physical area required when using a mouse is larger than ideal

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Input Devices

	Mouse	Touchpad	Multitouch
Force	Moderate	Moderate	Minimal
Repetitive load	Focused on Finger/ button Hand/arm	Finger	

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Background: Touchpad

- The touchpad is a fixed-size surface, operated by a finger, provides positional data to the system, uses a resistive tablet to track the point of contact between two conducting surfaces
- Touch tablet was introduced in the 1970s for drawing with a stylus
- In 1994, the Powerbook™ laptop was introduced by Apple containing the touchpad and now has come into widespread use, integrated into laptop computers
- Advantages: little necessity for learning, very fast and very accurate devices with times as fast, or faster than a mouse.” (Douglas & Mithal, 1997) In addition, a touchpad can be used with either hand and a choice of fingers.
- Disadvantages: cannot easily perform drawing tasks. (Douglas & Mithal, 1997), stationary nature causes wrist deviation

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Background: Tasks of Input Devices

- Pointing/positioning and selecting
- Dragging
- Drawing
- Domain-specific tasks: target acquisition, text selection, text editing and entering, and continuous tracking tasks

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Background: Musculoskeletal Disorders

- Musculoskeletal disorders are associated with tasks involving:
  - Repetitive motions
  - Sustained posture
  - forceful exertions
  - awkward postures
  - mechanical stresses

(Tittiranonda et al., 1999).

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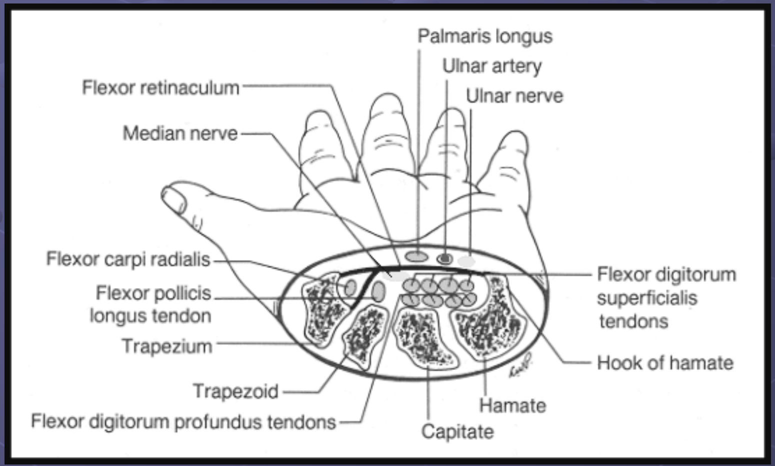
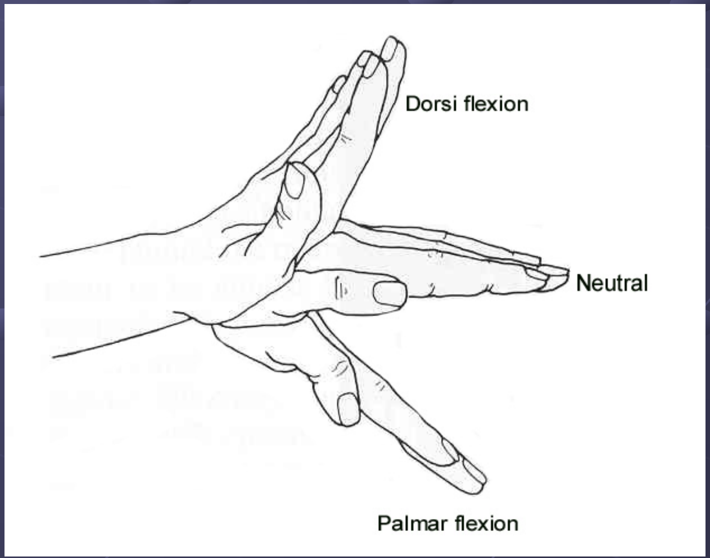
Background: CTS

- Carpal tunnel syndrome
- If not in a neutral position, the protective sheaths surrounding the tendons can thicken and swell, causing the carpal tunnel to be constricted and friction in the joint





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Background: Physical Keyboard & Workstation

- Keyboard design influences hand and wrist position, typing productivity, and preference. (Zecevic et al., 2000)
- Split angle
- Key force
- Keyboard slope
- Height of keyboard from the table and floor surfaces

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Objectives

Purpose

to explore a relatively new input technology and to determine how well a touch surface works as a combined keyboard input, cursor positioning, and gesture control device when compared with current input technologies.

The following questions were explored:

- Is keying input faster and more comfortable for a MultiTouch surface than for a keyboard?
- Is cursor positioning faster, more comfortable, and safer for a touch surface than for a touch pad or a mouse?
- Is text editing faster and more comfortable using MultiTouch gesture commands than using a mouse?

Shanis, J. and Hedge, A. (2003) Comparison of mouse, touchpad and multitouch input technologies. Proceedings of the Human Factors and Ergonomics Society 47th Annual Meeting, Oct. 13-17, Denver, CO, 746-750.

Hypotheses

- The gestures, after being learned, will save much time when compared with using file menus and control commands to perform text editing tasks.
- Because of the elimination of a need for force, less fatigue will be reported by subjects using MultiTouch for data input.
- Cursor positioning will be faster and more accurate with MultiTouch than with the mouse because it is more direct, and than the touchpad, and because of the two finger electric field sensing technology.

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