CRE-MSD
Centre of Research Expertise for the Prevention of Musculoskeletal Disorders

GLOBAL ERGONOMICS MONTH WEBINAR SERIES

Supporting remote office work, pivoting back to the workplace during a pandemic, and the future of virtual workspaces

Expanding the Bounds of Seated Virtual Workspaces

Mark McGill
October 27, 2021

Presented by CRE-MSD in partnership with

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Public Services Health & Safety Association
PSHSA.ca
Workplace Safety & Prevention Services
Occupational Health Clinics for Ontario Workers Inc.
Centres de santé des travailleurs (ses) de l'Ontario Inc.

Expanding the Bounds of Seated Virtual Workspaces

Mark McGill @ CRE 2021

October 27th 2021

Some Background…

Lecturer at **University of Glasgow** (Scotland, UK) in School of Computing Science

Been conducting research into **Human-Computer Interaction** (HCI) and **Mixed Reality** for the last ~8 years

Todays talk covers a few topics:

- A primer on Mixed/Virtual/Augmented Reality

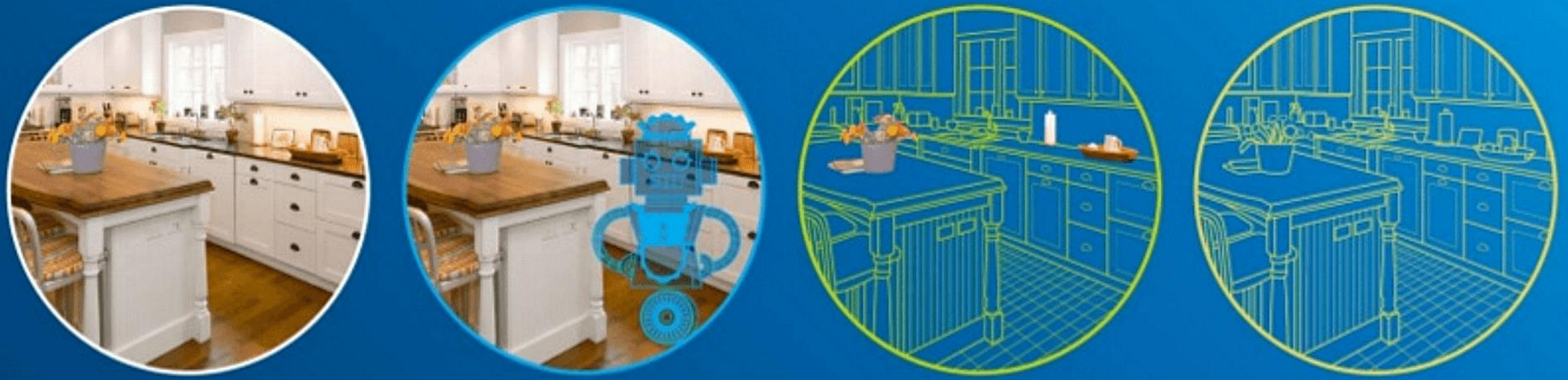
- Benefits of VR/AR for creating more ergonomic/usable virtual workspaces

- How VR/AR might significantly alter passenger experiences / productivity for remote/mobile work

What is Mixed Reality?

VIRTUALITY CONTINUUM

MIXED REALITY



REALITY

AUGMENTED REALITY (AR)

AUGMENTED VIRTUALITY (AV)

VIRTUAL REALITY

Milgram's Reality-Virtuality / Mixed Reality Continuum http://etclab.mie.utoronto.ca/publication/1994/Milgram_Takemura_SPIE1994.pdf

Also referred to as eXtended Reality (XR)

Image from https://medium.com/@Maria_Nova/4rs-or-get-your-head-around-virtuality-continuum-625e256ddd1d


COMBO
13
45 007
74
100
x4
STEAMVR beta 1.5.15
Now Playing
Beat Saber

HoloLens 2 AR Headset: On Stage Live Demonstration - https://www.youtube.com/watch?v=uIHPPtPBgHk

Everyday Consumer AR

"We won't be able to opt out from wearing AR glasses in 2035 any more than we can opt out of owning smartphones today… "

https://mssv.net/2020/08/16/digital-sight-management-and-the-mystery-of-the-missing-amazon-receipts/

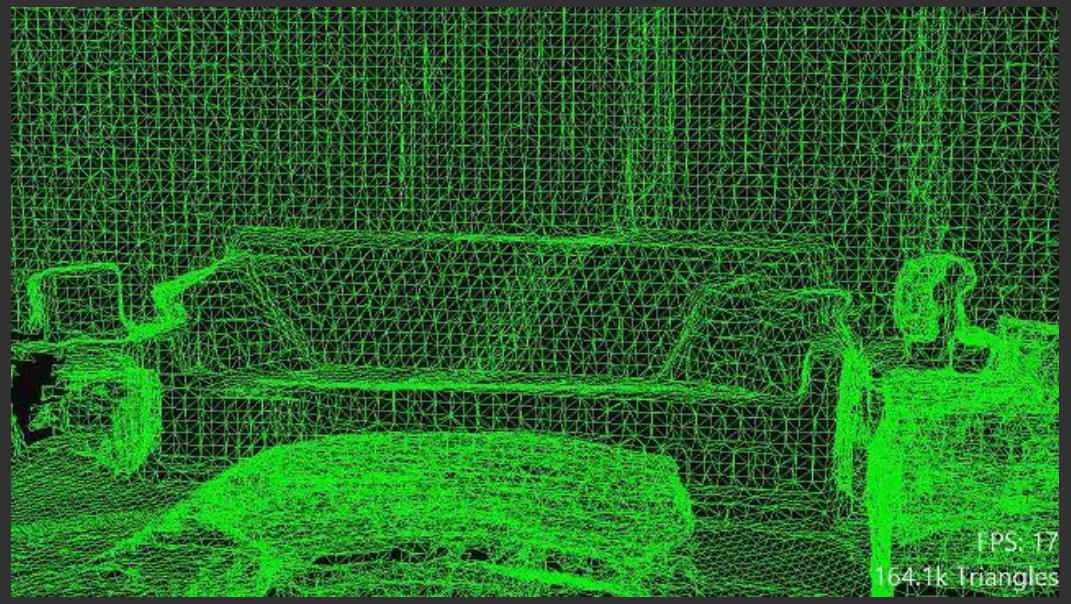
HYPER-REALITY

https://www.youtube.com/watch?v=YJg02ivYzSs

Inside-Out Positional Tracking

Inside-Out (e.g. Oculus Quest, AR headsets/smartphones) utilize **Simultaneous Localization and Mapping** (SLAM) cameras / sensing on the headset/device to track the environment, enabling 6DoF tracking

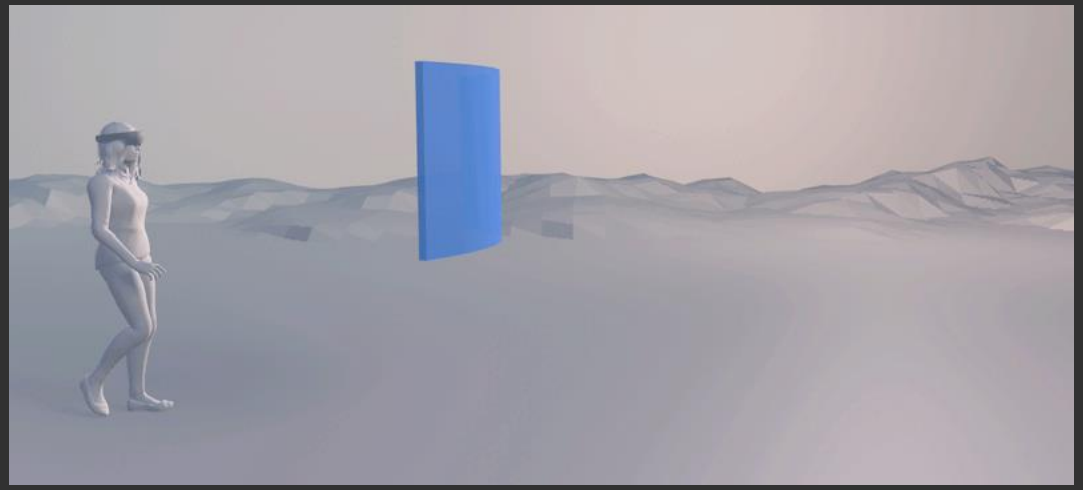
Tracked landmarks https://www.andreasjakl.com/basics-of-ar-slam-simultaneous-localization-and-mapping/



Hololens Spatial Mapping

Reference Frames

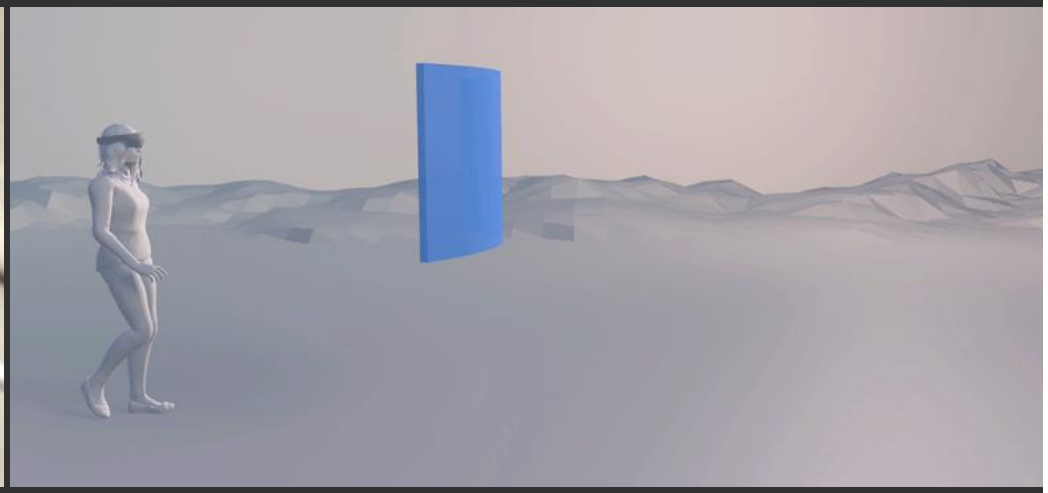
…describe the location of the virtual objects in space.

