WEBINAR

MSD Prevention and Ultrawide Computer Displays for Office Work

Dr. Kaitlin Gallagher | February 22, 2023

Today's Objectives

- Review literature on multiple screen configurations

- Define ultrawide and curved display characteristics

- Why ultrawide?

- Review initial performance and usability metrics for large display configurations.

- Provide results of laboratory and survey studies on user-preferred positioning and use of ultrawide curved displays.

- Summarize and take home

Does Using Multiple Computer Monitors for Office Tasks Affect User Experience? A Systematic Review

Kaitlin M. Gallagher⊙, Laura Cameron, University of Arkansas, Fayetteville, USA, Diana De Carvalho⊙, Memorial University of Newfoundland, ON, Canada, and Madison Boulé, University of Arkansas, Fayetteville, USA

- **18** articles/proceedings/theses assessed health or productivity outcomes when using multiple monitors.

- Only **6** had health-related outcomes.

Gallagher et al. (2021) *Human Factors*.

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

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Display research had not kept up with market changes
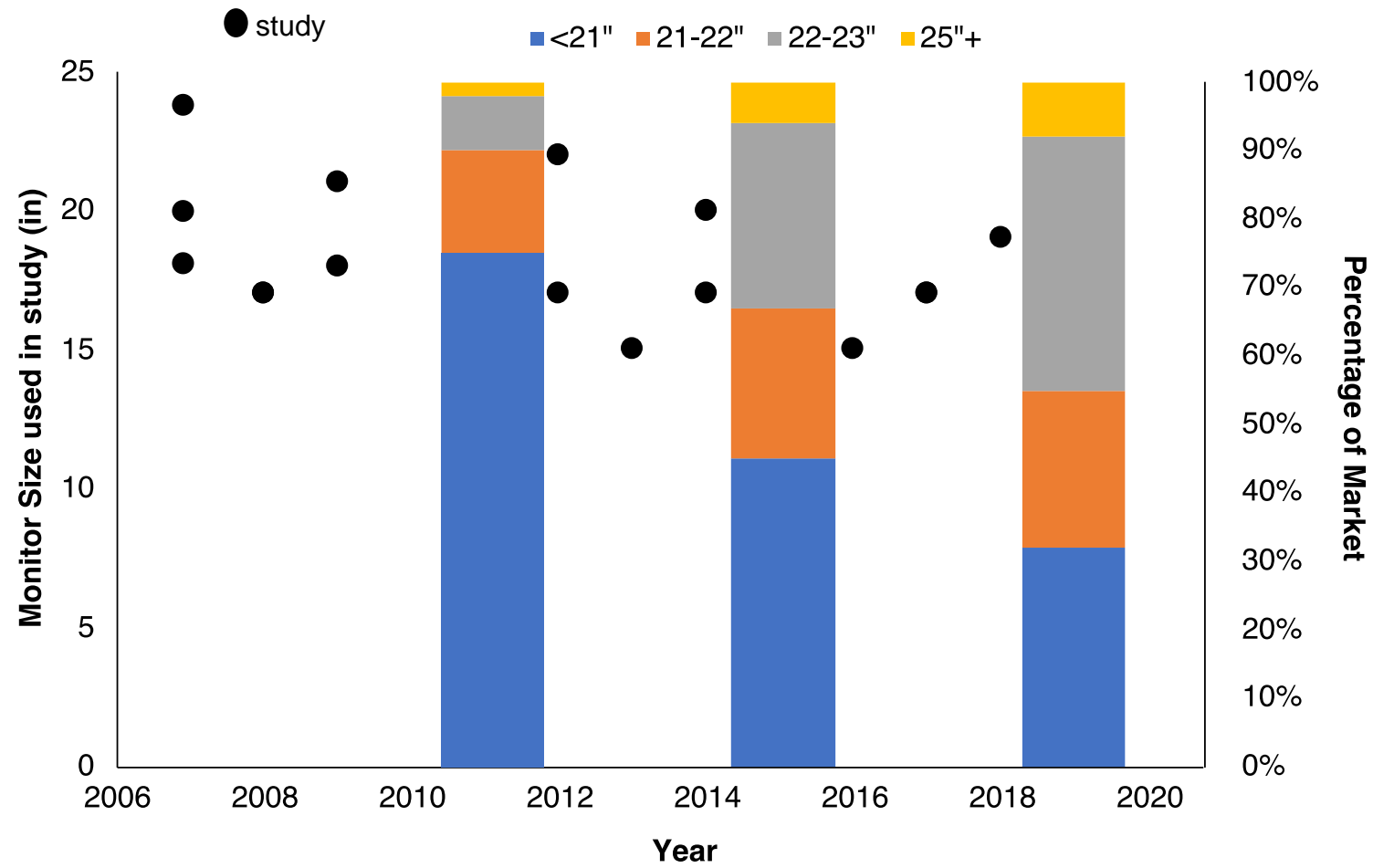
Gallagher et al. (2021) *Human Factors*.

Percentage sales taken from IDC (2015)

Curved and Ultrawide Displays

Curved monitors had a **44.7%** year-over-year growth in 2Q19.
Many of these monitors are ultrawide (21:9 or 32:9)

Global PC Monitor Volume Declines in the Second Quarter of 2019, According to IDC [press release]. 2019. https://www.idc.com/getdoc.jsp?containerId=prUS45567419

FYI: 16:9 Curved Exist

Initial Work – Microsoft (2003)

Figure 1. User working on experimental Dsharp display.
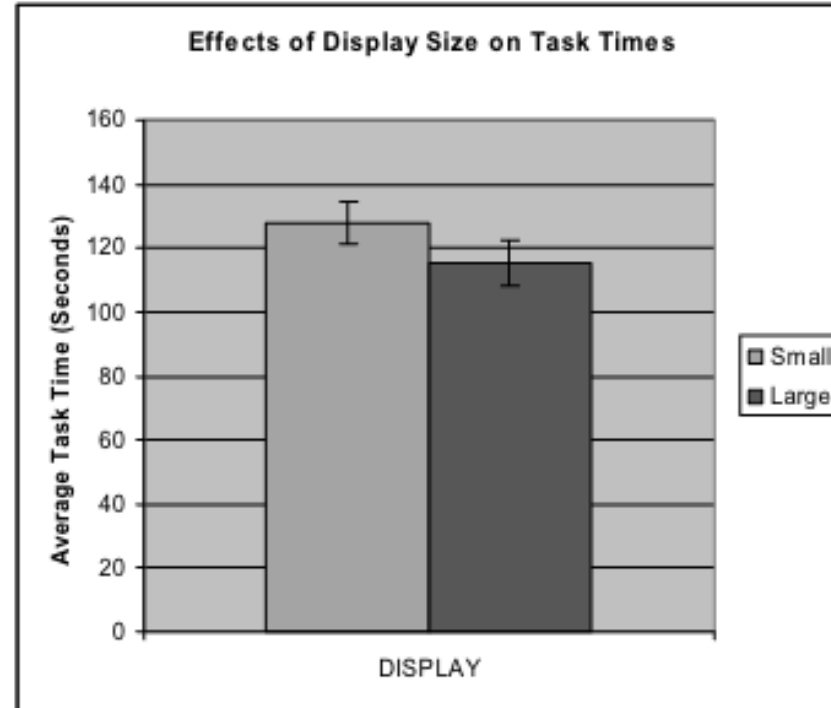
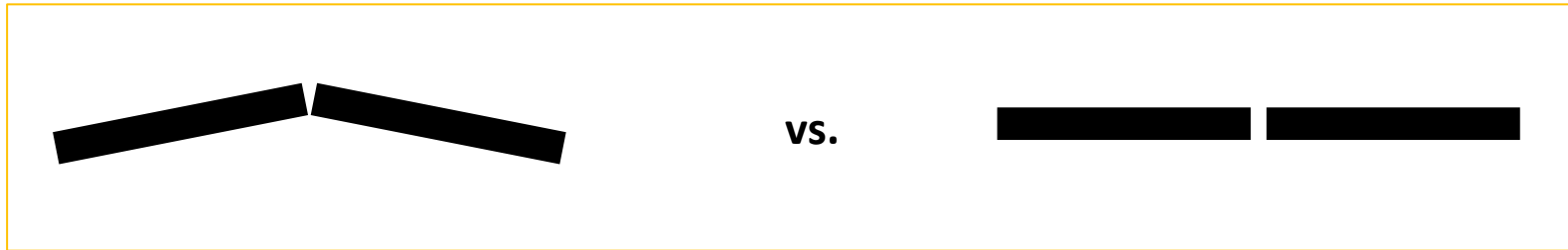Figure 2. Average task times for 15" LCD v. DSharp.

300 more window events on small display

Czerwinski, M., et al. (2003). *Toward Characterizing the Productivity Benefits of Very Large Displays.* (2003) Interact

Why curved ultrawide, not just ultrawide?

