The use of multiple and ultrawide monitors on user experience

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In Data Deluge, Multitaskers Go to Multiscreens

By MATT RICHTER  FEB. 7, 2012

Discovering Two Screens Aren’t Better Than One

It’s Time for Accountants to Ditch Dual Monitors

By MEGAN LEWCZYK
Display size continues to **increase**

- **23.8”** expected to take the top position as most popular monitor size by 2023 (currently 21.5”)

- **Curved** monitors demonstrated a **44.7%** year-over-year growth in 2Q19

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<table>
<thead>
<tr>
<th>Level of Evidence (direction of effect)</th>
<th>Outcome Measure (# of studies)</th>
<th>Message</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strong (positive)</td>
<td>User preference (7)</td>
<td>Implementing dual monitors is in line with users’ preference</td>
</tr>
<tr>
<td>Moderate (negative)</td>
<td>Increased neck rotation (3)</td>
<td>Implementing multiple monitors may result in non-neutral neck postures for users; ergonomists should consider this when installing new monitor configurations and training users</td>
</tr>
<tr>
<td>Moderate (positive)</td>
<td>Efficiency (3)</td>
<td>Controlled laboratory studies demonstrate that multiple monitors may increase task efficiency with decreased desktop interaction</td>
</tr>
<tr>
<td></td>
<td>Desktop interaction (5)</td>
<td></td>
</tr>
<tr>
<td>Limited (positive)</td>
<td>Time savings (2)</td>
<td>Not enough evidence from the scientific literature to guide current policy/practices</td>
</tr>
<tr>
<td>Mixed</td>
<td>Neck muscle activity (4)</td>
<td>Not enough evidence from the scientific literature to guide current policy/practices</td>
</tr>
<tr>
<td>Insufficient</td>
<td>Eye muscle activity (1)</td>
<td>Not enough evidence from the scientific literature to guide current policy/practices</td>
</tr>
<tr>
<td></td>
<td>Eye strain (1)</td>
<td></td>
</tr>
</tbody>
</table>
Has display research kept up with market changes?

Gallagher et al. *Human Factors*. Accepted 2019

Percentage sales taken from IDC (2015)
Gaps in biomechanics studies

- **Comparing** between studies is **difficult**
  - Tasks interaction not typically assessed
  - Inconsistent configuration comparisons and controls

- **Curved** and **ultrawide** monitors have not been assessed for musculoskeletal strain

Gallagher et al. *Human Factors*. Accepted 2019
Overall Objective

Determine how monitor configuration influences user biomechanics, discomfort, and performance

Establish evidence-based guidelines on computer monitor implementation that are informed from both a biomechanical and performance perspective
Specific Aims

Specific Aim #1: Determine the effects of computer monitor configuration on **neck biomechanics** and **discomfort**

- Certain monitor configurations will allow for a more neutral neck posture and lower neck muscle activity; however, *this may be task-dependent.*

- Certain monitor configurations will result in lower discomfort outcomes.
Specific Aims

Specific Aim #2: Determine the effects of computer monitor configuration on user performance and preference

• Certain monitor configurations will demonstrate better user performance and user preference; however, this may be task-dependent
Participants

17 Graduates students (male and female) > 18 years old

Exclusion Criteria: Head, neck, back, or upper extremity injuries; a history of migraines or concussion
Single 24"
Curved Ultrawide
Dual 24” - Centered
24” + Laptop
Dual 24” - Primary +Landscape Secondary
Dual 24” - Primary +Portrait Secondary
Instrumentation

Motion Capture
- Three-dimensional head and trunk position
- Three-dimensional neck angle
- Right hand markers

Questionnaires
- 100 mm Visual Analog Scales (VAS) for discomfort development
- Modified Post-Study System Usability Questionnaire (PSSUQ) (Lewis, 1995)
Experimental Design

• Repeated measures design

• **Six** monitor configurations

• **Five** tasks per monitor configuration

• Each monitor configuration was tested for 50-minutes on **six** separate days
Protocol

• Six lab visits

• 1 hour protocol (one configuration per session = 6 sessions)
  • Tasks (T1-T5) randomized for each configuration
Task and configuration **interactions** are plausible

**Compare**
- Draw
- Original

**Drag-Drop**

**Copy-paste**
- Power point slide
- Paste images from google

**Referencing Info**
- Preparing Report
- Information from Amazon

**Monitoring Info**

**Excel File**
- Stock 1
- Stock 2
- Stock 3
- Stock 4

Tasks were based on previous work (Stringfellow 2007)
**Workstation Setup**

- The left-most monitor (or side of the screen) was always assigned as the main monitor

- Workstation design set up for each participant and kept consistent throughout
  - Exception with ultrawide: Piloting found that participants thought the monitor was too close when positioned at the same distance away as the 24” monitors

- Windows-based default screen sizing was used

- Window placement kept consistent across tasks (not user defined)
Outcome variables