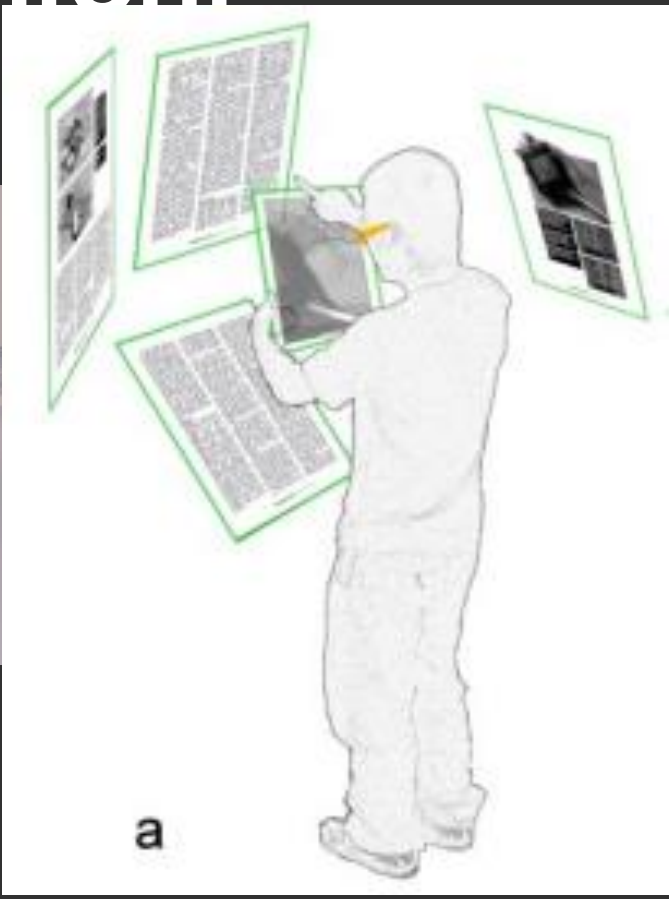


Egocentric: describes an object's location with respect to the perceiver's perspective

Exocentric: describes an object's location independently of the perceiver's perspective or location.

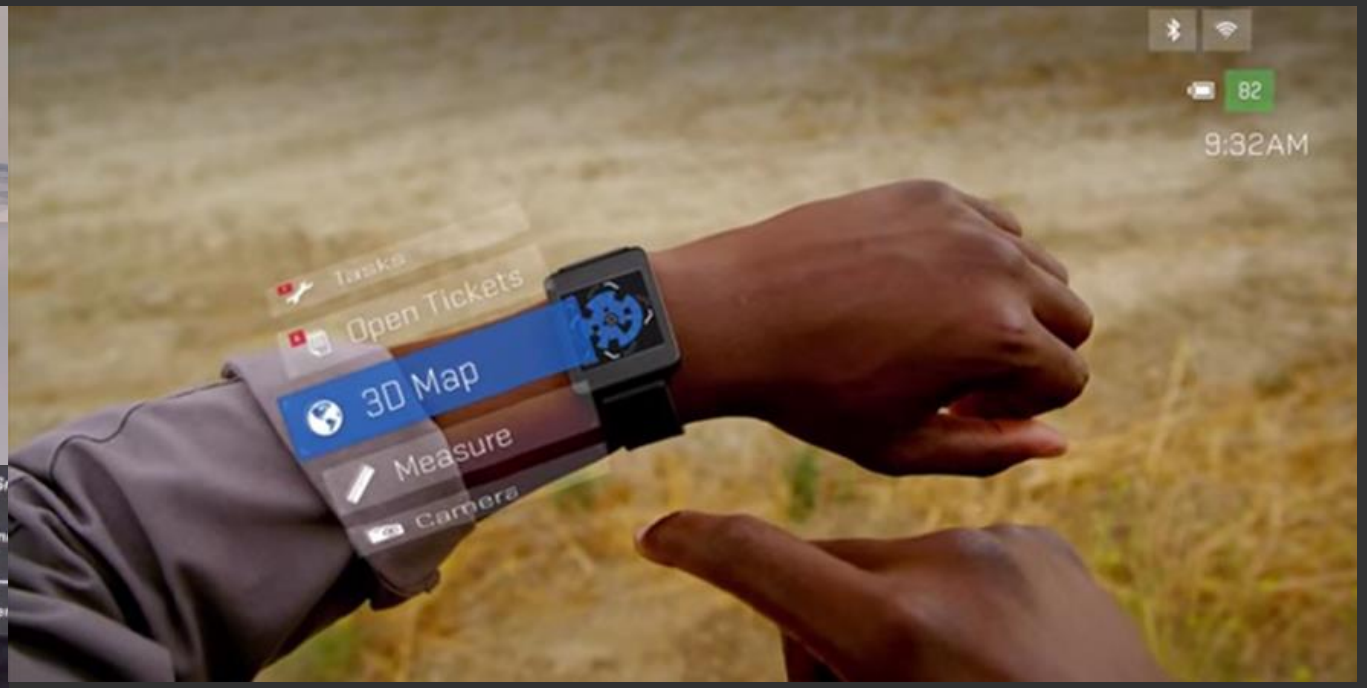
Egocentric perspective: Display locked / {View, Body, Hand}-fixed content





Egocentric: describes an object's location with respect to the perceiver's perspective

Exocentric, grounded, world-fixed



Exocentric: describes an object's location independently of the perceiver's perspective or location.

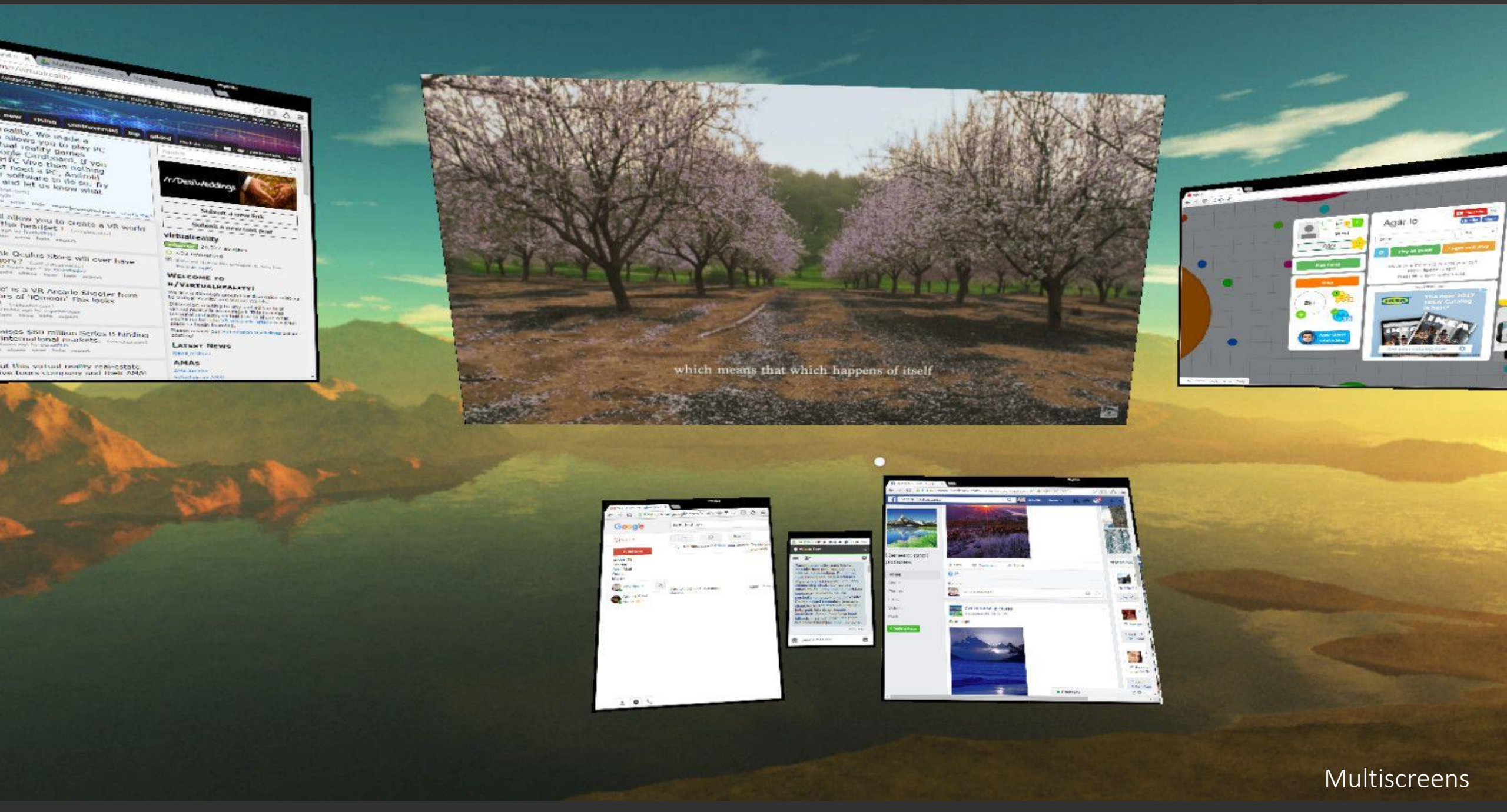
Virtual Displays and Productivity


University of Glasgow
SCHOOL OF COMPUTING SCIENCE
Get in touch
STUDY
Our programmes
Information for current students
International
RESEARCH
Research
EXPLORE
Expanding The Bounds Of Seated Virtual Workspaces
TOCHI
acm
Author Information
SAMSUNG
Mark McGill
Google
THE MULTISENSORY DRIVER
HUMAN ERROR
DELL

