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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]

[1] BLS, 2003; [2] Scaffidi, Shaw, & Myers, 2005; [3] IJmker et al., 2007; [4] Punnett & Bergqvist, 1997

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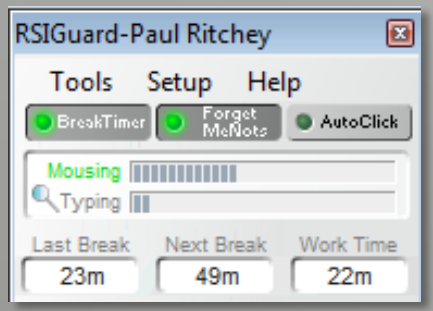
Modern Office Ergonomics

- 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]



[5] Elouri, 2009; [6] Filgueiras, Rebelo, & Moreira da Silva, 2011; [7] Dennerlein et al., 2008)

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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

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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)

3. Select a level of effort that best describes your physical effort, how hard you felt your muscles worked, during the task you just completed:

Light	(Barely noticeable or relaxed effort)
Somewhat Hard	(Noticeable or definite effort)
Hard	(Obvious effort)
Very Hard	(Substantial effort)
Near Maximal	(Uses shoulder or trunk for force)

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

Created a self-report using items from these tools

→Informed via interview with geoscientists

→Testing for reliability and sensitivity

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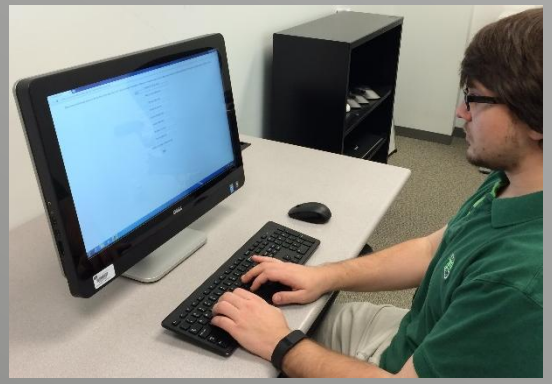
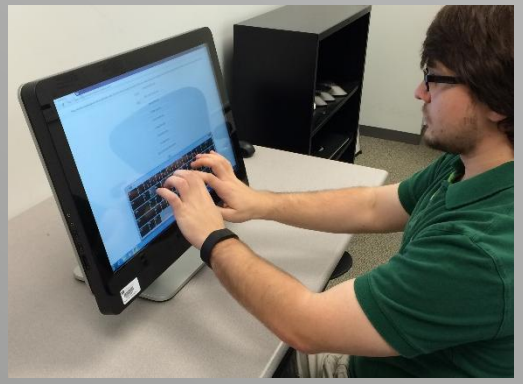
Method

- 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

Indirect Input



Direct Input



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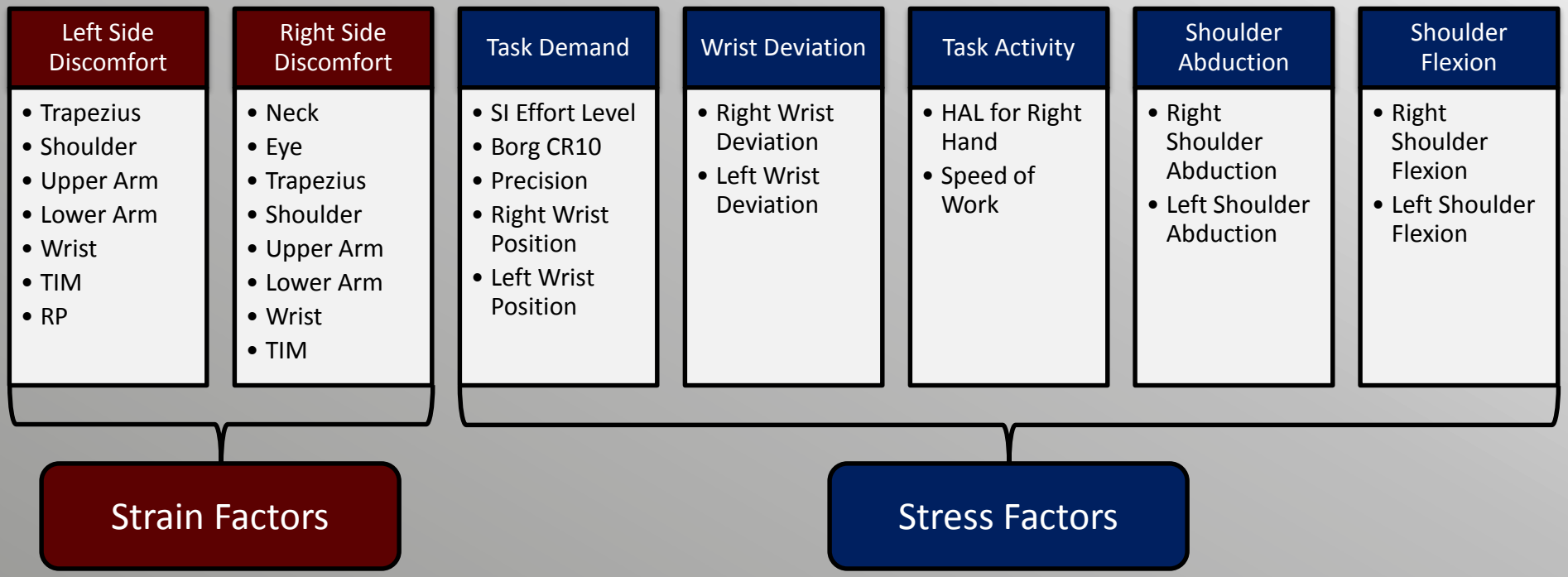
PCA Results - Reliability