Less distortion

Viewer

Distortion at edges

Distortion at edges

Viewer

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Why curved ultrawide, not just ultrawide?

vs.
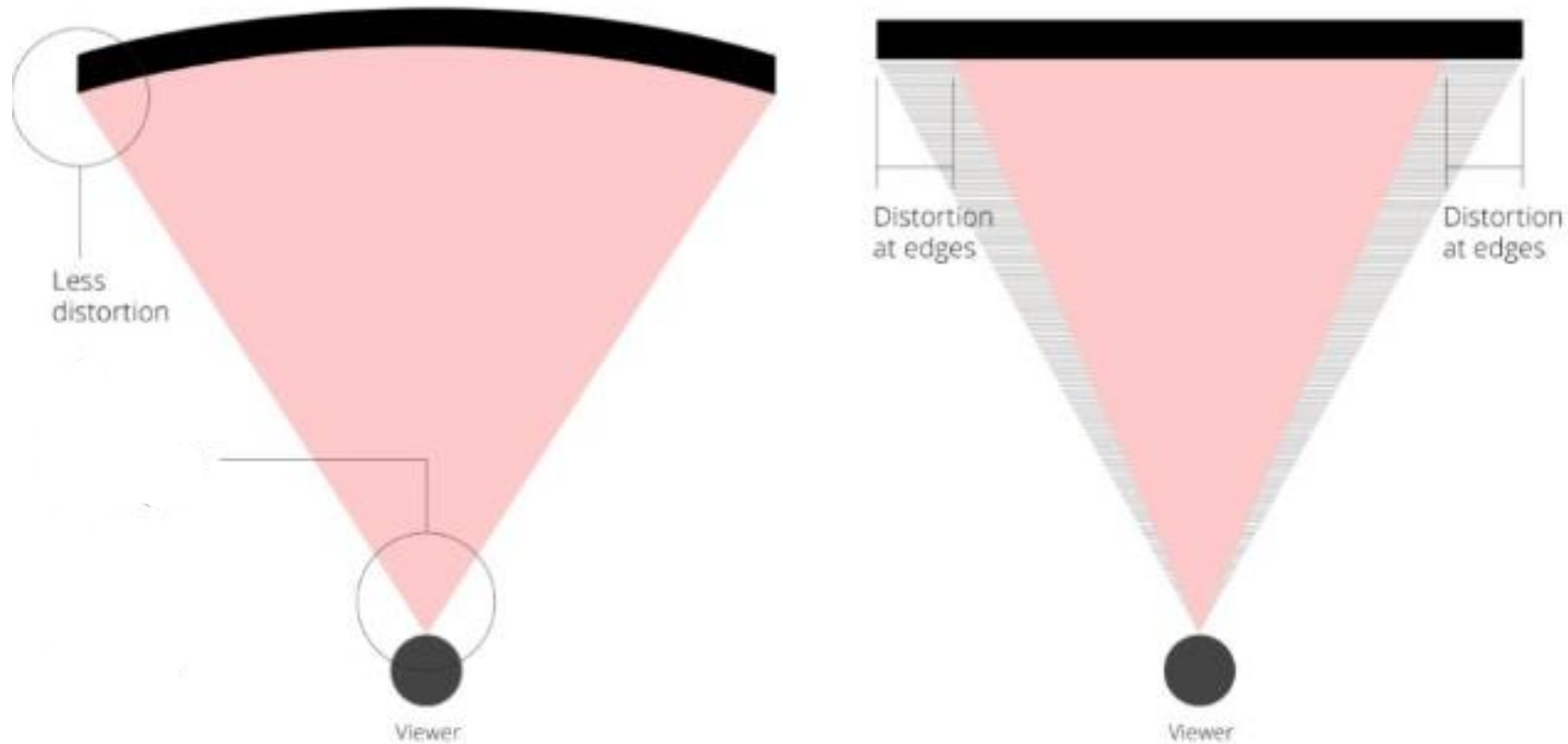
People will lean forward
to shorten the horizontal distance

a) Simple neck rotation to view peripheral screen (uncommon practice)

b) Participant shifts body back-left as indicated by the red arrow and then rotates neck to view peripheral screen (common practice)

Stringfellow (2007)
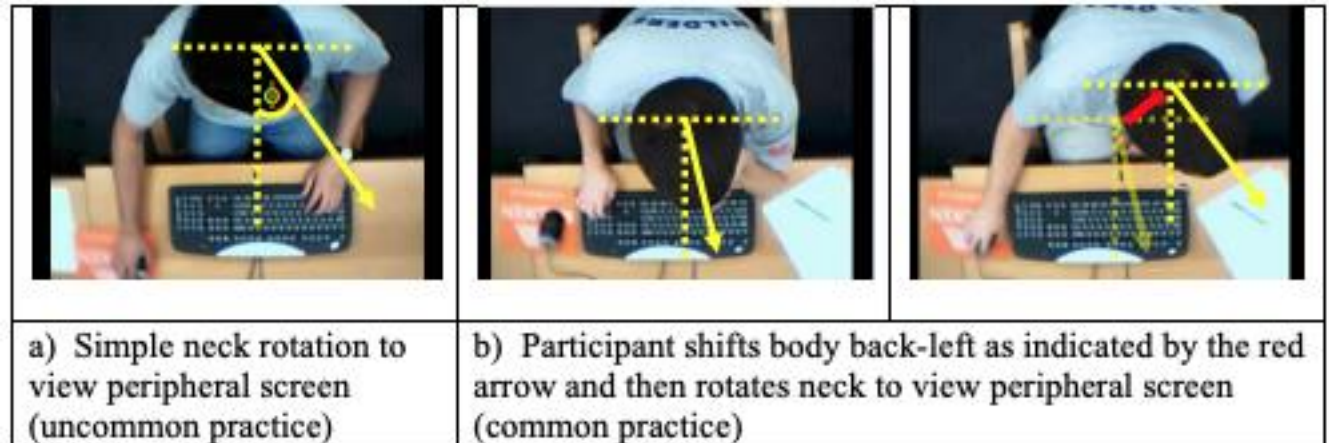
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What is a curvature radius?

1800R
3000R
3800R
etc.
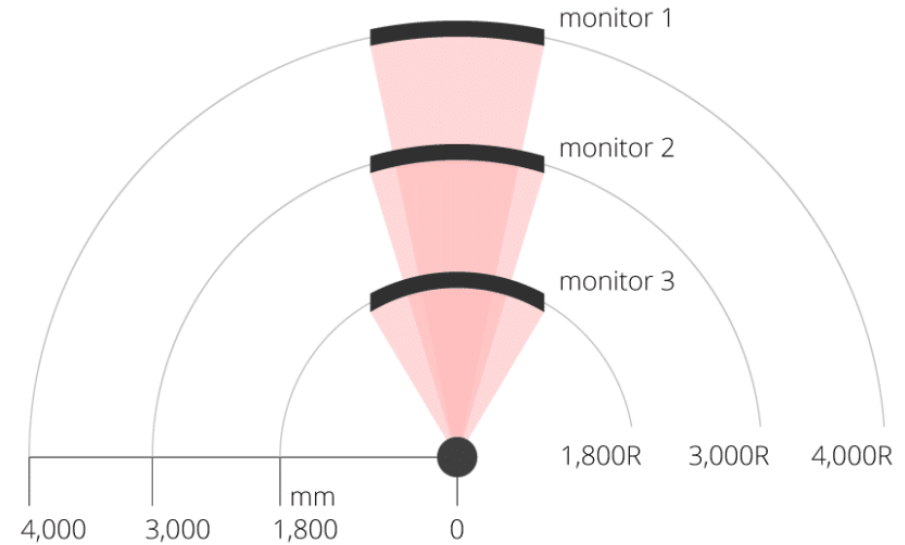
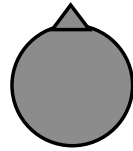**Two 24" diagonal flat panel (16:9)**

34" diagonal ultrawide curved (21:9)

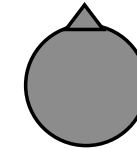| Screen Width	53.8 * 2 = 107.6 cm	80.8 cm
Screen Height	31.1 cm	36.5 cm
Cost	$349.99*2 = $699.98 CAD	$619.99 *Can go much higher for different features*
Brightness	250 cd/m²	300 cd/m²

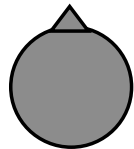# Initial Study – Display Comparisons

Single 24"

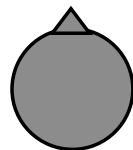Initial feedback
Too close!
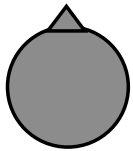
Curved Ultrawide
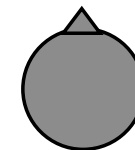
Dual 24" - Centered

24" + Laptop

Dual 24" - Primary
+Landscape Secondary

Dual 24" - Primary
+Portrait Secondary

Burruss et al. Human Factors, published online

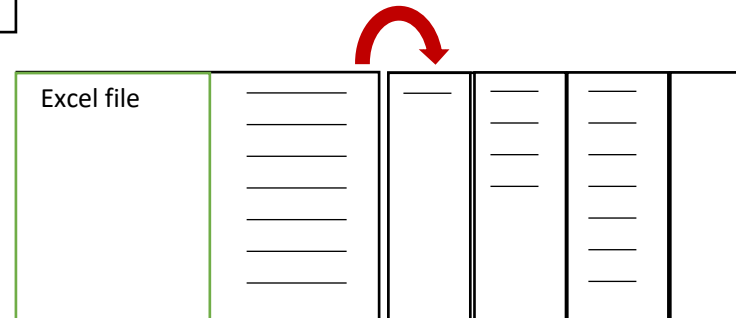UNIVERSITY OF
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Task and configuration **interactions** are plausible