Cons of existing multi-monitor spaces

- a physical barrier to the world – cuts me off from others
- displays not easily adjustable or adaptable to specific task
- limited to how many physical displays you have
- ergonomically problematic (e.g. difficult to position/orient, no adaptation over time or based on seating position / posture)
- don’t travel / translate to mobile usage (e.g. limited to laptop)

https://www.roadtovr.com/bigscreen-video-file-player/



Multiscreens


file:///C:/Users/Xiao/AppData/Roaming/Pygmal%20Technologies/SPACE%20Technical%20Preview/assets/en/preferences.html
SPACE


Recycle Bin
Documents
SteamVR
Virtual Desktop
Bing
bing.com
Images
Videos
Maps
News
Explore
Search History
MSN
Office Online
Outlook.com
bing
GOP debate · Family of 6 killed · 'I can't really run' · Oxford fellows · $5.48 legal pot sales · Back for Super Bowl · LA bridge coming down
PANDORA ONE
Framing Hanley Radio
Built For Sin
by: Framing Hanley
on: The Moment
SETTINGS
BINDINGS
GAMES
PHOTOS
360
VIDEOS
Screen Size
63°
F2
F3
Screen Distance
1.50 m
Environment
Dark Nebula
Reset Orientation F4
Reset to Defaults
Screen Options
Curved
Multi-Monitor
Floating
Transparent
Clear Wallpaper
SBS Options
On Screen F6
On Screen Anamorphic F7
To Headset F8
To Headset + Distortion F9
Oculus Options
High Quality
Queue Ahead
Latency HUD
Render HUD
Performance HUD
Audio Options
Voice Commands
Accuracy: 70%
Vocal Feedback
Environment Sounds
Windows Integration
Mirror Headset to:
Window
Force OpenVR
Show Error Notifications
Start when Windows Starts
Adapter: AMD Radeon (TM) R9 390 Series
Version: 1.0.0
Frame Rate
75 fps
Capture Rate
60 fps
CPU Utilization
0.8%
HMD Latency
13.5 ms
Guy Godin
Most used
Visual Studio 2015
Windows Media Player
Skype
Command Prompt
Paint
OculusConfigTool
Recently added
OBS Studio (64bit)
File Explorer
Settings
Power
All apps
Life at a glance
Saturday
6
Mail
Microsoft Edge
Steam
OneNote
Skype
Sway
Cortana
Play and explore
Xbox
Pandora
Epic Games Launcher
Virtual Desktop
Mirror Window
Pandora
Bing - Microsoft Edge
Virtual Desktop

https://www.engadget.com/facebook-infinite-office-181634992.html

Citi HoloLens Holographic Workstation
https://www.youtube.com/watch?v=0NogItmewmQ

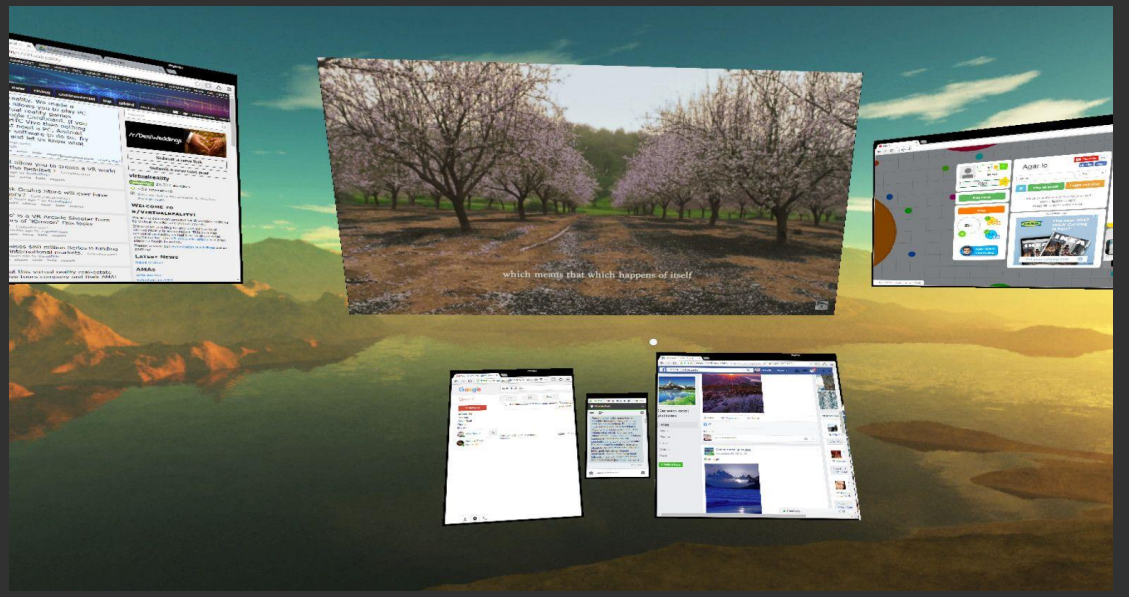
Benefits of Virtual Displays

Fundamentally, we can manipulate virtual displays/apps in ways that are difficult-to-impossible to do with physical displays*

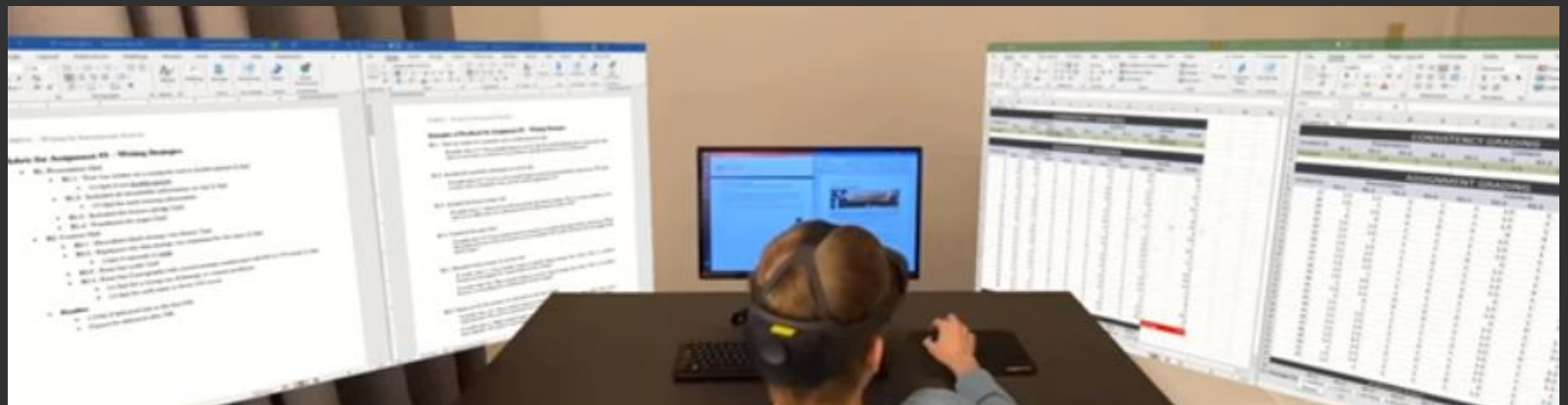
The question is – **what manipulations are worthwhile e.g. for usability, ergonomics, efficiency…?**

*with some allowances for spatial/projective AR ☺

Size / Shape / Orientation
(flat, curved, conforming to physical surfaces etc)