- Principal Component Analysis revealed 7 components



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

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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)

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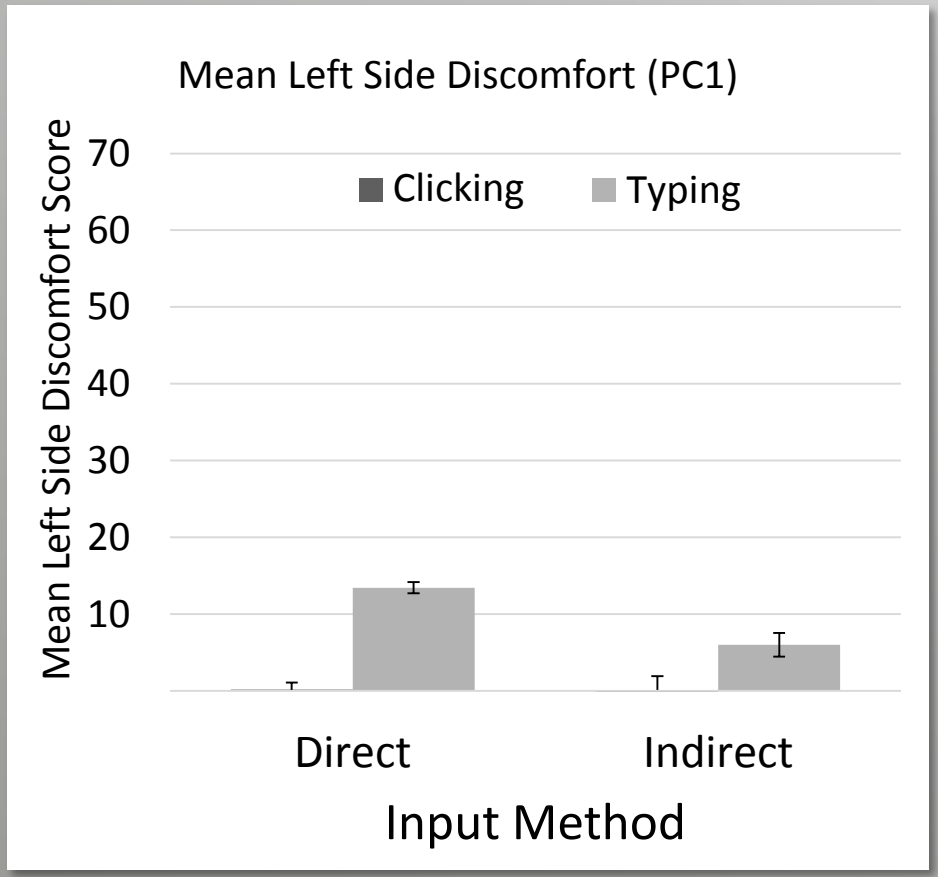
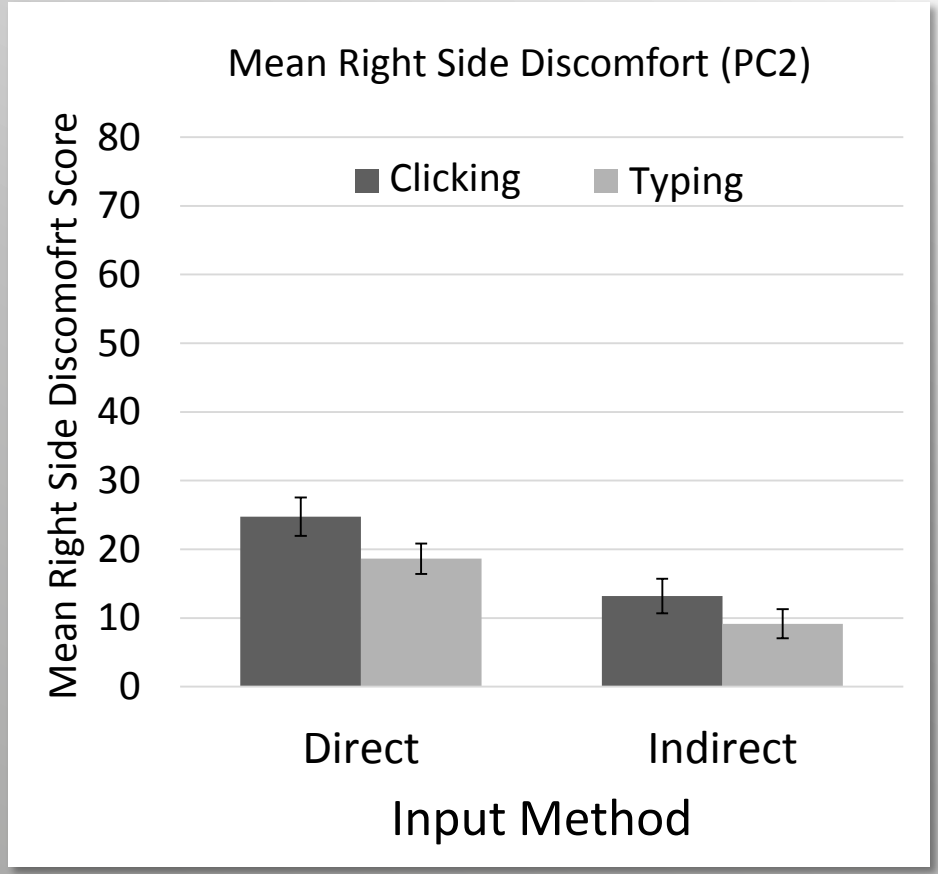
Discomfort Components (Strain)