Compare
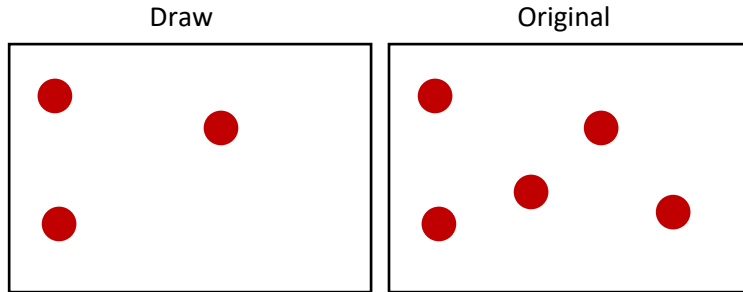
Draw

Original

Referencing Info

| Preparing Report | Information from Amazon |

Drag-Drop

Excel file

Copy-paste

| Power point slide | Paste images from google |

Monitoring Info

Excel File	Stock 1
	Stock 2
	Stock 3
	Stock 4
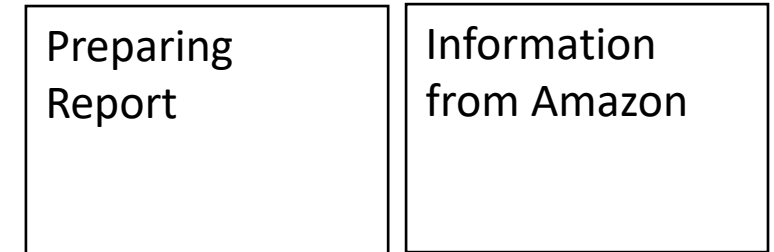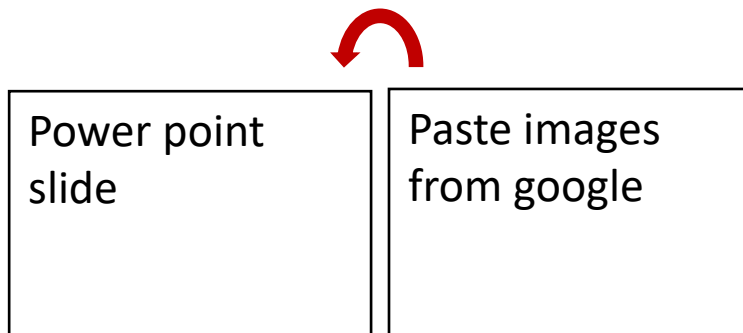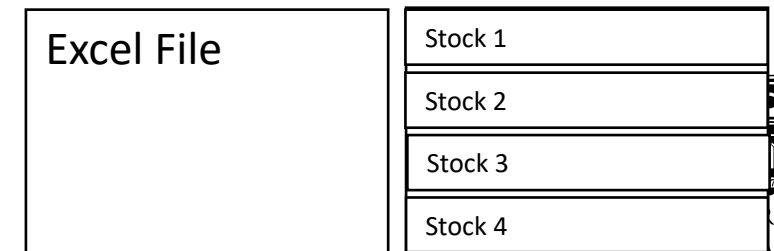
(Burruss et al., 2022; Stringfellow 2007)

Copy & Paste
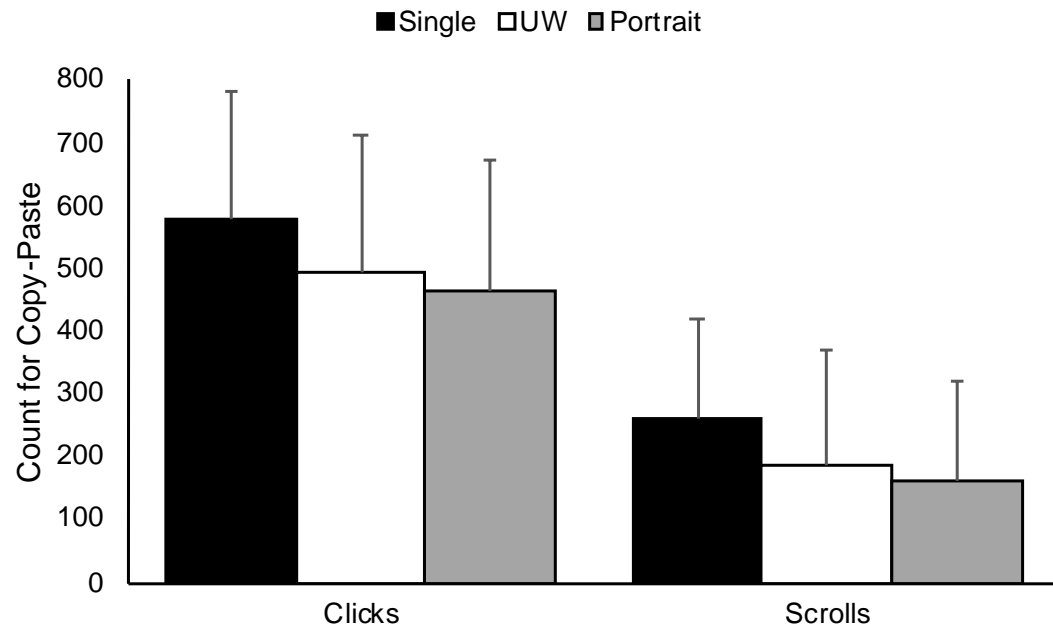
Monitor Information
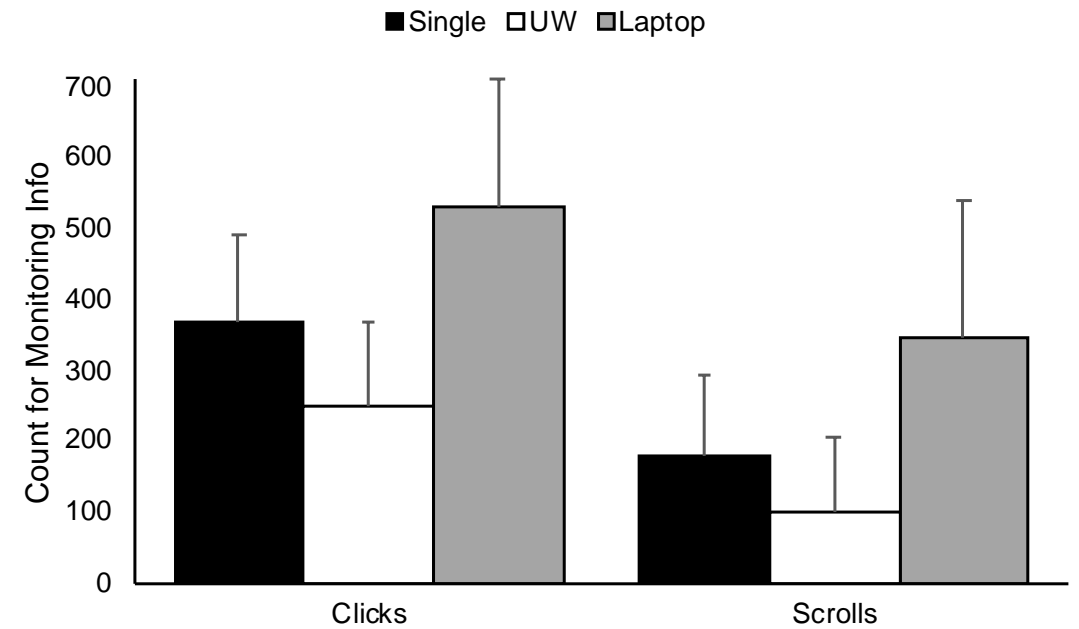
Present monitor conditions different from SINGLE

Participants liked horizontal space

TABLE 4: Median (Interquartile Range) PSSUQ Survey Scores and Statistics Compared to SINGLE

	Single	UW	Dual	Second	Portrait	Laptop
Score out of 77	66.5 (61.25–76.75)	71.5 (66.75–77.0)	74.0 (61.5–77.0)	69.5 (66.25–77.0)	70 (64.25–76.5)	61.0 (51.75–70.75)

Burruss et al. Human Factors, published online
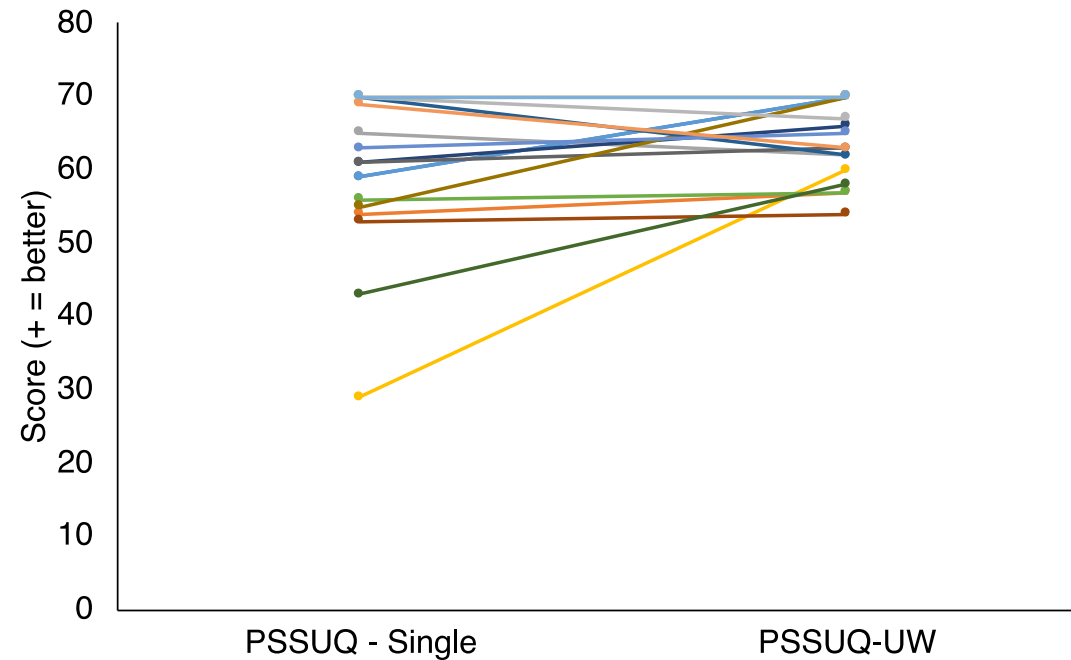
Observations

Larger displays are not sized
well for portrait mode

User placement and posture

DIAGONAL SIZE	23.8 in | 60.45 cm	34 in |86.5 cm	39.7 in | 100.85 cm
CURVATURE RADIUS	N/A	1900R	2500R
ASPECT RATIO	16:9	21:9	
DISPLAY AREA (H x V)	527.0 mm x 296.5 mm	798.2 mm x 334.8 mm	929.3 mm x 392.0 mm
BRIGHTNESS	250 cd/m^2	300 cd/m^2	

