User Interface Biomechanics:
Developing a new self-report ergonomic assessment tool

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Motivation

• Personal computing changed how we work
  – Reliance on computers and software

• Ergonomic risks associated with computer work
  – Awkward postures
  – Repetitive, low force movements
  – Development of CTDs$^{3,4}$

Modern Office Ergonomics

• Current focus on physical and behavioral interventions
  – Chairs, input devices, desks
  – Breaks and stretches

However, office workers still suffering and being injured

• User Interface and Interaction Design could be the cause
  – Can alter upper body posture$^{5,6}$
  – User satisfaction can affect physical risk factors$^7$

Study Objective

Designed to begin a programmatic line of research

• Develop self-report measure sensitive enough for evaluating user interface and interaction design

  1. Design the measure
  2. Assess the measure
      • Reliability
      • Sensitivity

The measure needs to be effective during the design phase
Developing the Measure

• Leveraging existing ergonomic assessment tools
  – Borg CR10 (Borg)
  – Strain Index (SI)
  – Body Discomfort Diagram (BDD)
  – Hand Activity Level (HAL)
  – Rapid Upper Limb Assessment (RULA)

Created a self-report using items from these tools
  → Informed via interview with geoscientists
  → Testing for reliability and sensitivity
Method

• 166 pp (65 female) from a Texas conference and TAMU
  – Ages 18 to 80 (Mean = 32; SD = 13.4)
• Participants completed two computer tasks
  – Tasks designed to be biomechanically different
  – Interaction Methods: Typing and Clicking task (3 min each)
  – Input Methods: Direct (Touch) and Indirect (Keyboard & Mouse)
  – Measure: Self-report administered after each task
PCA Results - Reliability

- Principal Component Analysis revealed 7 components

<table>
<thead>
<tr>
<th>Strain Factors</th>
<th>Stress Factors</th>
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<tbody>
<tr>
<td><strong>Left Side</strong></td>
<td><strong>Right Side</strong></td>
</tr>
<tr>
<td>Discomfort</td>
<td>Discomfort</td>
</tr>
<tr>
<td>• Trapezius</td>
<td>• Neck</td>
</tr>
<tr>
<td>• Shoulder</td>
<td>• Eye</td>
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<tr>
<td>• Upper Arm</td>
<td>• Trapezius</td>
</tr>
<tr>
<td>• Lower Arm</td>
<td>• Shoulder</td>
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<tr>
<td>• Wrist</td>
<td>• Upper Arm</td>
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<tr>
<td>• TIM</td>
<td>• Lower Arm</td>
</tr>
<tr>
<td>• RP</td>
<td>• Wrist</td>
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<table>
<thead>
<tr>
<th>Task Demand</th>
<th>Wrist Deviation</th>
<th>Task Activity</th>
<th>Shoulder Abduction</th>
<th>Shoulder Flexion</th>
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<tbody>
<tr>
<td>• SI Effort Level</td>
<td>• Right Wrist Deviation</td>
<td>• HAL for Right Hand</td>
<td>• Right Shoulder Abduction</td>
<td>• Right Shoulder Flexion</td>
</tr>
<tr>
<td>• Borg CR10</td>
<td>• Left Wrist Deviation</td>
<td>• Speed of Work</td>
<td>• Left Shoulder Abduction</td>
<td>• Left Shoulder Flexion</td>
</tr>
<tr>
<td>• Precision</td>
<td>• Right Wrist Deviation</td>
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<td></td>
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<tr>
<td>• Right Wrist Position</td>
<td>• Left Wrist Deviation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Left Wrist Position</td>
<td>• Right Wrist Deviation</td>
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</tbody>
</table>

- Differentiate between Strain and Stress related factors
- Differentiate strain between left and right
Results

Independent Variables (Within-Subject)

Input Method
1. Direct
2. Indirect

Interaction Method (Task)
1. Typing
2. Clicking

Dependent Variables

• Principle Component (PC) Based Score
  Summation of items that loaded onto PCs
  PC1 Left Side Discomfort
  PC2 Right Side Discomfort
  PC3 Task Demand
  PC4 Wrist Deviation
  PC5 Task Activity
  PC6 Shoulder Abduction
  PC7 Shoulder Flexion

• Repeated Measures ANOVA for each dependent variable
  – 2 (input method) X 2 (interaction method)
  – Repeated measures logistic regression for PC4 and PC6 (Chi-square post-hoc)
Discomfort Components (Strain)

- Higher scores for **direct input** compared to indirect
  - Left: $F(1,165) = 65.95, p < .001, \eta^2 = .286$; Right: $F(1,165) = 159.33, p < .001, \eta^2 = .491$
- Higher scores for **clicking** compared to typing for the right side
  - $F(1,165) = 103.34, p < .001, \eta^2 = .385$
• Higher scores for **direct input** compared to indirect
  - $F(1,158) = 238.12$, $p < .001$, $\eta^2 = .601$
• Effect of task was small with typing > clicking
  - $F(1,158) = 7.46$, $p = .007$ $\eta^2 = .045$
More likely to report deviation for the **typing task** compared to the clicking task

- Right wrist: indirect only, $\chi^2(1, N = 332) = 22.30$, $p < .001$
- Left wrist: both direct, $\chi^2(1, N = 332) = 108.47$, $p < .001$, and indirect $\chi^2(1, N = 332) = 94.09$, $p < .001$
Task Activity - PC5 (Strain)