- Higher scores for **direct input** compared to indirect
  - Left: $F(1,165) = 65.95$, $p < .001$, $\eta p^2 = .286$); Right: $F(1,165) = 159.33$, $p < .001$, $\eta p^2 = .491$
- Higher scores for **clicking** compared to typing for the right side
  - $F(1,165) = 103.34$, $p < .001$, $\eta p^2 = .385$

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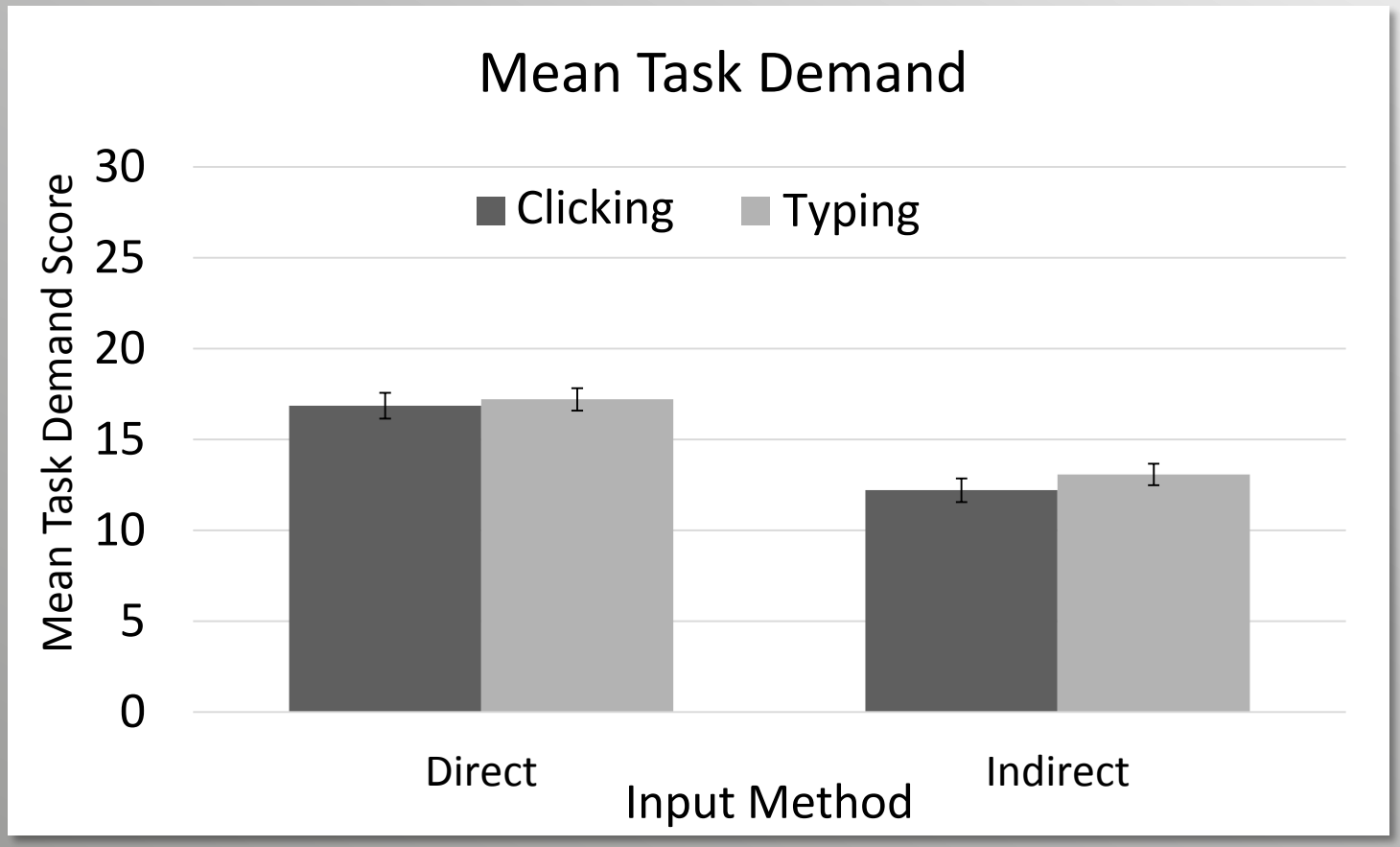
Task Demand - PC3 (Strain)



- Higher scores for **direct input** compared to indirect
  - $F(1,158) = 238.12$, $p < .001$, $\eta p^2 = .601$
- Effect of task was small with typing > clicking
  - $F(1,158) = 7.46$, $p = .007$ $\eta p^2 = .045$