Gallagher et al., Unpublished

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Lab Study - Participants

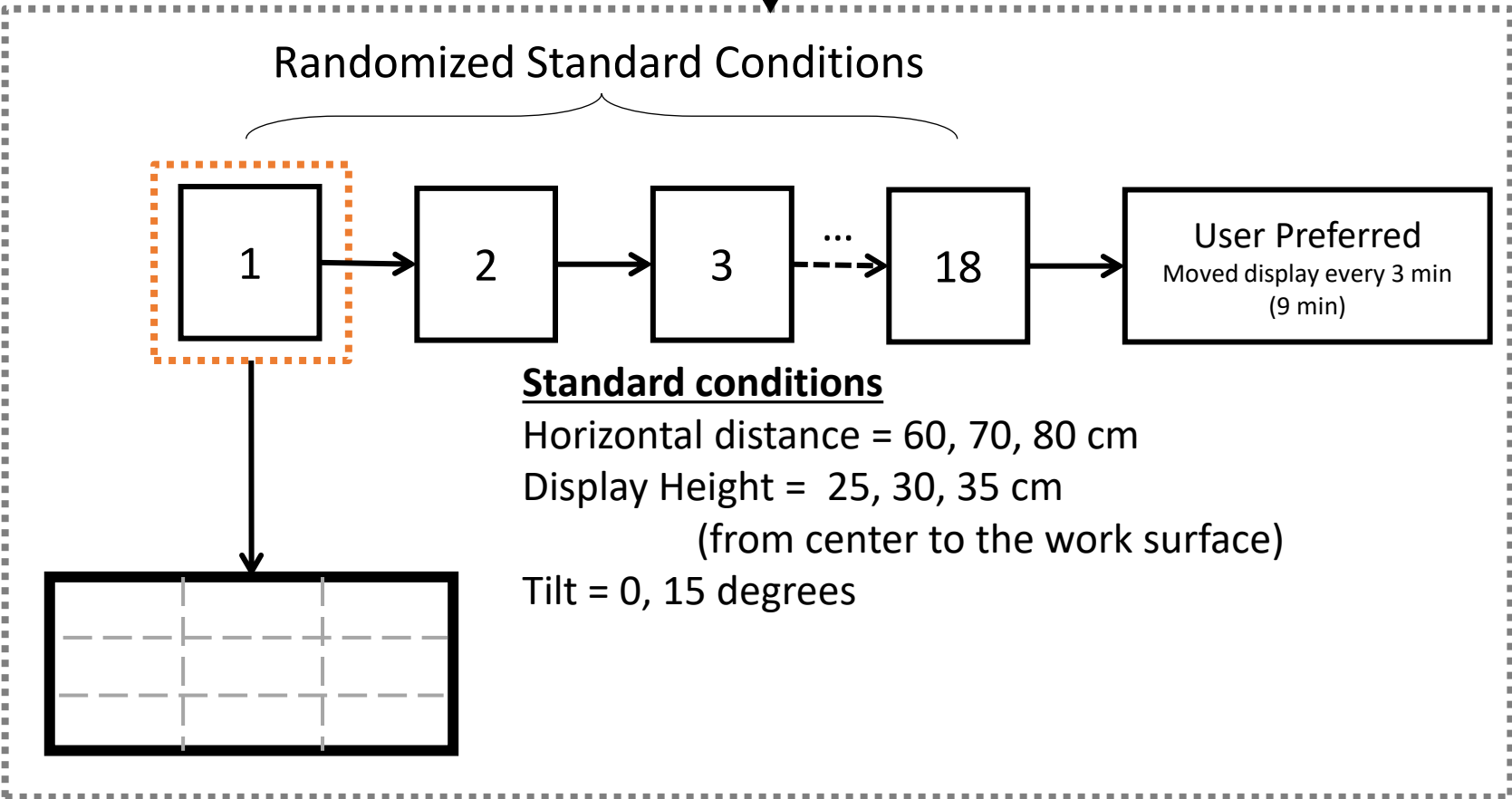|			
n=21 (n=20 with motion capture)	Graduate assistants at the University of Arkansas whose work requires computer use	18-35 years of age	Normal or corrected to normal vision with contacts

Gallagher et al., Unpublished
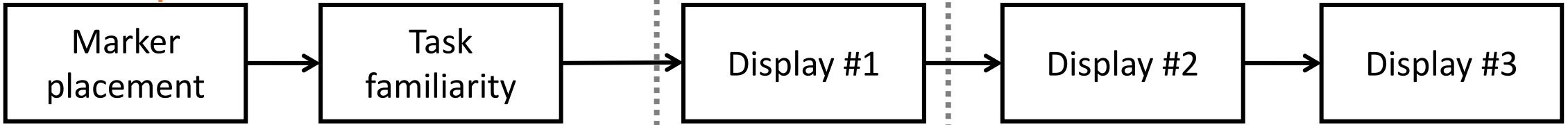
Workstation

Desk

- 36-inch desk depth (Steelcase)
- Height adjusted to each participant

Chair

- Leap (Steelcase) adjusted to the individual and locked backrest.
- Participants chose a position at the desk and maintained it for the entire study.

Usual base for each display

- Only 26% of our survey respondents used display arms at work.

Display brightness standardized

- 120 cd/m^2
- Default brightness varied greatly between displays (40" started at ~200 cd/m^2)

Gallagher et al., Unpublished

Outcomes

A

Horizontal Distance

Gaze angle

B

Neck twist range

Created in **BioRender.com**
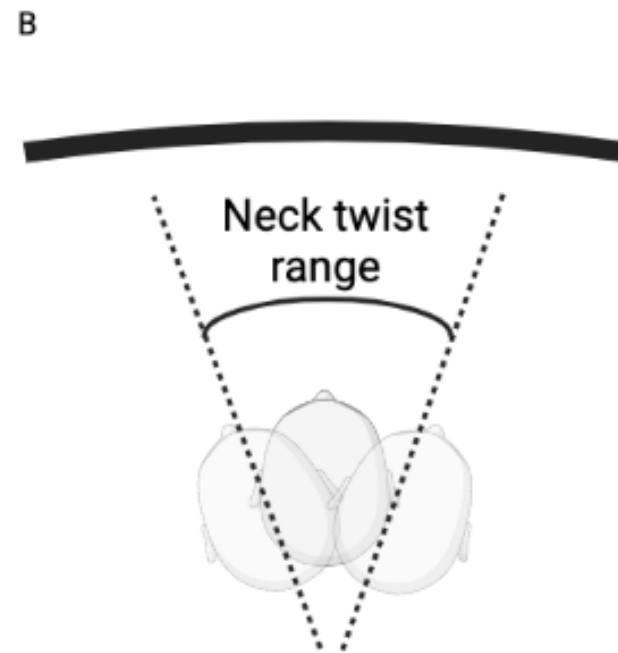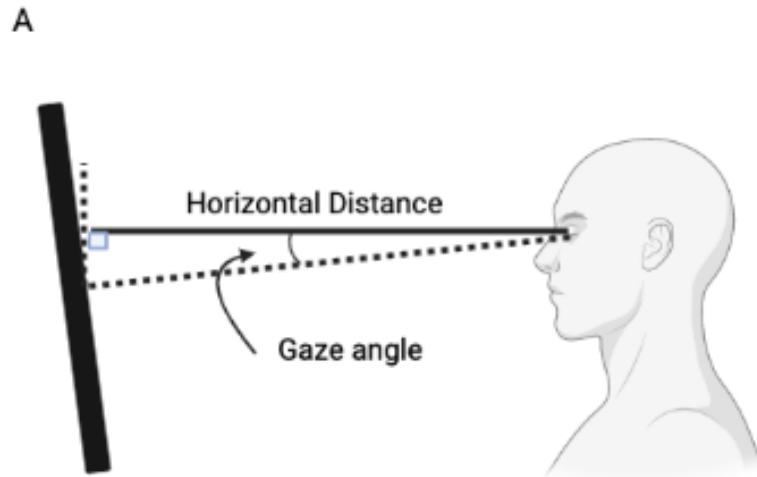
- Repeated measures ANOVA with factor of display size
- Co-variates of display angle and display height (to the center of the display)

Neck rotation range
higher for larger displays

	Display Size		
	24"	**34"**	**40"**
Neck Rotation Range (degrees)	**21.9 (5.9)[A]**	**32.7 (6.5)[B]**	**36.5 (6.9)[C]**

A Horizontal Distance / Gaze angle

B Neck twist range

Significance p<0.05   Gallagher et al., Unpublished

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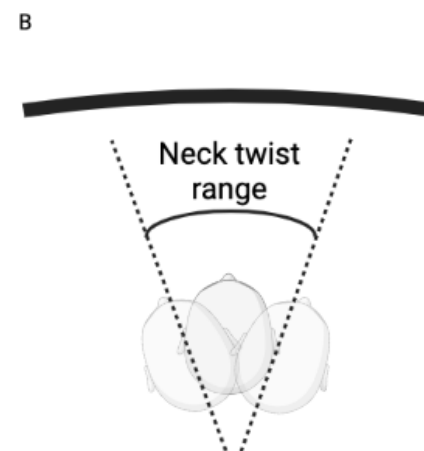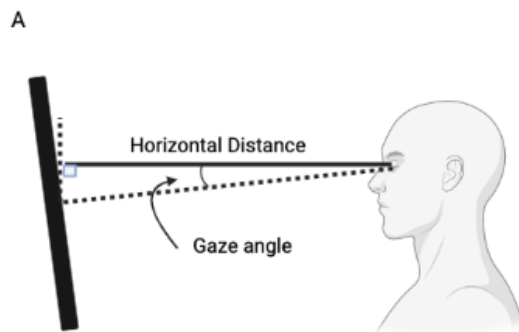
Small **horizontal viewing distance** increase