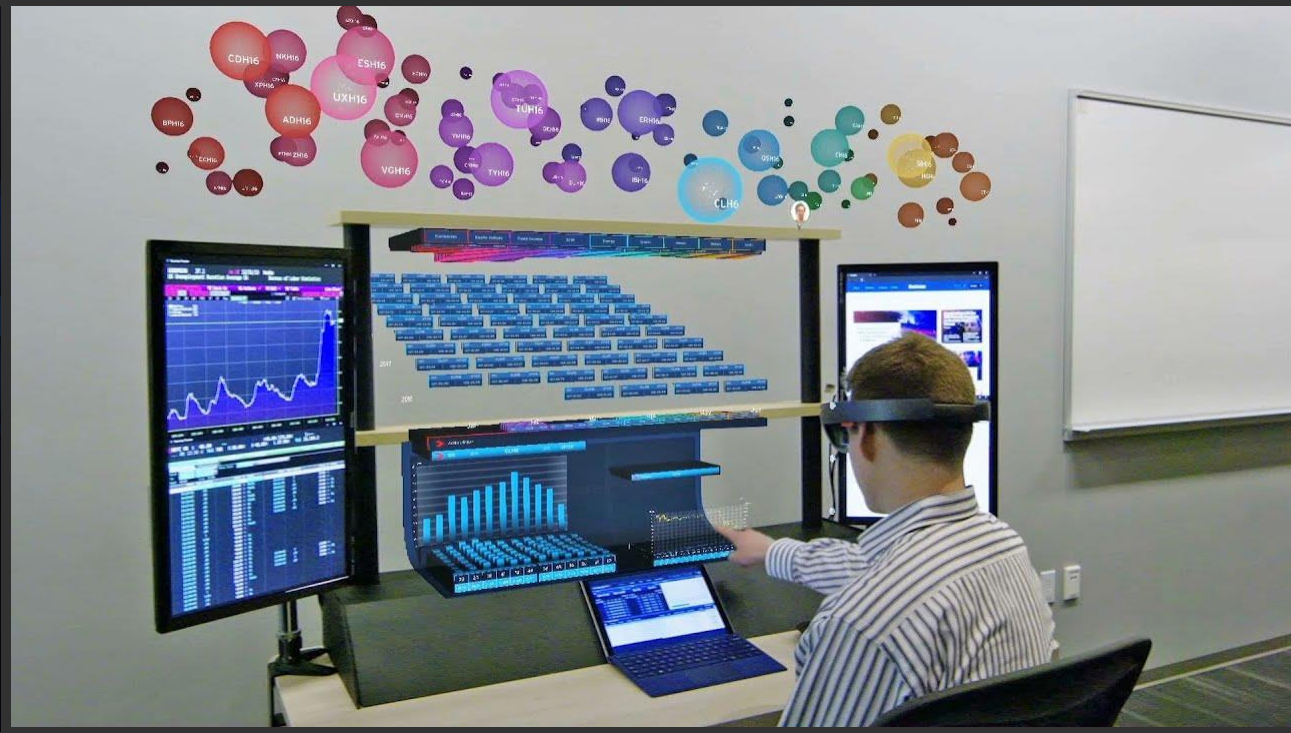


Supplementing or supplanting physical displays

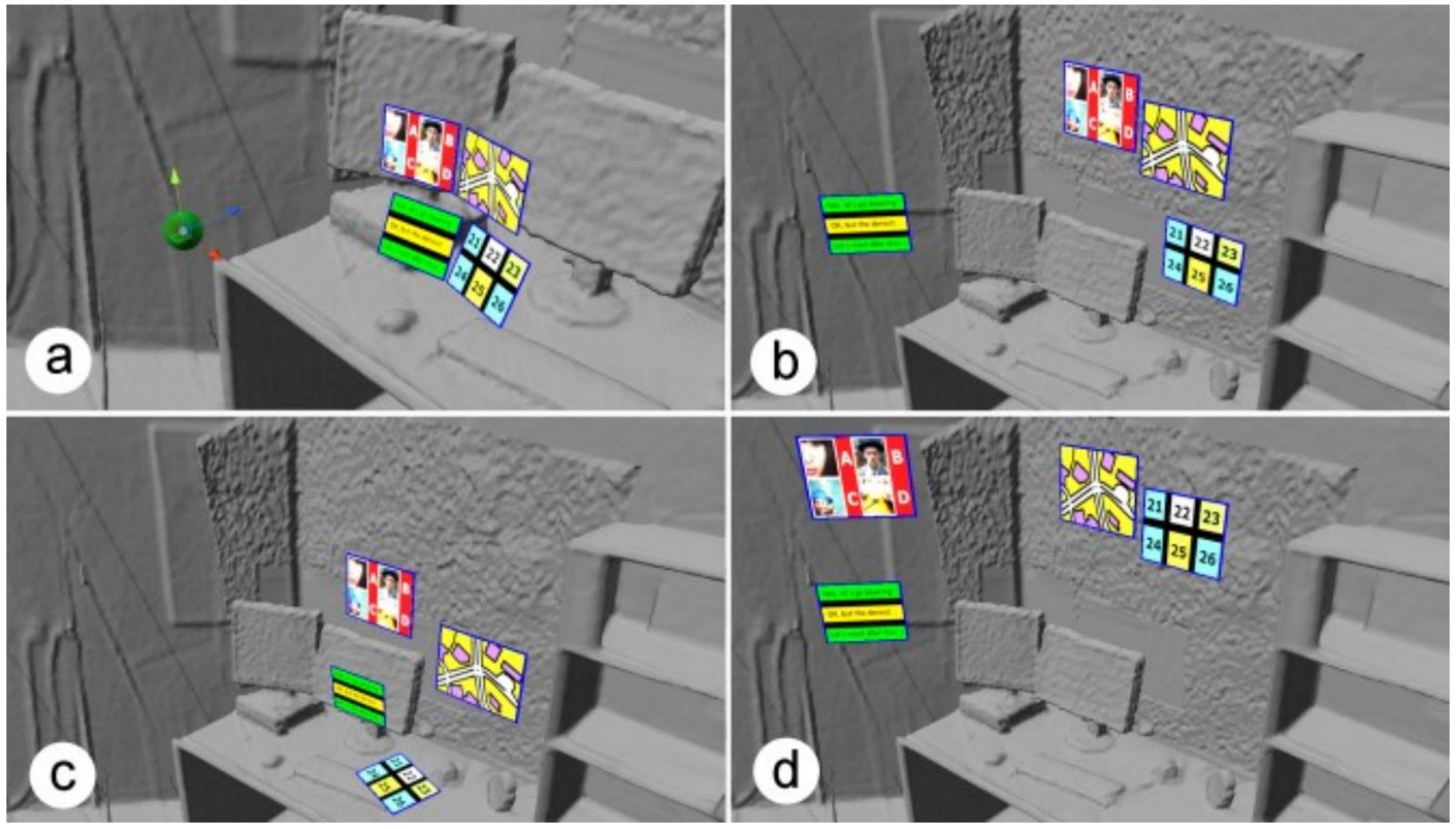


Designing Augmented Reality Virtual Displays for Productivity Work
https://wordpress.cs.vt.edu/3digroup/2020/12/02/ar-virtual-monitors/

Depth (of display, and of content on display)



Placement e.g. exocentrically based on spatial constancy, visual saliency etc.



Barrett Ens, Eyal Ofek, Neil Bruce, and Pourang Irani. 2015.

Spatial Constancy of Surface-Embedded Layouts across Multiple Environments.

In Proceedings of the 3rd ACM Symposium on Spatial User Interaction (SUI '15). Association for Computing Machinery, New York, NY, USA, 65–68. DOI:https://doi.org/10.1145/2788940.2788954

Number of Displays (e.g. dynamically determined)

Barrett M. Ens, Rory Finnegan, and Pourang P. Irani. 2014.

The personal cockpit: a spatial interface for effective task switching on head-worn displays.

In Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI '14). Association for Computing Machinery, New York, NY, USA, 3171–3180. DOI:https://doi.org/10.1145/2556288.2557058

Our focus: Ergonomics of wide virtual workspaces

-We can render **multiple virtual displays around us**, going up to and beyond what we might typically do in a physical workspace

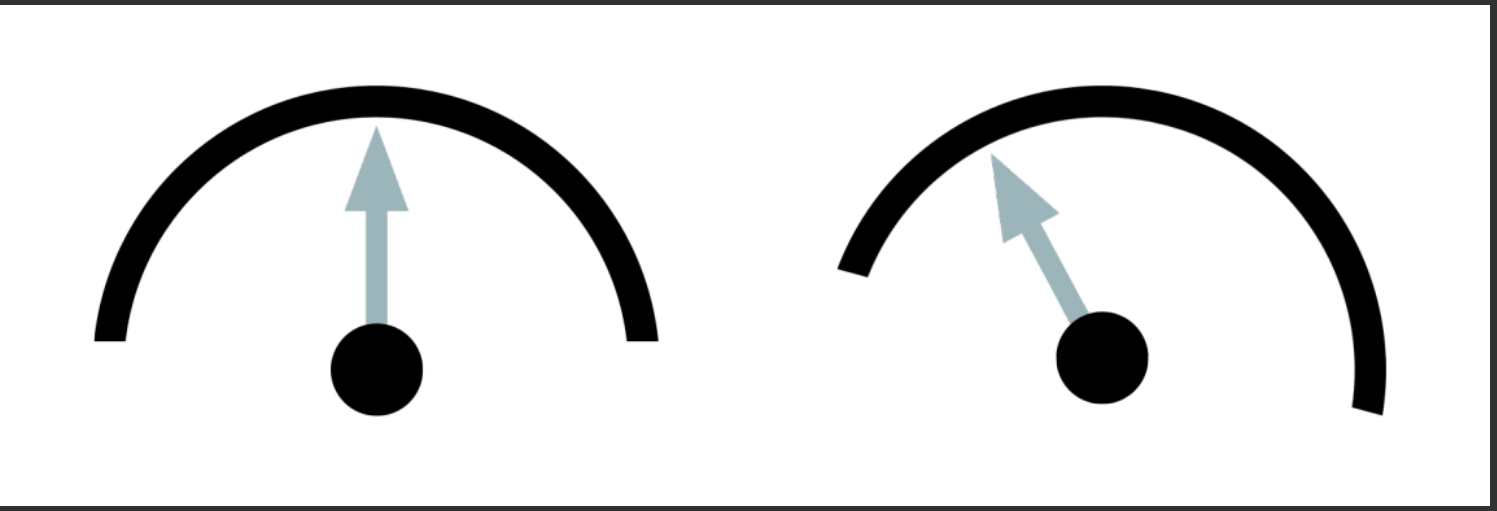
-Multiple displays **benefit sensemaking and awareness**, enabling spatial partitioning of sub tasks, greater information density/availability