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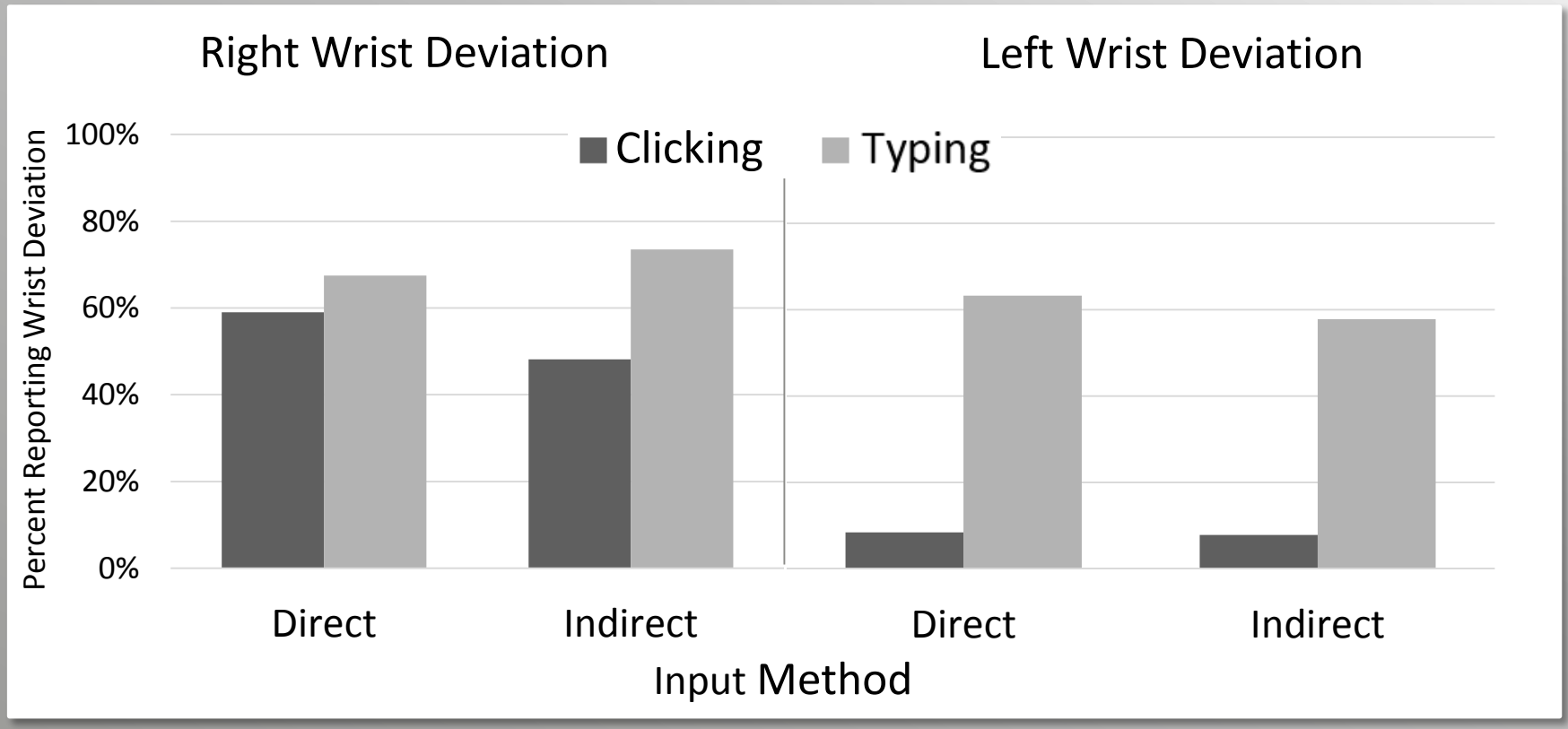
Wrist Deviation - PC4 (Strain)



- 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 $\chi^2(1, N = 332) = 94.09$, $p < .001$