• Neck axial rotation
  • Median (APDF 50\textsuperscript{th} percentile) and range (APDF 90-10\textsuperscript{th} percentile)

• Hand position
  • Total movement of the hand centroid in a plane created by the table
  • Compare and drag-drop only

• VAS score
  • changes over 1 hour (does not take into account the task)
Performance and usability outcomes

Screen information tracked with Techsmith Morae

• Number of mouse clicks
• Number of window switches
• Number of mouse scrolls

• PSSUQ scores for each task in each configuration
Statistical Analyses

**Neck Rotation (median & range) (alpha = 0.05)**
Repeated Measures ANOVA for each task (5 in total)
  - Configuration (6 levels)
  - Post hoc tests: Tukey

**Hand Position and Performance Data (alpha = 0.05)**
- Not normally distributed
- Wilcoxon signed rank tests with SINGLE as a control
Kinematics

Neck Rotation Angle

Hand distance
Median Neck Rotation (degrees)

Rotation Range of Motion (degrees)

Referencing Information

Left

Right
## Neck Rotation: Summary

<table>
<thead>
<tr>
<th>Task</th>
<th>Neutral</th>
<th>Non-Neutral</th>
<th>“Static”</th>
</tr>
</thead>
<tbody>
<tr>
<td>Compare</td>
<td>LAPTOP</td>
<td>SINGLE</td>
<td>SINGLE</td>
</tr>
<tr>
<td></td>
<td>SECOND</td>
<td>UW LEFT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>PORTRAIT</td>
<td>DUAL</td>
<td></td>
</tr>
<tr>
<td>Copy &amp; Paste</td>
<td>SINGLE</td>
<td>LAPTOP</td>
<td>SINGLE</td>
</tr>
<tr>
<td></td>
<td>UW</td>
<td>SECOND RIGHT</td>
<td>UW</td>
</tr>
<tr>
<td></td>
<td>DUAL</td>
<td>PORTRAIT</td>
<td></td>
</tr>
<tr>
<td>Referencing</td>
<td>SINGLE</td>
<td>LAPTOP</td>
<td>SINGLE</td>
</tr>
<tr>
<td></td>
<td>UW</td>
<td>SECOND RIGHT</td>
<td>UW</td>
</tr>
<tr>
<td></td>
<td>DUAL</td>
<td>PORTRAIT</td>
<td></td>
</tr>
<tr>
<td>Drag &amp; Drop</td>
<td>SINGLE</td>
<td>DUAL</td>
<td>SIMILAR</td>
</tr>
<tr>
<td></td>
<td>UW</td>
<td>LEFT</td>
<td></td>
</tr>
<tr>
<td></td>
<td>LAPTOP</td>
<td>SECOND PORTRAIT</td>
<td></td>
</tr>
<tr>
<td>Monitor Information</td>
<td>ALL</td>
<td>SINGLE</td>
<td></td>
</tr>
</tbody>
</table>
### Hand Distance in 10 minutes (meters)

<table>
<thead>
<tr>
<th>Task</th>
<th>Single</th>
<th>UW</th>
<th>Dual</th>
<th>Second</th>
<th>Portrait</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Compare</strong></td>
<td>2.1 (2.0-3.3)</td>
<td>2.7 (2.2-5.8)*</td>
<td>3.1 (2.5-3.8)</td>
<td>2.7 (2.3-3.5)</td>
<td>2.5 (2.0-3.2)</td>
</tr>
<tr>
<td><strong>Drag &amp; Drop</strong></td>
<td>4.0 (3.8-4.6)</td>
<td>4.6 (4.1-5.6)*</td>
<td>4.3 (3.7-5.3)</td>
<td>4.7 (3.6-5.4)</td>
<td>4.5 (3.8-5.2)</td>
</tr>
</tbody>
</table>

Presented as median (interquartile range)

* = significantly different than Single ($p<0.05$)

- Laptop not include because monitor stand interfered with the hand markers
- These two tasks were mouse dominant
# VAS Scores (in mm from 0-100 mm)