-However, **wide virtual workspaces may lead to excessive head/neck movement**, with content not easily/comfortably reachable

- Increased risk of musculoskeletal disorders - this might cause harm if used every day for hours at a time
- BUT some variety of head motion is required (e.g. dual monitor setups appear to lead to less musculoskeletal disorders than single monitors)

-**Can we improve the usability of these wide virtual workspaces?**

Our approach: Counter-rotating displays around Pivot point

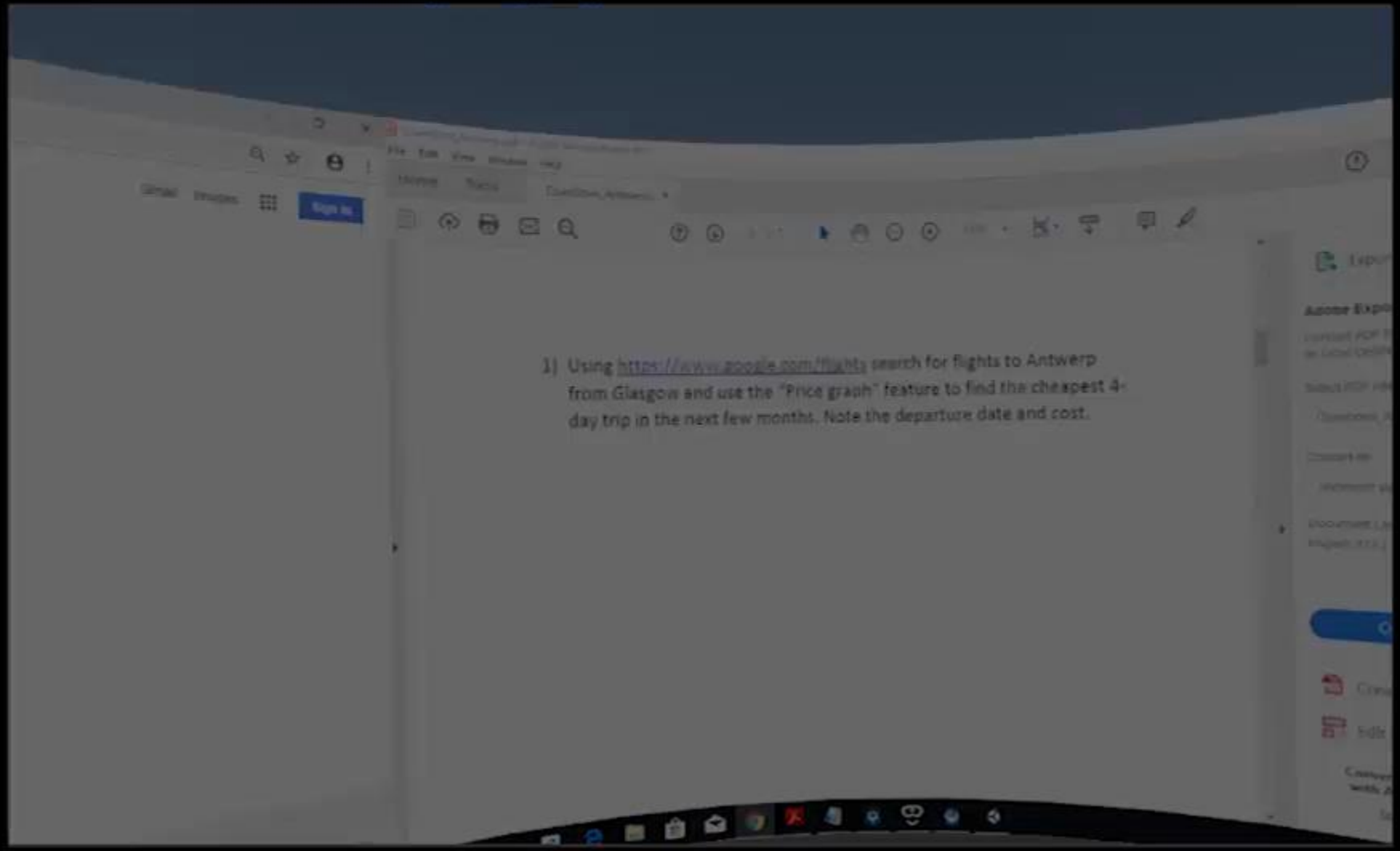


- XR User positioned (approximately) at pivot point

- Exploit implicit inputs (head orientation) to enact counter-rotations of displays (e.g. rotational gain or other mappings of head orientation to display position)

- End result: access wide display space in narrow(er) range of head motion

And Condition 3 (Boundary Switching) was an iteration on the best ranked technique from Study 1, allowing for implicit control of display position based on head orientation.