	Display Size		
	24"	**34"**	**40"**
Neck Rotation Range (degrees)	21.9 (5.9)[A]	32.7 (6.5)[B]	36.5 (6.9)[C]
Horizontal Viewing Distance (cm)	**66.6 (4.4)**	**67.8 (5.3)**	**70.6 (8.0)**

Significance p<0.05   Gallagher et al., Unpublished

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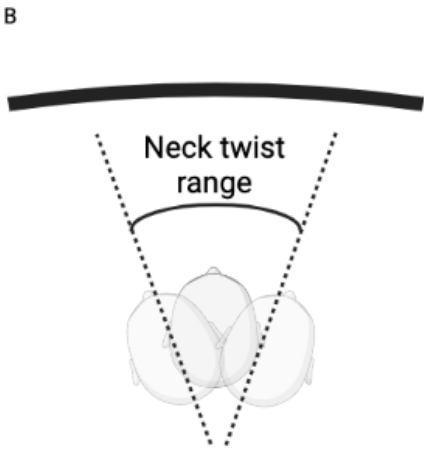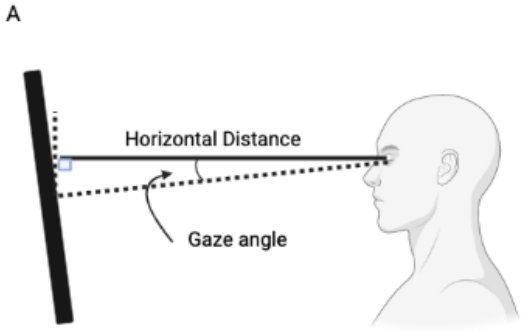
Preferred horizontal distance could result in the back of the display stand **exceeding a 24" desk depth**

Distance between front edge of desk and back of display stand (inches)
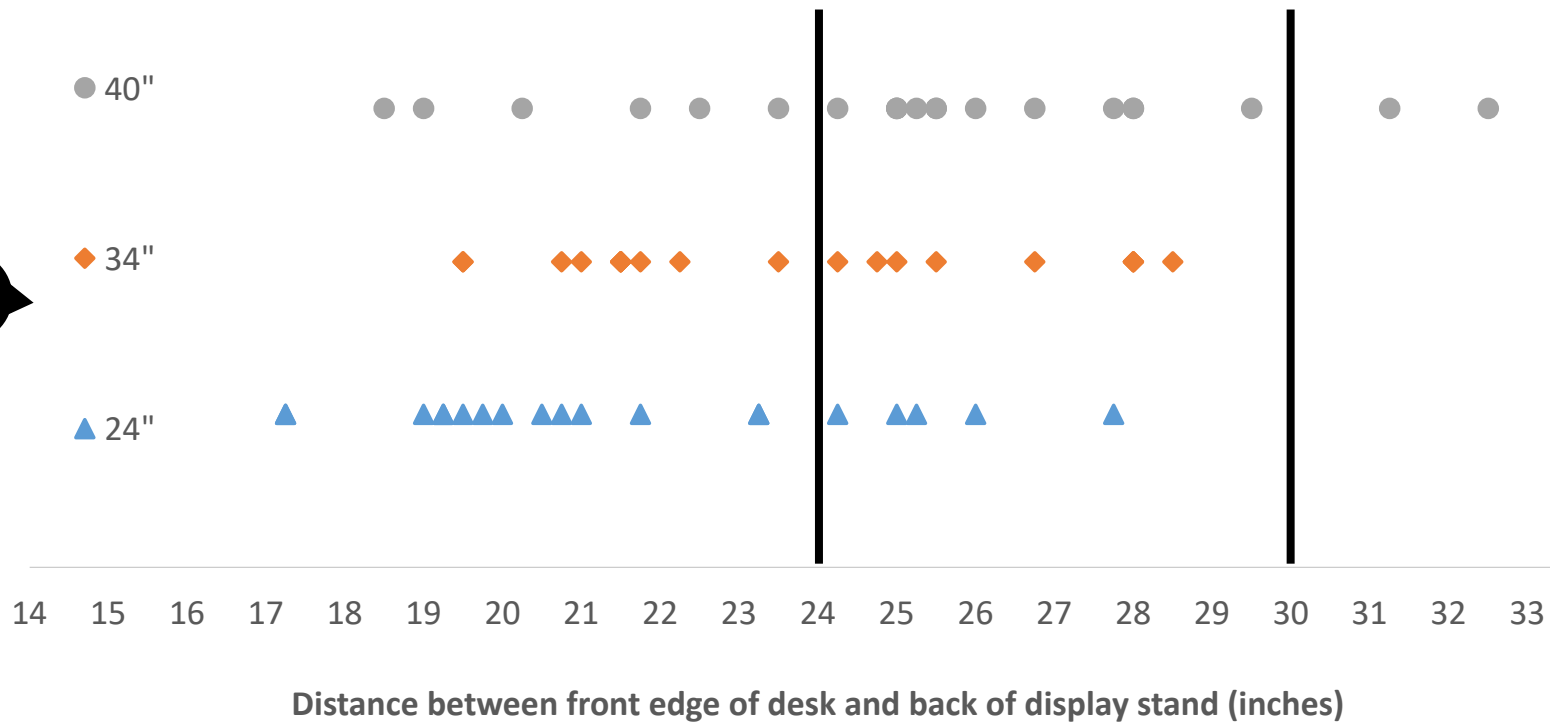
	Display Size		
	24"	**34"**	**40"**
Exceeding 24"✱			
No (n)	14	11	6
Yes (n)	5	9	**15**
Exceeding 30"			
No (n)	19	20	19
Yes (n)	0	0	2

✱Significant Chi-Square Test

Gallagher et al., Unpublished

Gaze angle did not differ

	Display Size		
	24"	**34"**	**40"**
Neck Rotation Range (degrees)	21.9 (5.9)[A]	32.7 (6.5)[B]	36.5 (6.9)[C]
Horizontal Viewing Distance (cm)	66.6 (4.4)	67.8 (5.3)	70.6 (8.0)
Gaze Angle (degrees)	**12.7 (3.4)**	**12.6 (3.3)**	**12.7 (3.3)**

Created in BioRender.com bio

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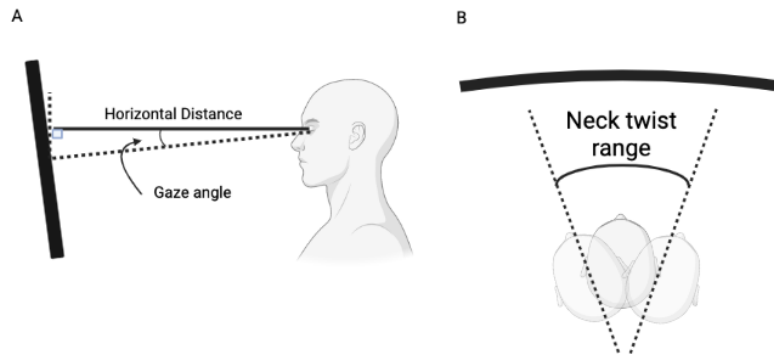
Task influences study results

Make sure the task researchers test is in line with your users

Xjfjads nature dafjk djfad nature dfjlkjlk. Nature djkd ajkfdjl. Dfjakdl fajdjdjf afdjkl qqerq nature erqqrop are reqfdasjkjk nature ajgj

Xjfjads nature dafjk djfad nature dfjlkjlk. Nature djkd ajkfdjl. Dfjakdl fajdjdjf afdjkl qqerq nature erqqrop are reqfdasjkjk nature ajgj

Xjfjads nature dafjk djfad nature dfjlkjlk. Nature djkd ajkfdjl. Dfjakdl fajdjdjf afdjkl qqerq nature erqqrop are reqfdasjkjk nature ajgj