- Greater task activity for **clicking with direct input** only
  - Interaction: Right wrist: indirect only, $F(1,164) = 20.40$, $p < .001$, $\eta^2 = .111$
Shoulder Abduction - PC6 (Strain)

- More reported right shoulder abduction for **direct clicking** compared to all others
  - Direct typing: $\chi^2(1, N = 332) = 28.768, p < .001$, Indirect tasks, $\chi^2(1, N = 332) = 16.913, p < .001$
- More reported left shoulder abduction for **direct typing** compared to all others
  - Direct Clicking: $\chi^2(1, N = 332) = 23.82, p < .001$, Indirect Typing: $\chi^2(1, N = 332) = 16.89, p < .001$, Indirect Clicking $\chi^2(1, N = 332) = 25.84, p < .001$
Shoulder Flexion - PC7 (Strain)

- Greater shoulder flexion for **direct input** method
  - $F(1,161) = 137.03$, $p < .001$, $\eta^2 = .46$
- Greater shoulder flexion for **typing task**
  - $F(1,161) = 130.40$, $p < .001$, $\eta^2 = .45$. 
Discussion

• PCA showed that items grouped by stress and strain
  – Right and left strain grouped separately
• Stress and strain components are sensitive to input method
  – Participants are able to report differences
  – Stress-Strain relationship is maintained for input method
• Less sensitive to interaction method (task), especially
  – Task Demand (PC3)
  – Task Activity (PC5)
  – Deviations from the Stress-Strain relationship
• Need for testing with many other interaction methods
• These are ordinal comparisons only
• Validate participant self-report with trained evaluation
Acknowledgements

• Research Funded by Office Ergonomics Research Committee

Questions?
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ritchey@tamu.edu
YOU SHALL NOT PASS

• YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!! YOU SHALL NOT PASS!!!!!!!
Right Side Discomfort - PC2

Mean Reported Right Side Discomfort

- Direct
- Indirect

Input Method
- Clicking
- Typing

Texas A&M ergonomics Center
Applied & Basic Research • Commercialization • Design
Tasks

Typing Task:

Please retype the following phrases in the text fields below them. Don't worry about correcting your mistakes. When you've completed typing each of the phrases please click the next button at the bottom of the page to bring up the next page of phrases to retype.

- Economical with the truth
- Make your hair stand on end
- The ends of the earth
- A feather in one's cap

Clicking Task:

For each of the following phrases click the word that is underlined and blue, then responded to the dialogue box. Do this for each phrase. After you've done this for each phrase hit the next button.

- Famous for fifteen minutes
- A legend in one's own lifetime
- Many a true word is spoken in jest
- Laugh like a drain
For each body part during the task you just completed, indicate the amount of discomfort perceived on a scale from 0 to 10, with 0 indicating that there was no perceived discomfort and 10 indicating very, very intense discomfort. Also, for each body part indicate the percentage of the time you feel that body part was used during the task you just completed.

4. Select the image that best reflects the position of your hand and wrist during the task:

1. Wrist Straight
2. Wrist Slightly Bent
3. Wrist Bent
1. Please indicate the rating of physical effort that you feel best describes your amount of physical effort, in other words how hard your muscles were working, during the task you just completed using any number from 0 to 10, 0 being no effort at all and 10 being extremely strong, almost maximum effort. You can use decimals, such as 1.5 or 2.5:

<table>
<thead>
<tr>
<th>Rating</th>
<th>Verbal Anchor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Nothing at all (At Rest)</td>
</tr>
<tr>
<td>1</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
</tr>
<tr>
<td>3</td>
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<tr>
<td>4</td>
<td>Strong</td>
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<td>5</td>
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<td>6</td>
<td></td>
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<tr>
<td>7</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Extremely Strong (Almost max, lifting 350 lbs. of weights)</td>
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<tr>
<td>9</td>
<td></td>
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<tr>
<td>10</td>
<td></td>
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</tbody>
</table>

2. For the task you just completed, on a scale from 0 to 10 please select the level of activity that best describes your hands. You will give a score for each hand. Consider a pause to be when your hand was idle or at rest.

<table>
<thead>
<tr>
<th>Rating</th>
<th>Verbal Anchor</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>Hand is idle most of the time, no regular physical efforts</td>
</tr>
<tr>
<td>1</td>
<td>Consistent and noticeable long pauses or very slow movements</td>
</tr>
<tr>
<td>2</td>
<td>Slow and steady movements with frequent but brief pauses</td>
</tr>
<tr>
<td>3</td>
<td>Steady movements and physical effort with few pauses</td>
</tr>
<tr>
<td>4</td>
<td>Fast and repetitive movements with no pauses</td>
</tr>
<tr>
<td>5</td>
<td>Fast and repetitive movements that cannot be maintained.</td>
</tr>
</tbody>
</table>
Software Biomechanics

- Software design affects how we work

- Which layout would be best for touch screen interaction?
Toward Biomechanically Informed UI Designs

• Mindful of the development life cycle
  – Quick and Iterative

• Need for an ergonomic assessment tool designed for computer work
  – Able to be used and interpreted by lay people
  – Quick

• Leveraging existing ergonomic assessment tools
  – Translating to a new domain and self-report
Limitations

• Tasks were abstracted

• Future work that expands the experimental conditions to different devices, tasks, and duration is warranted to generalize these findings to different software interaction parameters.

• Time limits from practical constraints

• Measure hasn’t been validated
Thoughts and Moving Forward

• Clearly participants are able to self-report differences
  – Between Task and Input Method
• Measure was sufficiently sensitive
• Ultimate goal is creating an effective and efficient measure