MANIPULATING THE MAPPING BETWEEN HEAD ORIENTATION AND WORKSPACE POSITION

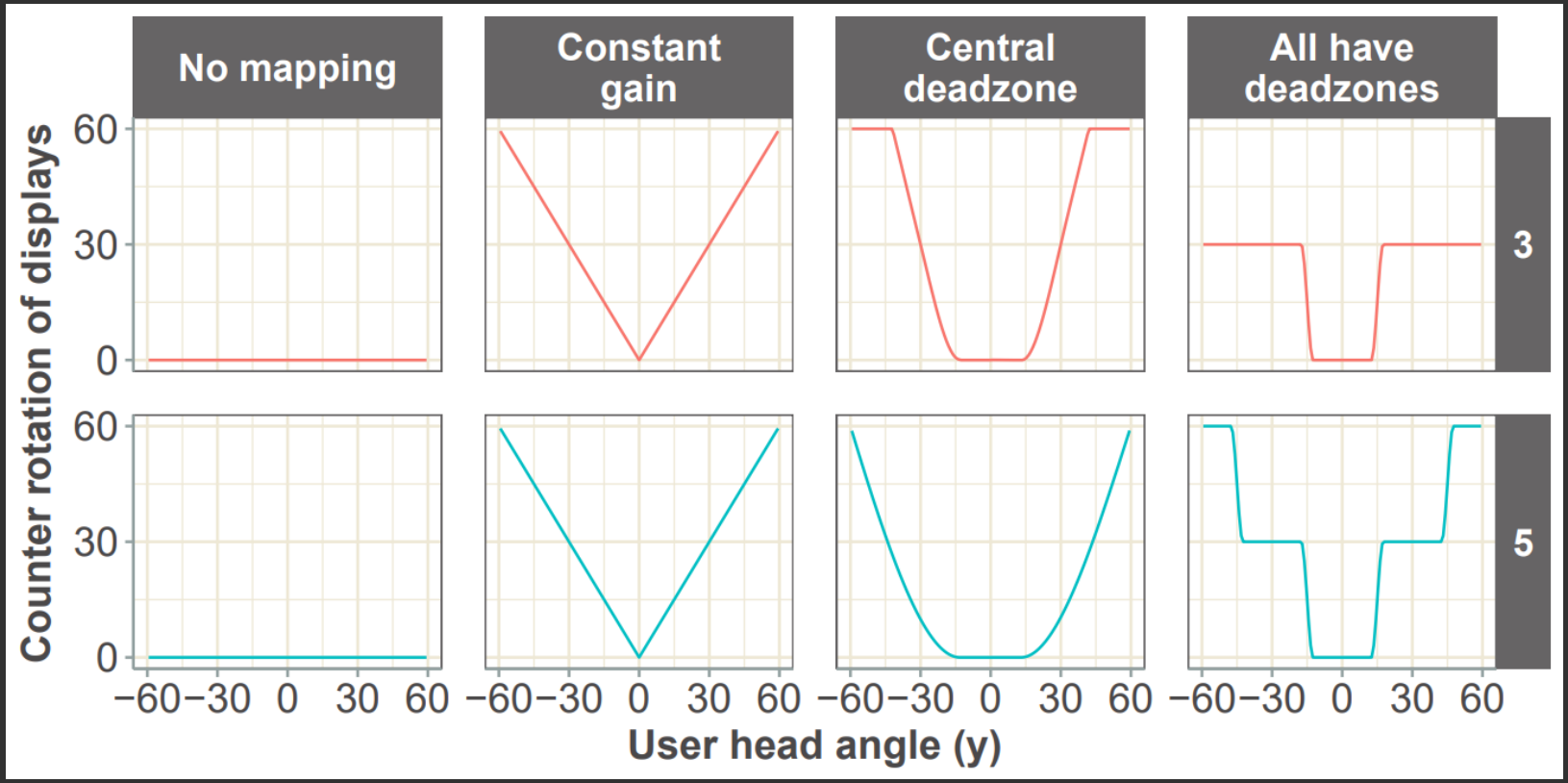
Study 1

Two factors:
No.OfDisplays * Mapping

Each display encompassed 60 degree range around pivot point

Three (180 deg) versus five (300 deg) displays layouts

Two factors: No.OfDisplays * Mapping



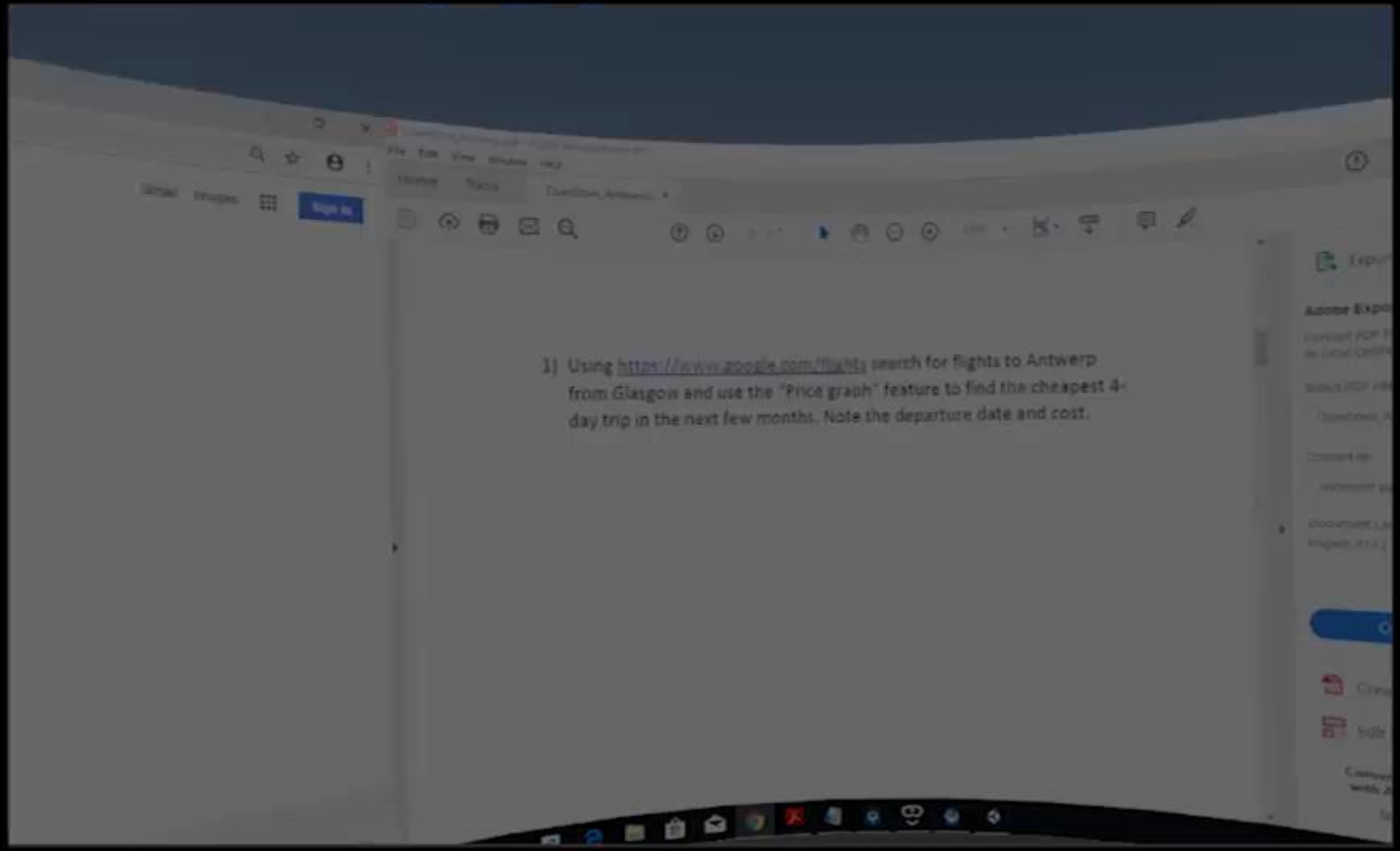
1: No mapping – Control condition

2: Constant assistance - constant 2x counter-rotational gain.

3: Central deadzone - fixed central display, with a ±12.5° deadzone and dynamic counter rotational gain

4: All displays have deadzones, with rapid transitions between displays as your gaze crossed the boundary between them

And Condition 3 (Boundary Switching) was an iteration on the best ranked technique from Study 1, allowing for implicit control of display position based on head orientation.



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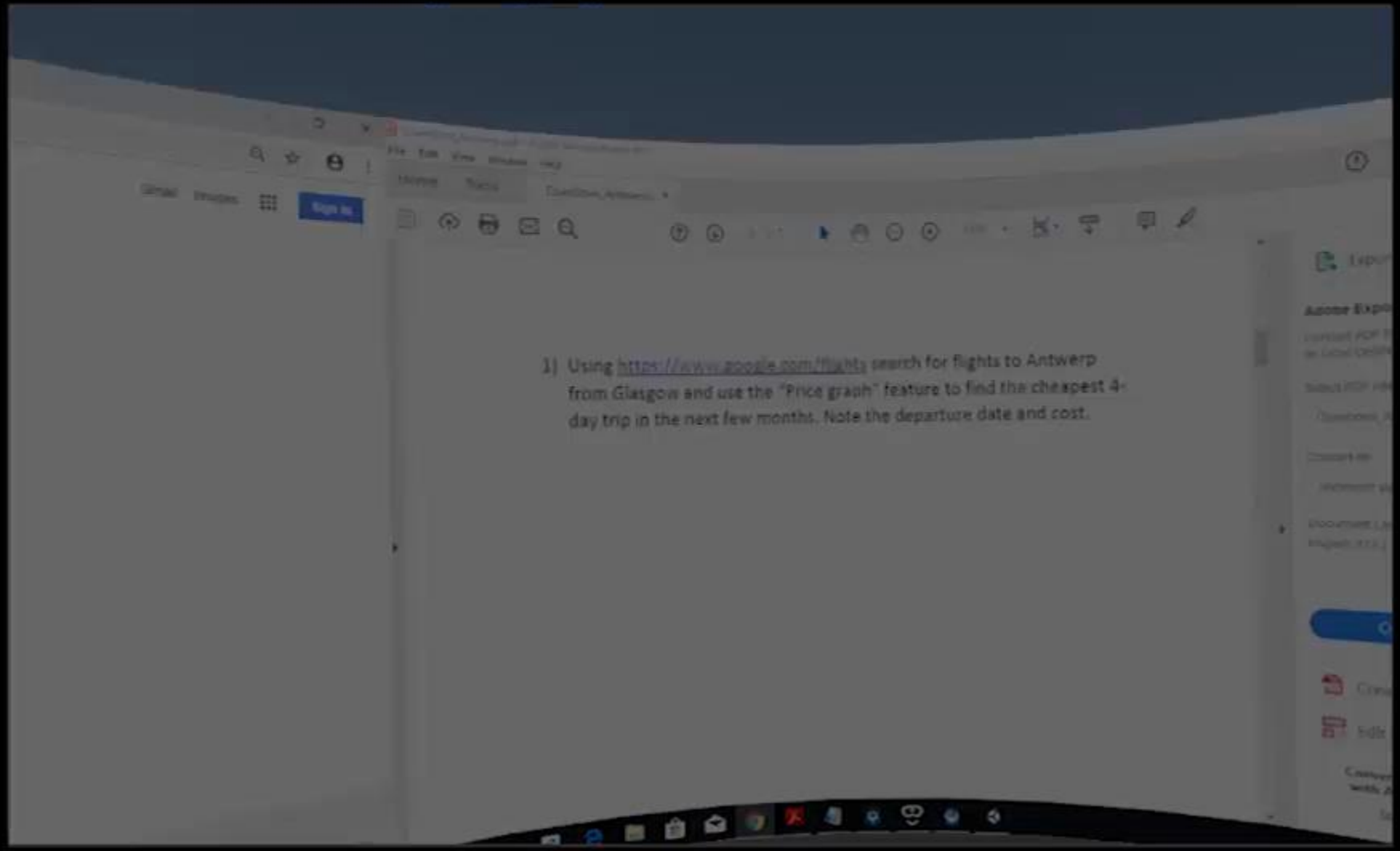