Gallagher et al., Unpublished

Task and configuration interactions occur

Compare

Draw

Original

Drag-Drop

Excel file

Referencing Info

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(Burruss et al., 2022; Stringfellow 2007)
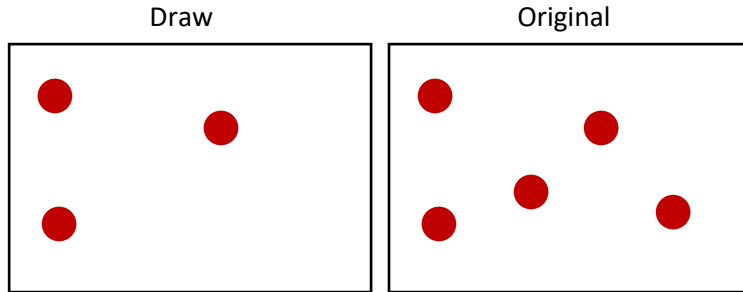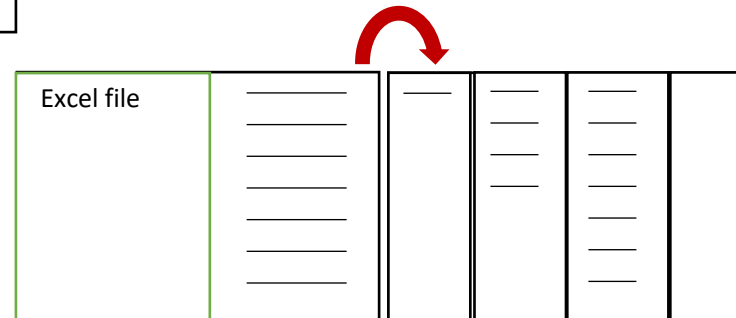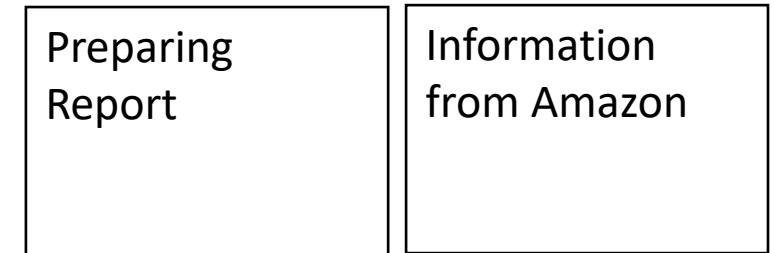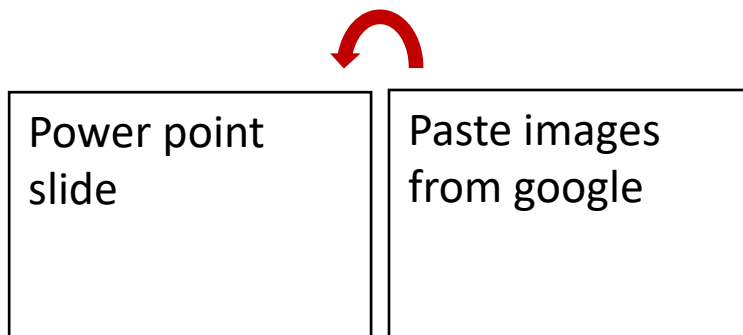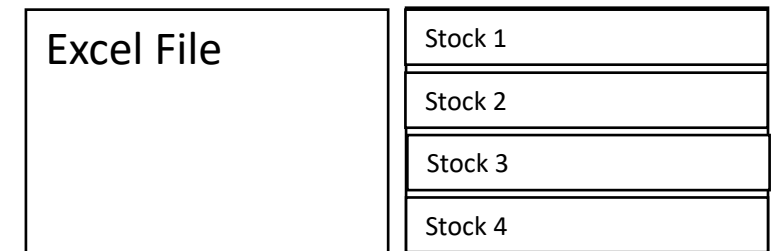
mean (range)	Current Study 34" curved	Bartha et al. (2020) 34" curved	Bartha et al. (2020) 34" flat
Location	Lab	Field	Field
Viewing Distance (cm, total distance)	70 cm (59 to 91)	72 cm (47 to 101)	70 cm (44 to 105)
Gaze Angle (degrees)	13 deg (8 to 21)	10 deg (7 to 24)	11 (-7 to 30)
Display Height (cm, surface to center)	34 cm (28 to 38)	34 cm (21 to 46)	33 (20 to 50 cm)
Screen tilt angle (degrees - = tilt back)	-10 deg (-4 to -18)	2 deg (15 to -12)	2.25 (-14 to 17)

Gallagher et al., Unpublished

Bartha, M. C., Allie, P., & Kokot, D. (2020). Field Observations of Placement for Large-Panel Flat and Curved Displays for Presbyopic and Prepresbyopic Computer Users. *Proceedings of the Human Factors and Ergonomics Society Annual Meeting*, *64*(1), 526–530. https://doi.org/10.1177/1071181320641119

57% preferred the 34" display for work

Size-related comments

"Prefer a wide monitor **but 40" too wide**. Liked the curve."

"Close between the 24" and 34"… Ease of being able to see everything and less screen for the mouse to get to for things (compared to the 40"). …[S]mall is good but bigger is better but large **(40") was too much mouse movement.**"

"The 34" is big enough."

"Could see things well [on 34"]. **40" way too much screen** and gave me a headache."

"Liked the wider [34"] screen **but [40"] was a lot.**"

"[For] 34" [liked] that it was large but not all screen when looking around. Liked that 40" was large with good screen clarity, really clear and liked curvature. **The 40" would feel like being engulfed…**"

57% preferred the 34" display for work

Head Movement

"Liked the 34". It was not too big to move your head around but big enough. The big one [40"] was good but it was "too much"."

"The 34" is big enough and didn't have to move head. The 40" had too much head movement."

"34" felt closest to a dual monitor set up and didn't need to move neck."

"Liked the 34" the best. It was big enough to see everything but not so big that [I] had to turn [my] head too."

Gallagher et al., Unpublished

29% preferred the **40"** display for work

All comments

"Not a big difference in the 40 vs. 34."

"Liked 40" because they could see the letters very well. It **gave [me] enthusiasm to work** because I had a big screen."

"Easier and more natural to read words and less to adjust yourself."

"Liked the 40", but 34" was a close second. I liked that it was bigger and easier to read, **but I had to move it far away to like it.**"

"Liked the 34" size up and down and that it was smaller than the 40" and liked that, **but the 40" does have more room and if needed more room would take [40"].**"

"Liked the 34" the best. It was big enough to see everything but not so big that [I] had to turn [my] head too. They currently have dual monitors **but would keep dual or take [40"] to make distinct sections on the side.**"
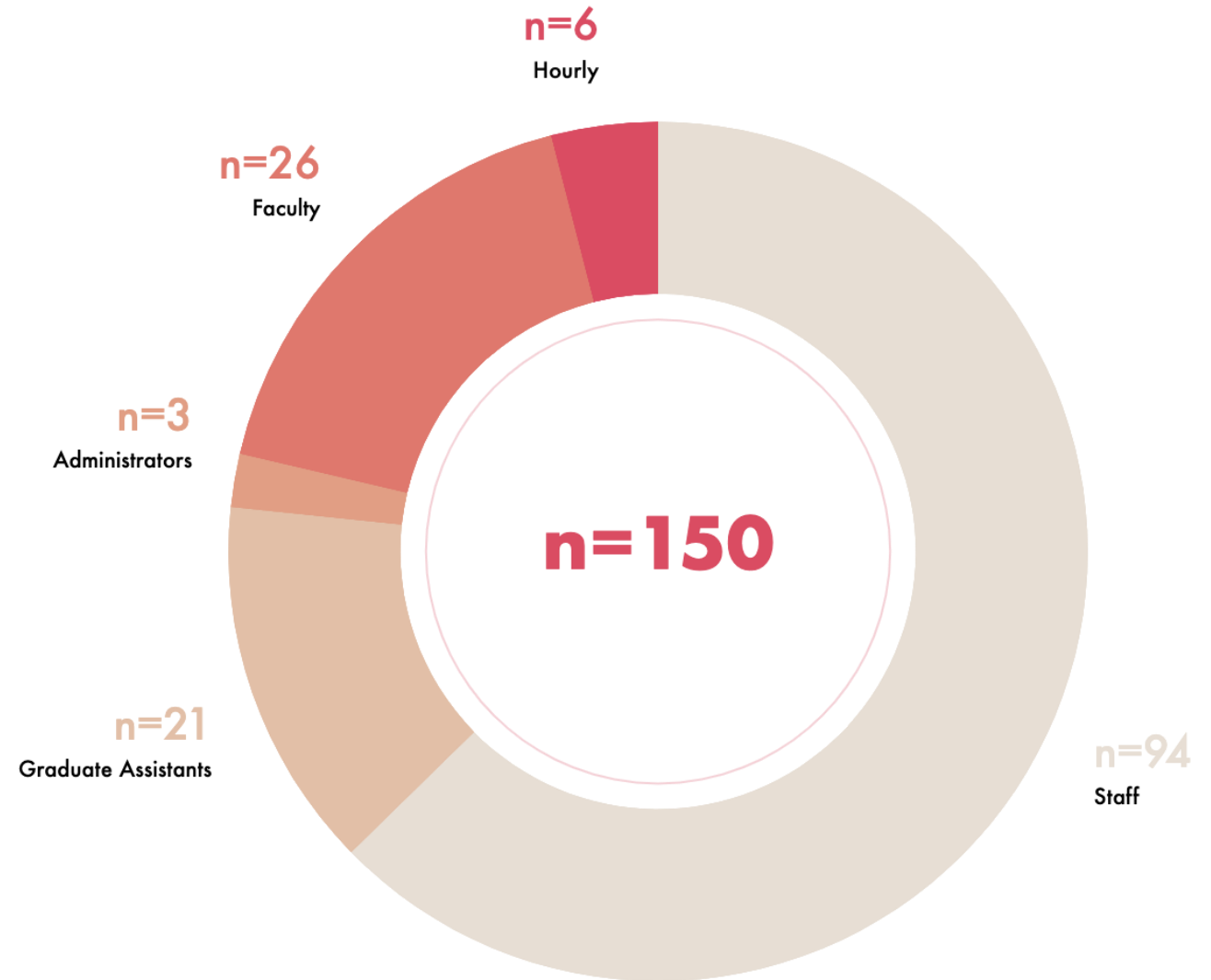
24" display chosen by **one** participant

Head Movement

"Liked the 24" because they didn't have to move head as much."

Survey Respondents by Role

Survey of ultrawide display usage on a university campus

n=6
Hourly

n=26
Faculty

n=3
Administrators

n=21
Graduate Assistants

n=150

n=94
Staff

Gallagher et al., Unpublished

23%
use an ultrawide display at work
(n=34)

28%
staff
(n=26)

12%
faculty
(n=3)

Gallagher et al., Unpublished

Themes

Window arrangement	**Screen Characteristics**	**Specific tasks**
Workstation considerations	**Discomfort**	**Learning Curve**

Gallagher et al., Unpublished

Window Arrangement

"I like the room to open multiple windows and to be able to enlarge documents when necessary."

"I do like being able to open a couple of pages at one time on one screen."

"I can have two windows open at the same time and see them without any problem"

"It's beneficial for keeping everything on one screen and still having space to spread everything out."

"It helps to organize all the things that I need to work on over one monitor instead of multiple"

"I like the extra room that allows for two documents to clearly be on the screen at once."

"Prefer to single or dual monitors. More space when utilizing several programs or documents together, without having to move my head so much between monitors."

"I love being able to have 2 full windows side by side and multitasking without them shrinking."