<table>
<thead>
<tr>
<th></th>
<th>Single</th>
<th>UW (0.0-11.8)</th>
<th>Dual (0.0-16.0)</th>
<th>Second (0.0-12.2)</th>
<th>Portrait (0.0-9.0)</th>
<th>Laptop (0.0-21.3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Neck</td>
<td>3.0 (0.0-6.5)</td>
<td>6.0 (0.0-11.8)</td>
<td>0.5 (0.0-16.0)</td>
<td>1.0 (0.0-12.2)</td>
<td>1.5 (0.0-9.0)</td>
<td>3.0 (0.0-21.3)</td>
</tr>
<tr>
<td>Upper Back</td>
<td>1.0 (0.0-6.0)</td>
<td>0.5 (0.0-12.5)</td>
<td>0.5 (0.0-8.5)</td>
<td>1.0 (0.0-10.0)</td>
<td>1.0 (0.0-4.3)</td>
<td>5.8 (0.1-16.0)</td>
</tr>
<tr>
<td>Lower Back</td>
<td>0.0 (0.0-3.3)</td>
<td>0.0 (0.0-4.8)</td>
<td>0.0 (0.0-7.0)</td>
<td>0.0 (0.0-5.0)</td>
<td>0.5 (0.0-4.8)</td>
<td>0.0 (0.0-3.9)</td>
</tr>
<tr>
<td>Eye Strain</td>
<td>5.5 (0.0-7.0)</td>
<td>6.0 (0.0-7.0)</td>
<td>2.0 (0.5-13.0)</td>
<td>3.5 (0.0-12.0)</td>
<td>1.0 (0.0-7.0)</td>
<td>5.5 (0.3-17.9)</td>
</tr>
</tbody>
</table>

Presented as median (interquartile range)

* = significantly different than Single \( p<0.05 \)
Performance Variables
Monitor conditions significantly different from SINGLE (p<.05)
# PSSUQ Survey Scores (Out of 77)

<table>
<thead>
<tr>
<th></th>
<th>Single</th>
<th>UW</th>
<th>Dual</th>
<th>Second</th>
<th>Portrait</th>
<th>Laptop</th>
</tr>
</thead>
<tbody>
<tr>
<td>Survey</td>
<td>66.0</td>
<td>71.0</td>
<td>74.0</td>
<td>70.0</td>
<td>68.0</td>
<td>61.0</td>
</tr>
<tr>
<td>Score</td>
<td>(60.0-76.5)</td>
<td>(64.5-77.0)*</td>
<td>(60.5-77.0)*</td>
<td>(66.5-77.0)*</td>
<td>(62.0-76.5)</td>
<td>(51.8-70.8)</td>
</tr>
</tbody>
</table>

*Higher numbers = more positive ratings*

*Presented as median (interquartile range)*

* = significantly different than *Single* (*p*<0.05)
Compared to a single monitor (Preliminary)

- Ultrawide and portrait monitors require fewer clicks and scrolls when used with a copy and paste task

- Ultrawide monitors decrease the number of clicks and scrolls when monitoring information

- Laptop increased the number of clicks and scrolls when monitoring information
Compared to a single monitor (Preliminary)

• Hand movement increased when using an Ultrawide monitor for mouse-based tasks compared to a single monitor

• Ultrawide, dual, and secondary landscape configurations were prefered by users
Observations

• 24” not sized well for portrait mode
  • 24” + smaller monitors in portrait if this is desired? Other issues with different screens may arise
Limitations

• How does a person define their dominant monitor?
  • Could have resulted in more similar neck angles for copy-paste and referencing information

• Fixed window layouts

• Laptop condition was a “best” case scenario
  • With larger monitors, could provide a larger screen and not use the laptop as a secondary monitor
Summary

- The UW monitor compared well to the single monitor
  - Did resulted in a greater neck range of motion in some cases
  - Fewer clicks and scrolls across mouse-based tasks

- The UW median posture was similar to dual monitor; however, less neck movement
  - 24” Dual = 1036.8 mm horz x 324.0 mm vert = 335923.2 mm²
  - 34” UW = 798.2 mm horz x 334.8 mm vert = 267237.36 mm²

- More hand movement when using an ultrawide monitor compared to the single monitor in mouse-based tasks

- People preferred an increase in screen size, but only if it was an increase in width compared to the single monitor

- A dedicated monitor set up where the laptop does not need to be a secondary monitor may be ideal
Future work: Ultrawide/large monitors

- **Window organization**
  - How do people organize their windows when given no guidance?

- **Mouse-dominant tasks**
  - increase in arm workload?

- **Positioning of an ultrawide monitor**
  Previous OERC-funded work by Shin & Hedge (2010)
  - 19” (5:4/1280/1024): 68 cm (+/- 8 cm)
  - 24” (16:10/1920x1200): 72 cm (+/-12 cm)
  - 27.5” (16:10/1920x1200): 76 cm (+/-14 cm)
  .....  
  - 34” (21:9/3440x1440): ?
  - 38” (21:9/3840x1600): ?
  - 49” (32:09/5120x1440): ?
Dissemination Plans

May/June  Finish manuscript & submit to Human Factors

August?  Submitted neck kinematic data to the American Society of Biomechanics

October?  Submitted kinematic and performance data to HFES
Acknowledgments

• OERC

• Herman-Miller provided monitor and laptop arms

• Team members: Caleb Burruss and Elizabeth Bjornsen

• U of A Chancellor’s Innovation Grant provided additional money to compensate participants


IDC. (2017). Dell sees solid year-over-year growth in worldwide PC monitor market in second quarter of 2017, according to IDC.


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