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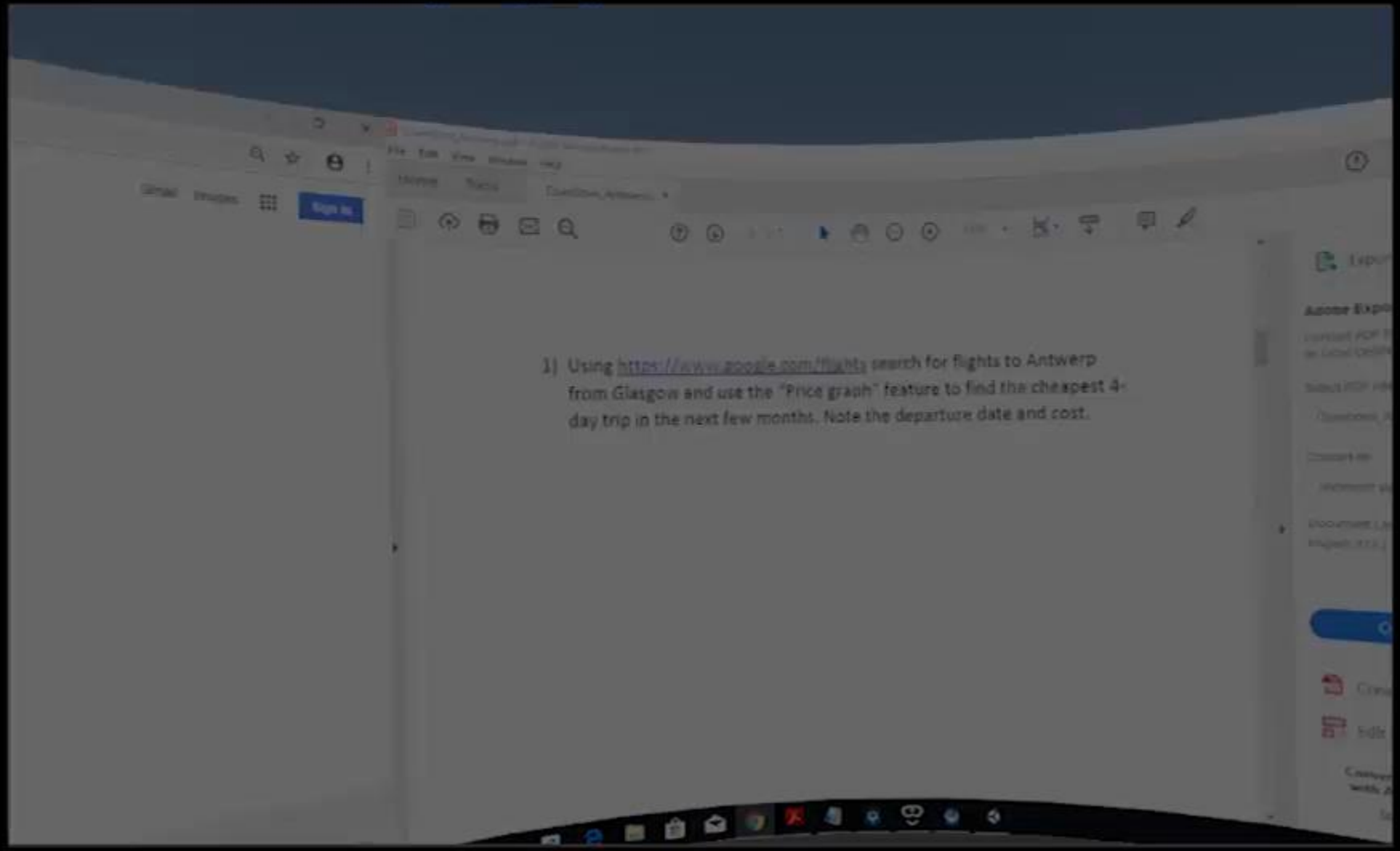
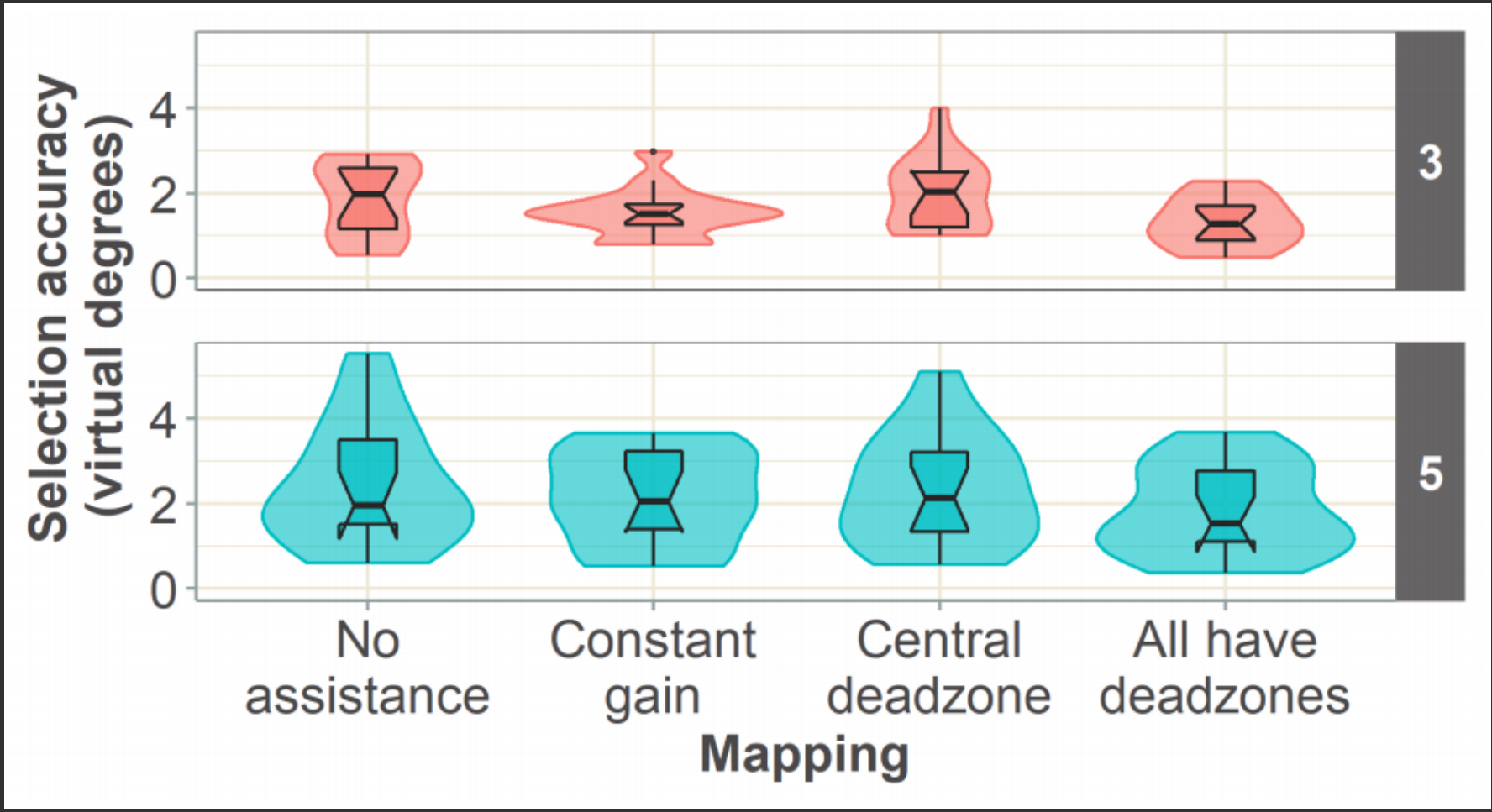
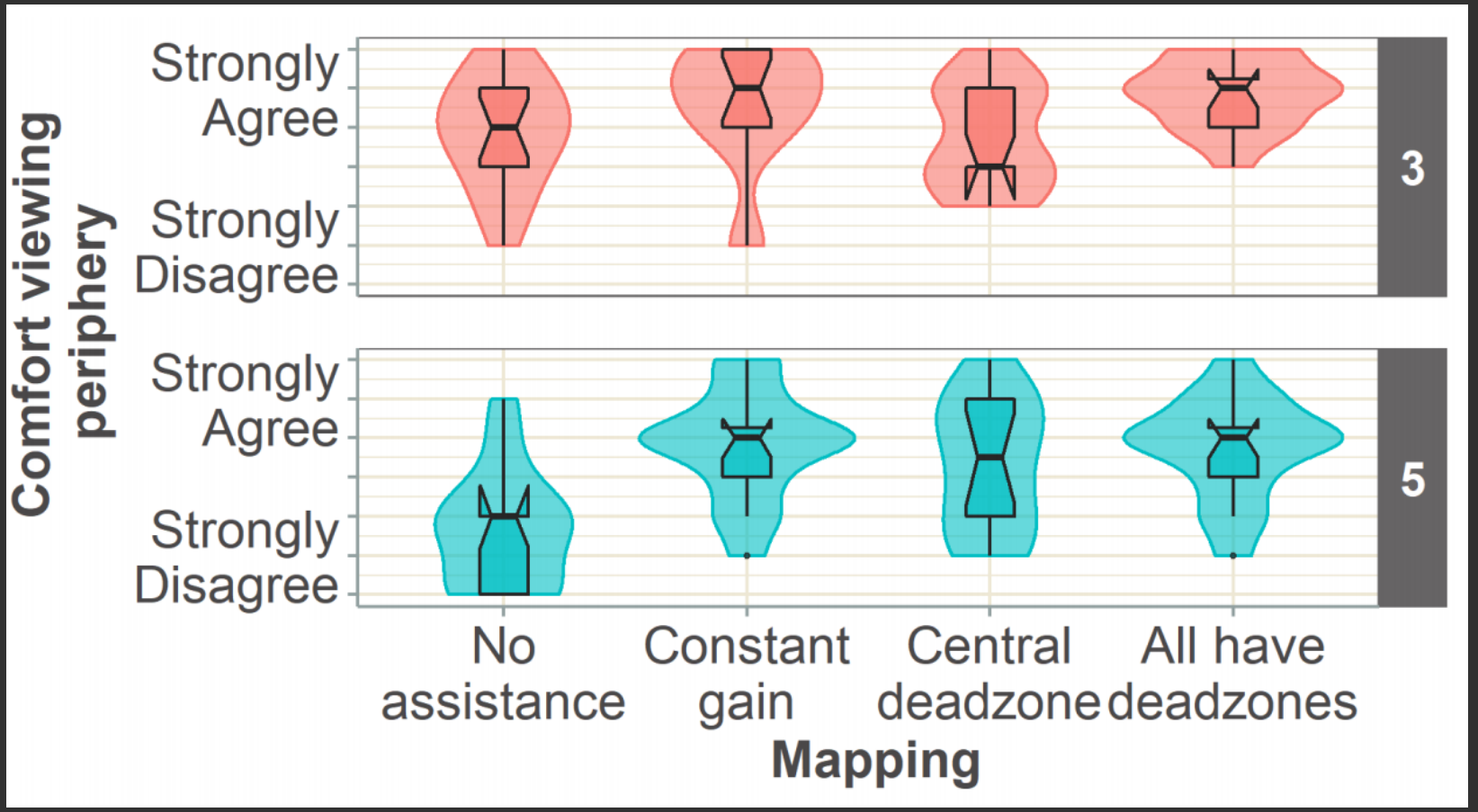