"It greatly aids in the completion of my tasks. I am able to have different tabs open onscreen and still be able to see them easily and clearly"

Type of Work
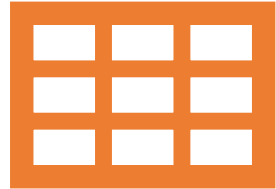
Spreadsheets

"I liked being able to have two windows open on one screen or using it for an excel workbook that had information across many columns."
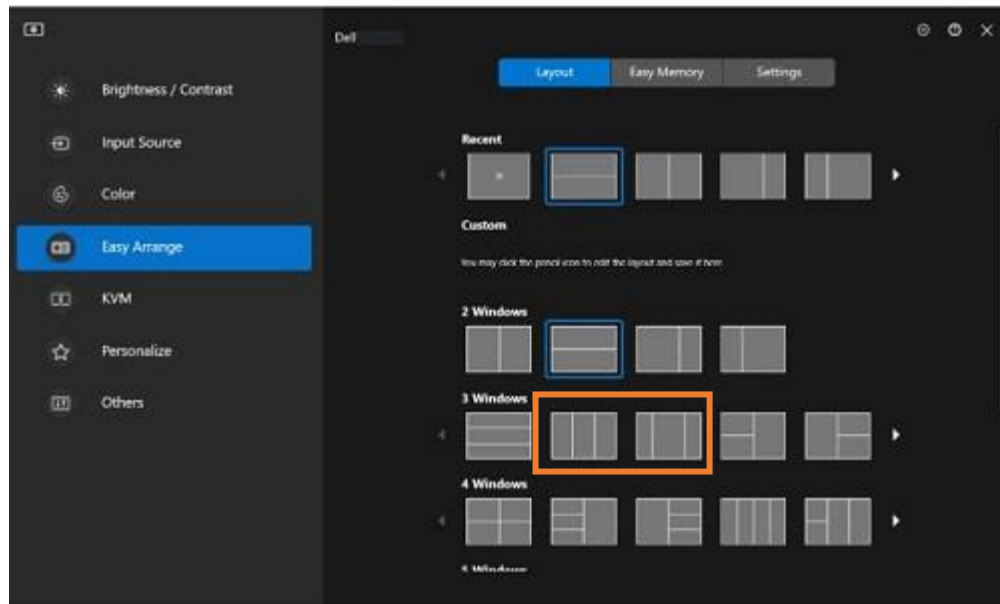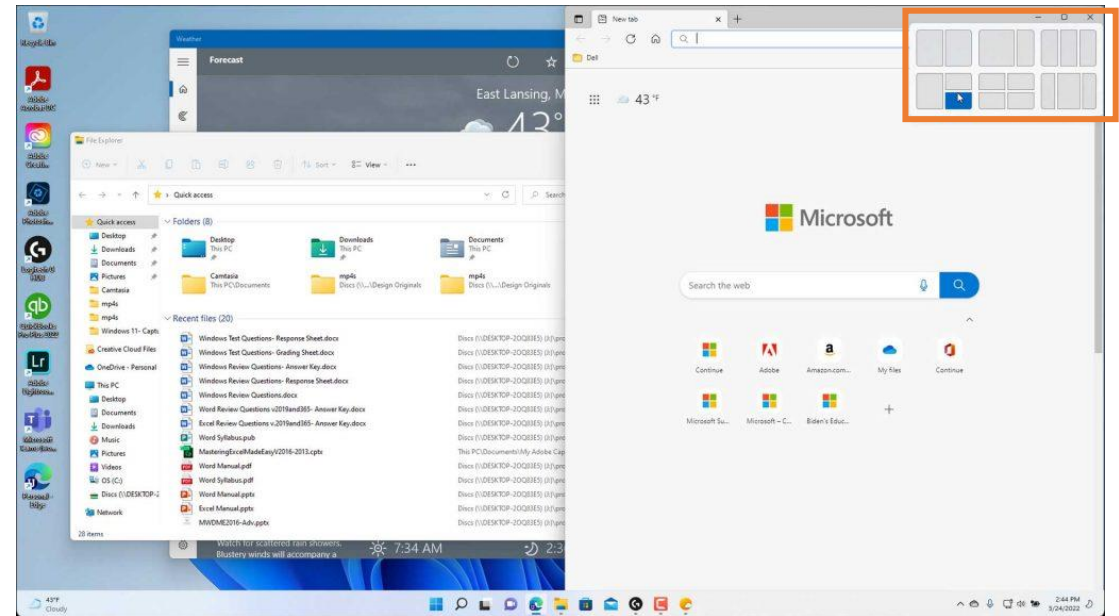

Potential issue?

"It's nice for having split screen for design work or other jobs that require alternating between two resources **but less ideal for focused work**."

Gallagher et al., Unpublished

Display managers needed improve use

Dell Display Manager

Windows 11

Screen Characteristics

Size

"I think it's a little too big and not necessary."

"At first I felt that the monitor was too big, over time I got used to it."

"Sometimes I only use half of the monitor because it is too wide."

"It is almost too wide."

Brightness

"At first it was hard to use (the new ones are REALLY bright) but once we adjusted that I got used to it and liked them."

"the screen, being larger, is also brighter…"

Resolution

"The resolution was much better and text was generally larger without my having to change those settings in Windows"

Gallagher et al., Unpublished

Workstation Considerations

"It felt awkward trying to put another monitor beside it. I normally like having three monitors because I need to keep several windows open to work".

"Ultrawide monitors often come with **large stands** that will take up a lot of space on your desk."

"I prefer because I can put more on the screen and can **sit a little further away** from the monitor."

"It's not as easy to adapt to rest on a sit-to-stand surface. My surface space provides enough room for the ultrawide monitor, but my **overhead storage** prevents there from being enough space for the ultrawide monitor to be lifted up (allowing a sit-to-stand surface)."

"I love it, but I do wish it could position it higher on my desk."

Gallagher et al., Unpublished

Discomfort

Eyes

- "The screen, being larger, is also brighter and I find my eyes getting fatigued quicker."
- "...can hurt my eyes."
- "I am not having any work or vision problems."
- "My eyes didn't seem to get as tired even while wearing my glasses."

Neck posture

- "...having two ultrawide monitors connected together is not ideal because I have to do a lot of head and body turning to look at the second monitor. I typically just use the second monitor for communication purposes so as to limit how much turning I have to do throughout the day."
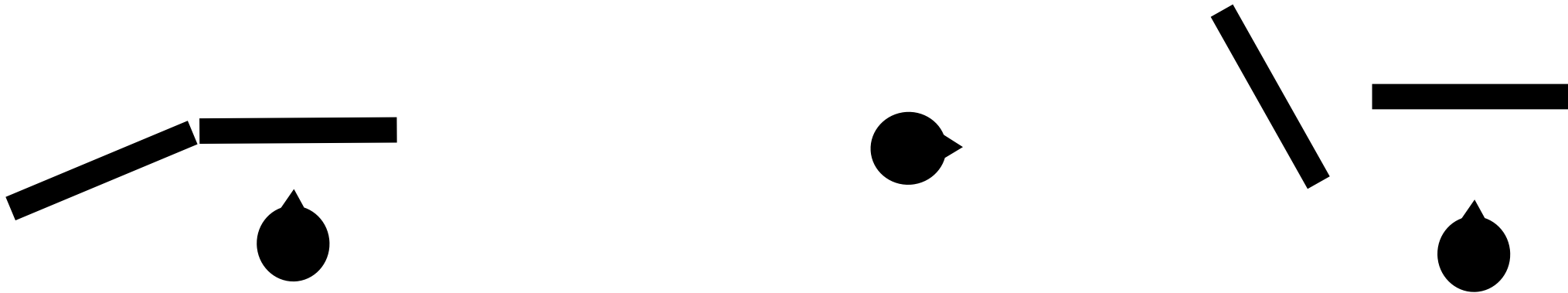
Learning Curve

"It took a little getting used to but I love having one."

"I found it a little overwhelming at first, but that may just be a learning curve"

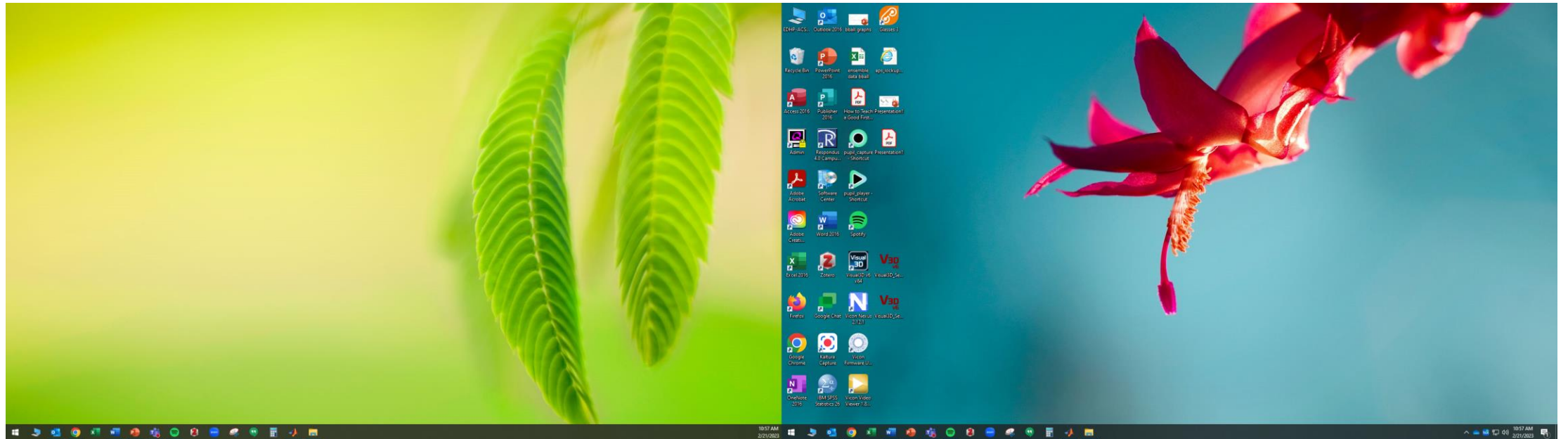"At first I felt that the monitor was too big, over time I got used to it and I like it …"