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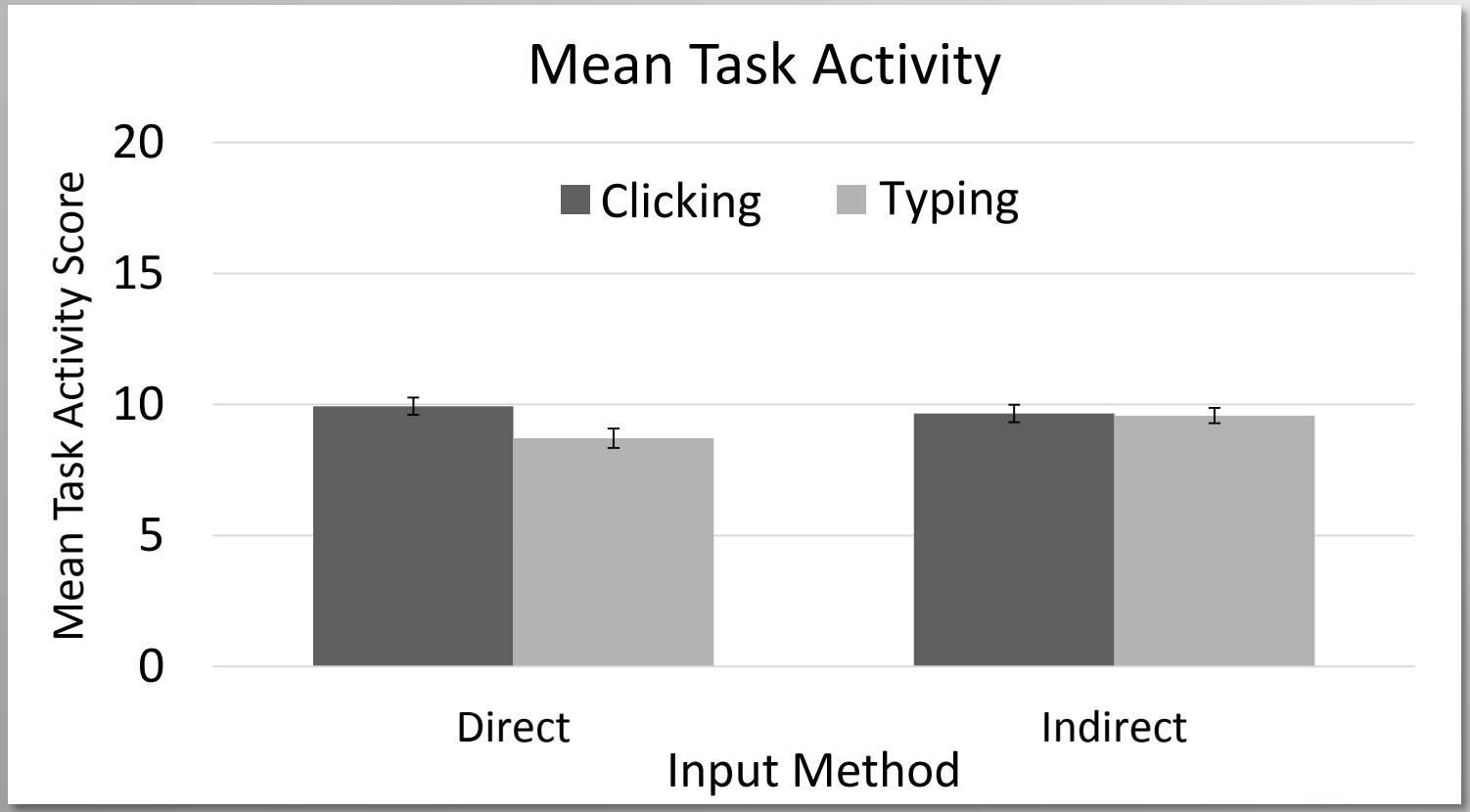
Task Activity - PC5 (Strain)



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

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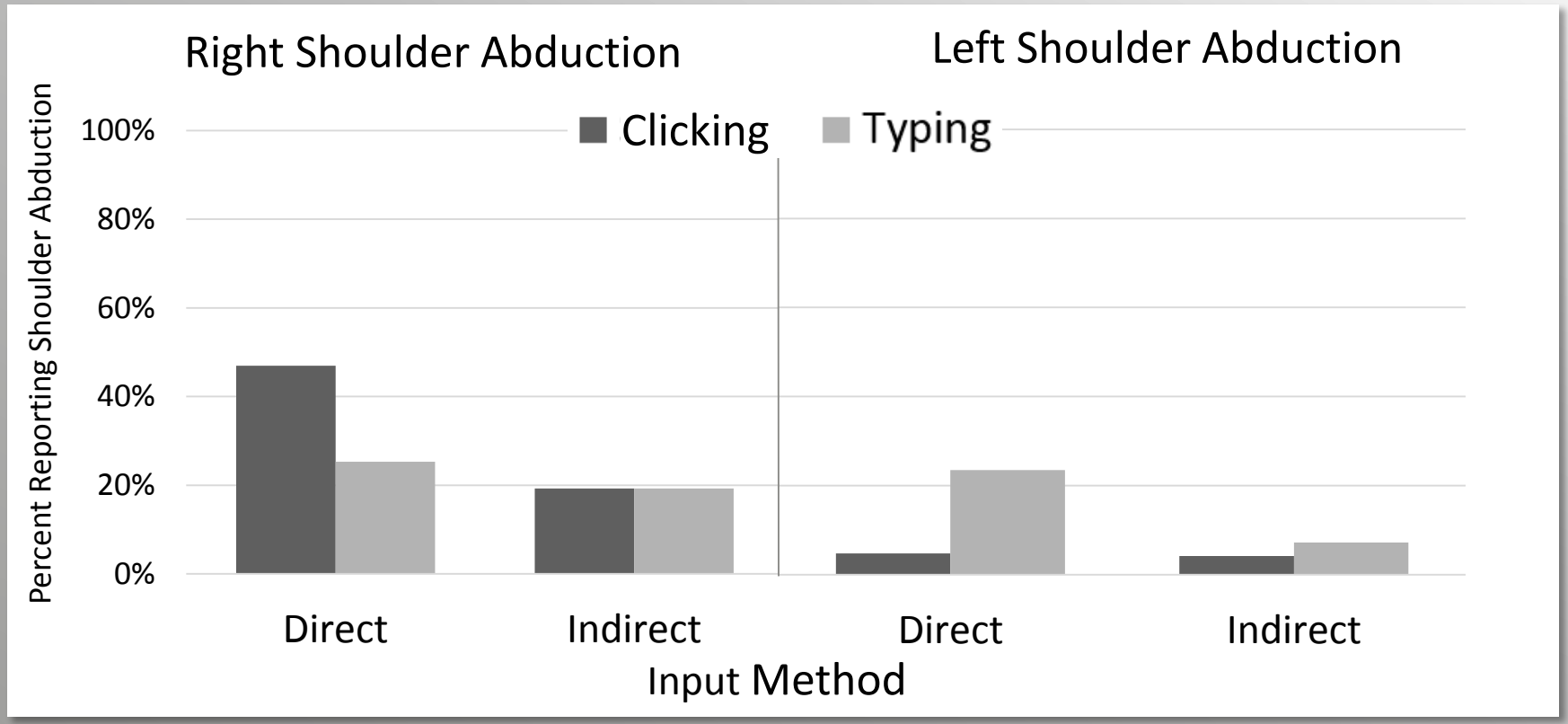
Shoulder Abduction - PC6 (Strain)