Potential Concerns

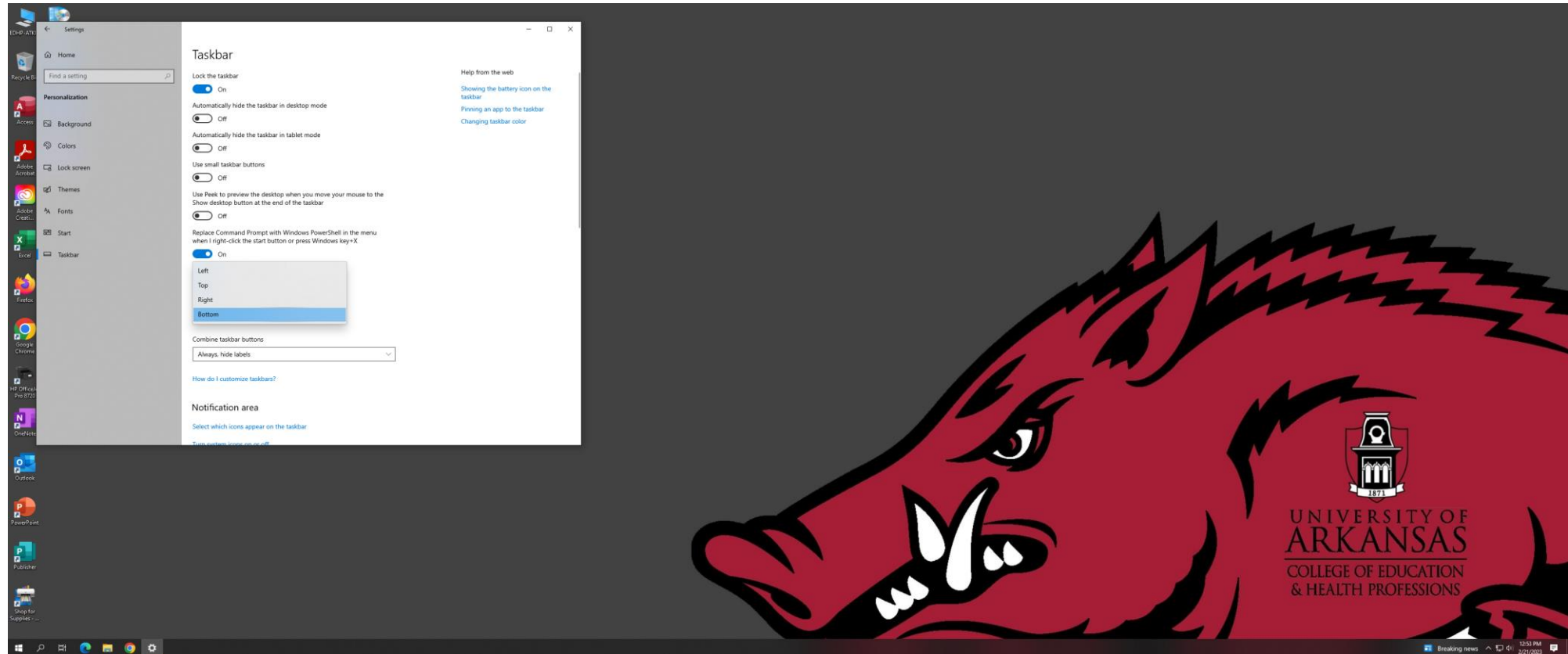Less configuration functionality and freedom with one ultrawide display

Window and Task Bar Configuration

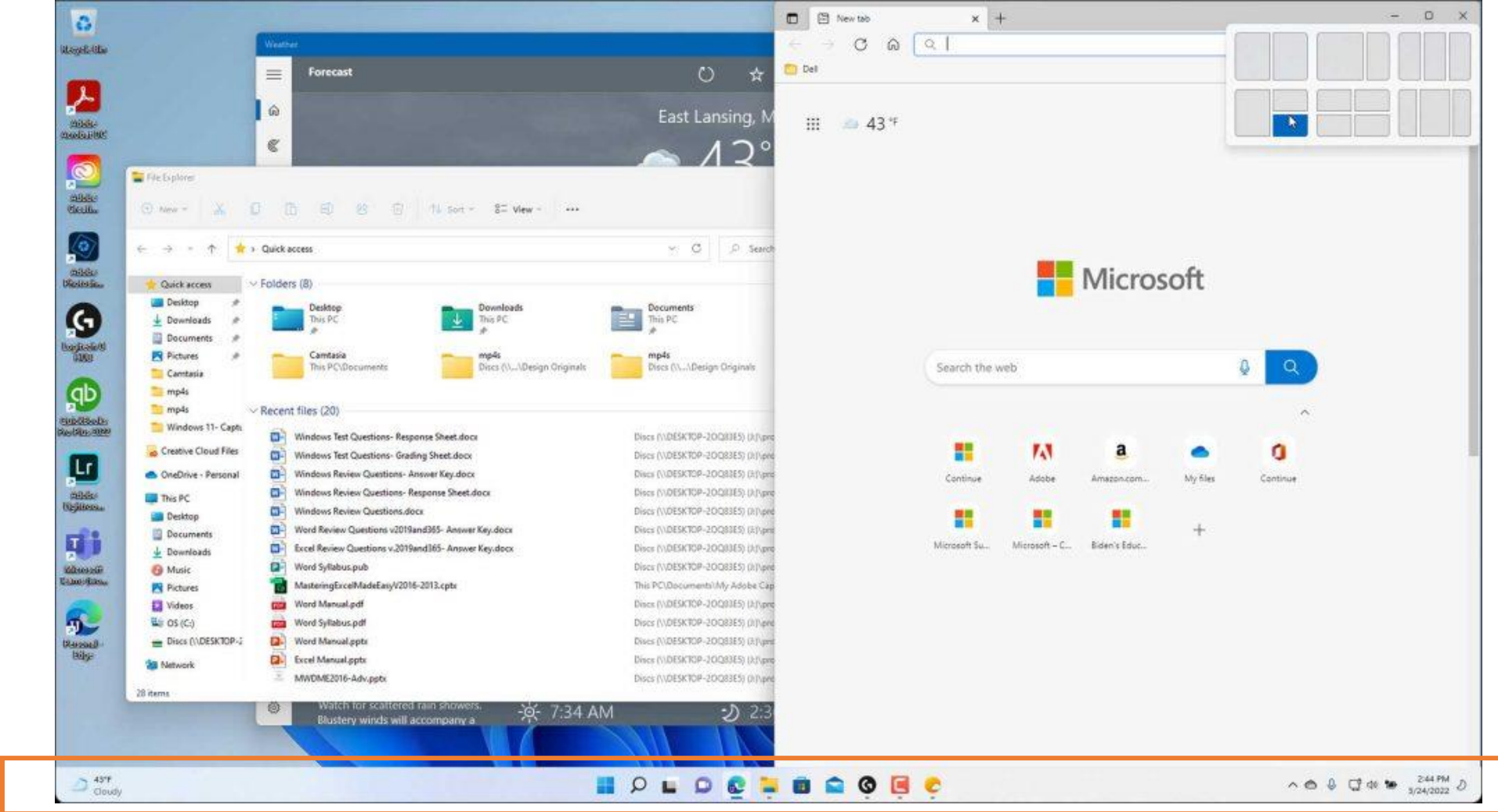**Dual – Taskbar on each display, if set there is easy partitioning**

Where should the task bar go?

Leaving at bottom (default) may increase awkward neck flexion + twist since preferred gaze angle is larger
Open to suggestions!

Windows 11

Take Home

Ultrawide curved displays are generally liked (lab and survey)

- May be a learning curve or upper limit on size people will tolerate

Wider displays = head rotation increased without gaze angle change.

- Assess how much the user needs to look at display extremes
- While higher position is recommended for dual monitors, the greater vertical height of these displays could result in neck extension

Potential constraint? – Desk depth

- Not necessarily due to increased horizontal viewing distance, rather the large stands (if used) that come with displays
- May need to install a keyboard tray to increase usable horizontal distance

Discuss tasks with potential user:

- Tasks
- Functionality (i.e., does user need to move display so others can see it?)

With newer displays, watch out for brightness!

Additional Questions

- **Dominant eye:** Yes, knowing about dominant eye could still be helpful when talking to users about the side of the display that they should use most often for organizing windows

- **Eye tracking with larger displays:** Yes! As eye tracking has advanced to interface with motion capture systems, so we now assess how people move their heads versus there eyes and if there are any differences in outcomes such as neck/eye discomfort associated with different patterns.

- **Glare:** I haven't seen research on this. Some of the monitor marketing information says that curved displays are better for reducing glare. Participants in the Bartha et al. (2020) study said that the edges of the displays were clearer in the curved position, so there may be less distortion there, but its unknown if that is some glare issues or has to do with replicating the field of vision. New monitors also have anti-glare screen coating, but I'm not sure how good this is at reducing glare in less than ideal lighting circumstances. In our survey, lighting was a huge complaint, so we would have to see if we can look to the environment first and if there is anything that can be done, or if the displays are very sensitive to glare no matter the lighting circumstances.

Bartha, M. C., et al. (2020). Field Observations of Placement for Large-Panel Flat and Curved Displays for Presbyopic and Prepresbyopic Computer Users. https://doi.org/10.1177/1071181320641119

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