- 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 $\chi^2(1, N = 332) = 25.84$, $p < .001$

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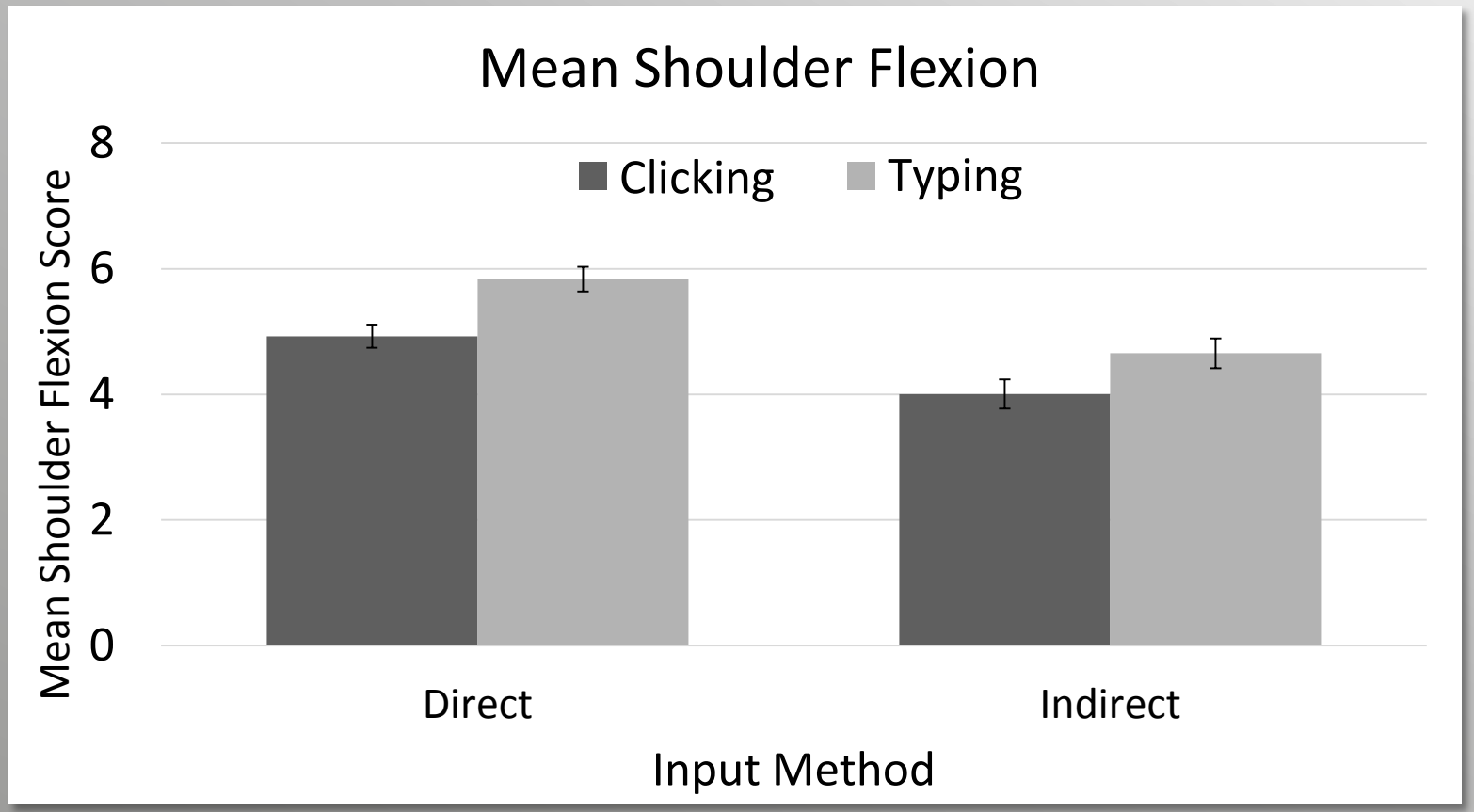
Shoulder Flexion - PC7 (Strain)



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

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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

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Questions?

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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!!!!!

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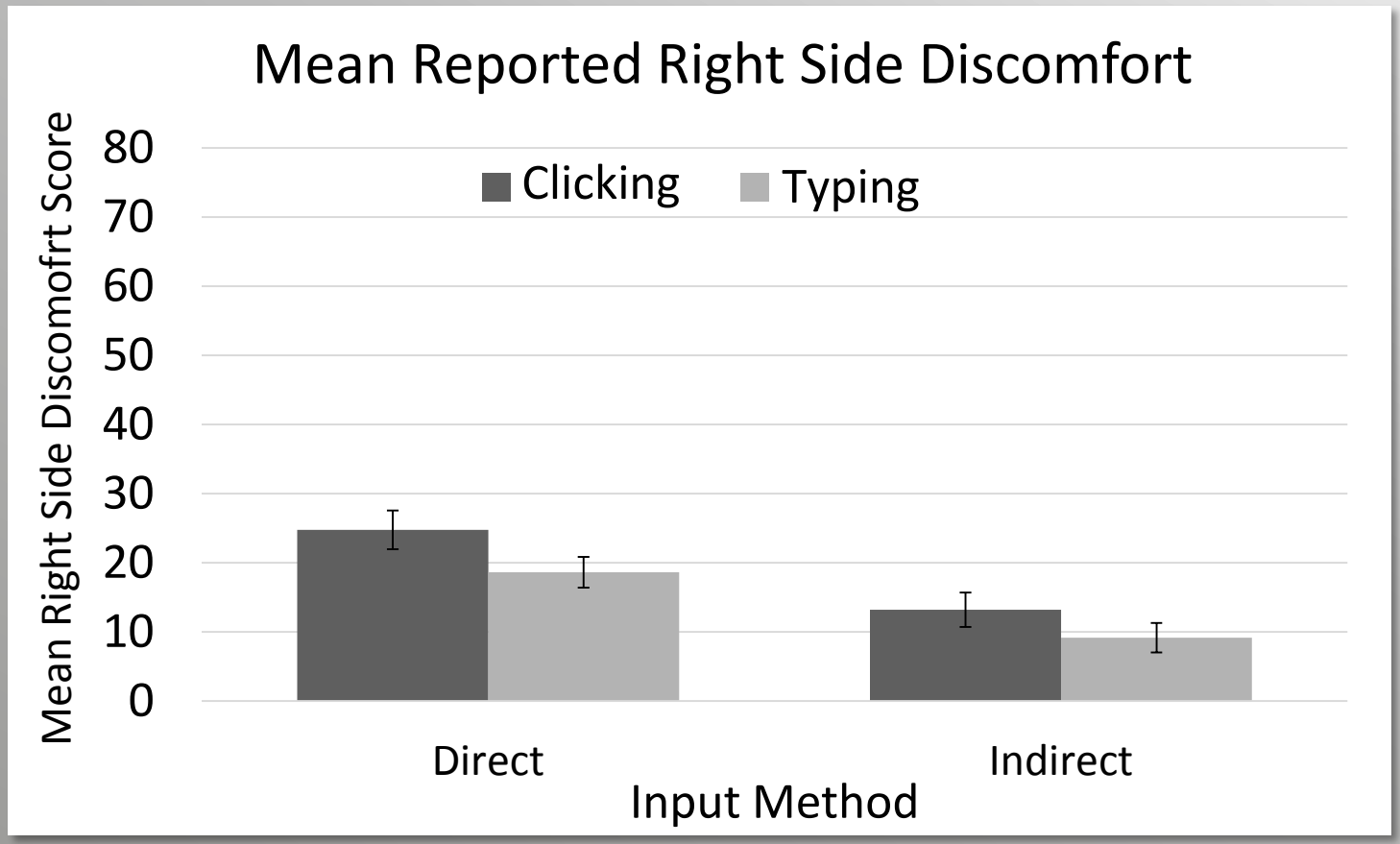
Right Side Discomfort - PC2



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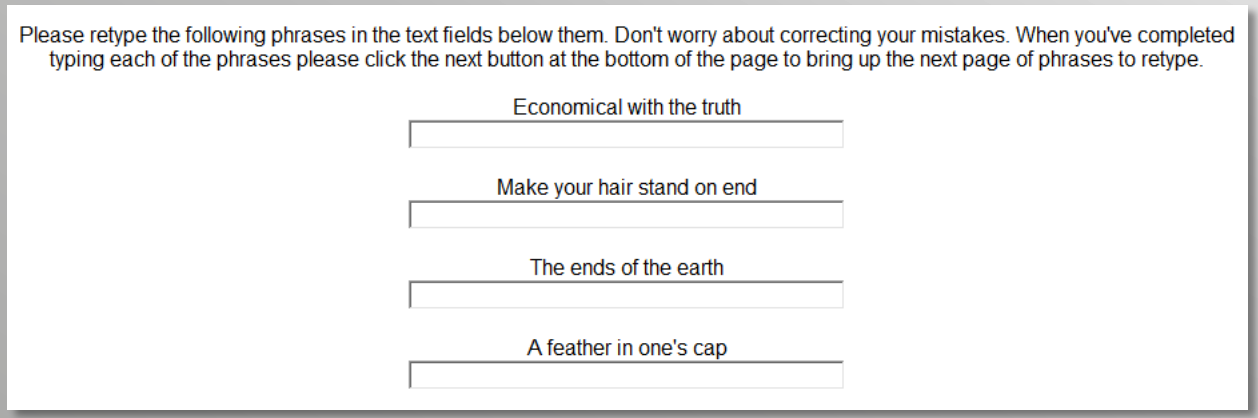
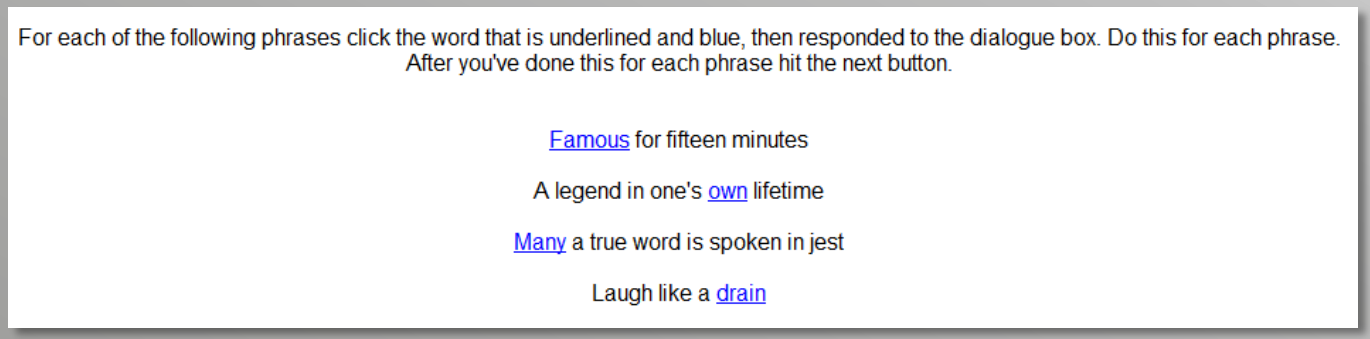
Tasks

Typing Task:



Clicking Task:



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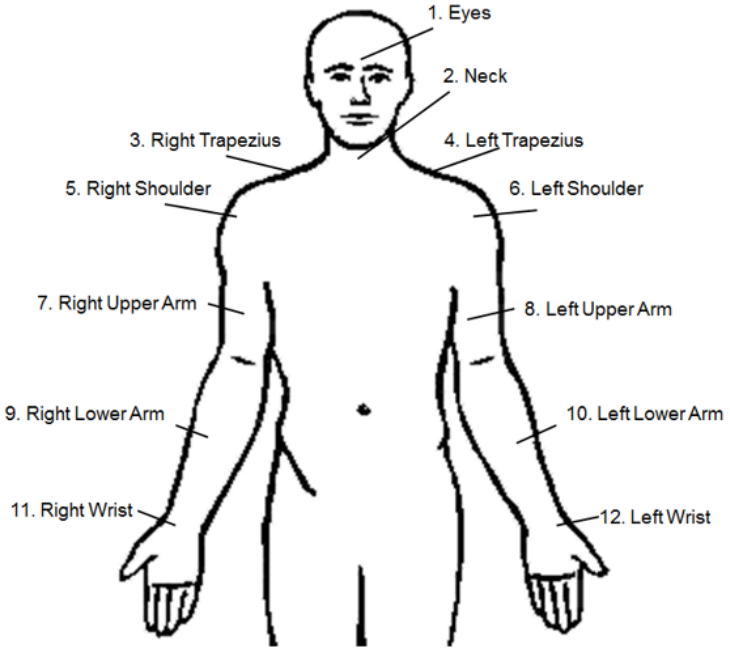
For each body part during the task you just completed, indicate the amount of discomfort perceived on a scale from 0 to 10, with 0 indicating that there was no perceived discomfort and 10 indicating very, very intense discomfort. Also, for each body part indicate the percentage of the time you feel that body part was used during the task you just completed.

0	1	2	3	4	5	6	7	8	9	10
Nothing at all (no discomfort)					Moderate					Very Intense discomfort



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**

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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:

Rating	Verbal Anchor
0	Nothing at all (At Rest)
1	
2	
3	
4	
5	Strong
6	
7	
8	
9	
10	Extremely Strong (Almost max, lifting 350 lbs. of weights)

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.

Rating	Verbal Anchor
0	Hand is idle most of the time, no regular physical efforts
1	
2	Consistent and noticeable long pauses or very slow movements
3	
4	Slow and steady movements with frequent but brief pauses
5	
6	Steady movements and physical effort with few pauses
7	
8	Fast and repetitive movements with no pauses
9	
10	Fast and repetitive movements that cannot be maintained.

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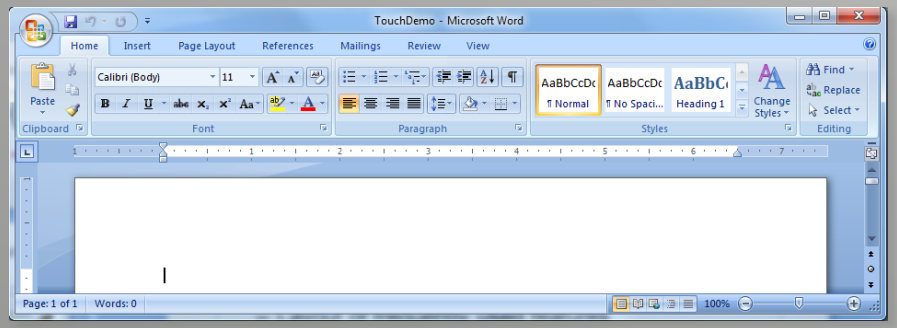
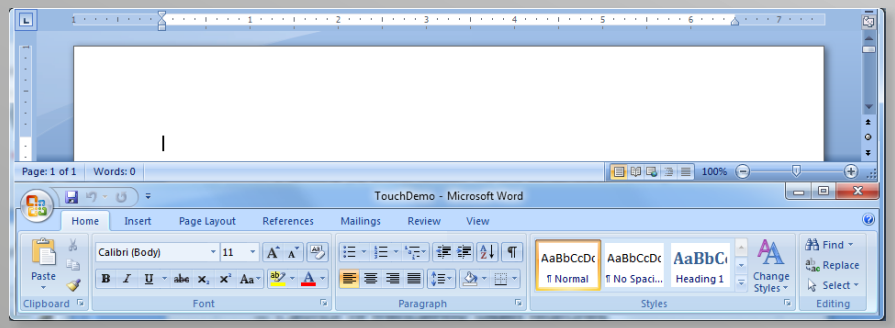
Software Biomechanics

- Software design affects how we work
- Which layout would be best for touch screen interaction?





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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

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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 a effective and efficient measure