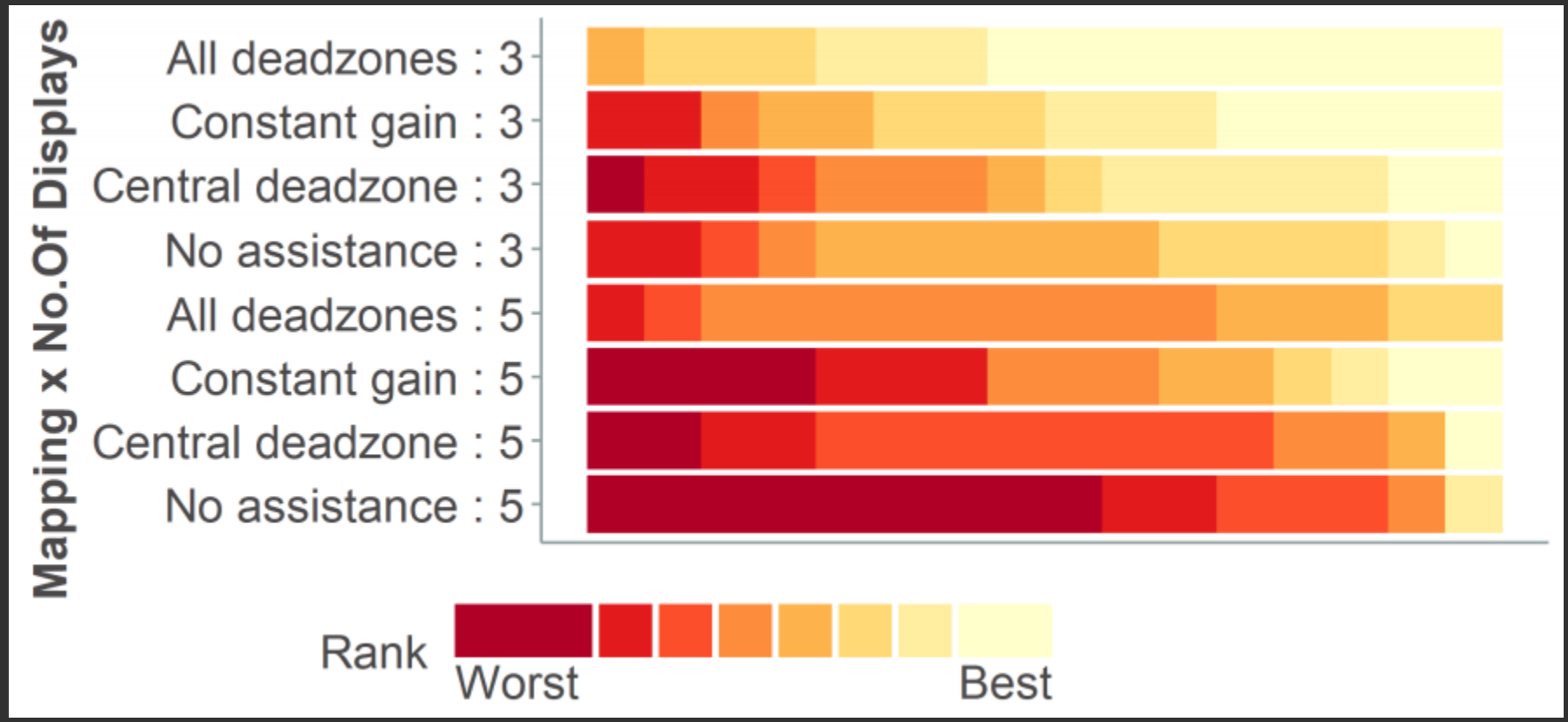
Results Minimal impact on accuracy



Results Counter-rotations made viewing peripheral displays more comfortable



Results Counter-rotations were preferred



… particularly the instant transitions based on display boundaries

… and for 3 displays over 5 displays

Overview

Our instant transitions based on head orientation allowed users to halve the amount of head/neck movement required to access the peripheral displays, leading to improvements in terms of amount of body movement, neck fatigue, discomfort, performance in selection time

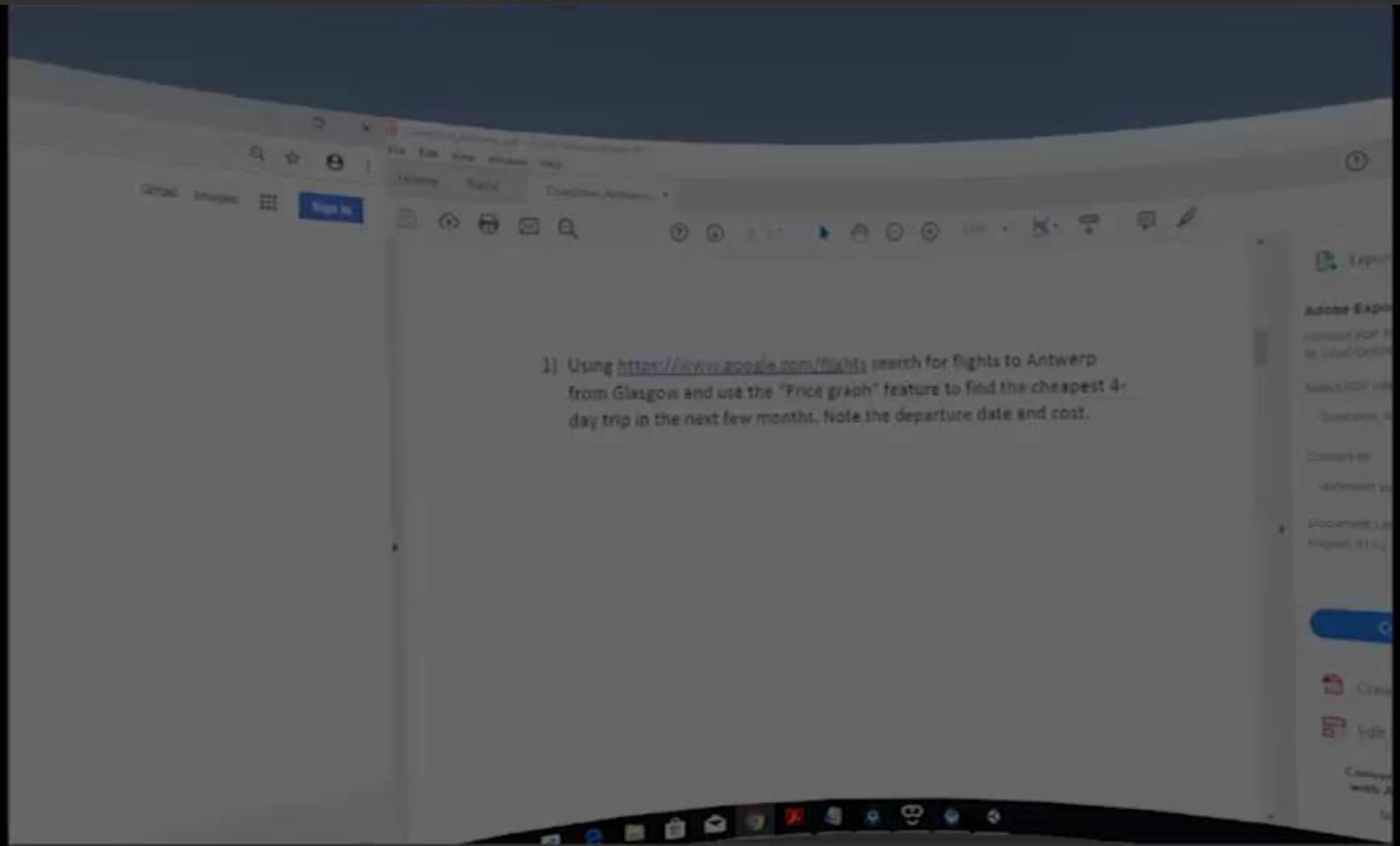
However, interview feedback suggested that the transition movements were at times too abrupt, and that the size of the deadzones may not have been large enough.

There also remained the question of implicit versus explicit control of these movements – was implicit control based on head orientation actually preferable/beneficial, particularly in a “real” workspace as opposed to an artificial targeting task?

IMPLICIT VERSUS EXPLICIT CONTROL OF WORKSPACE

Study 2

- Greater ecological validity – real workspace, real productivity task
- Iterate on boundary switching mechanism based on feedback
- Explore the utility of implicit versus explicit control over display position



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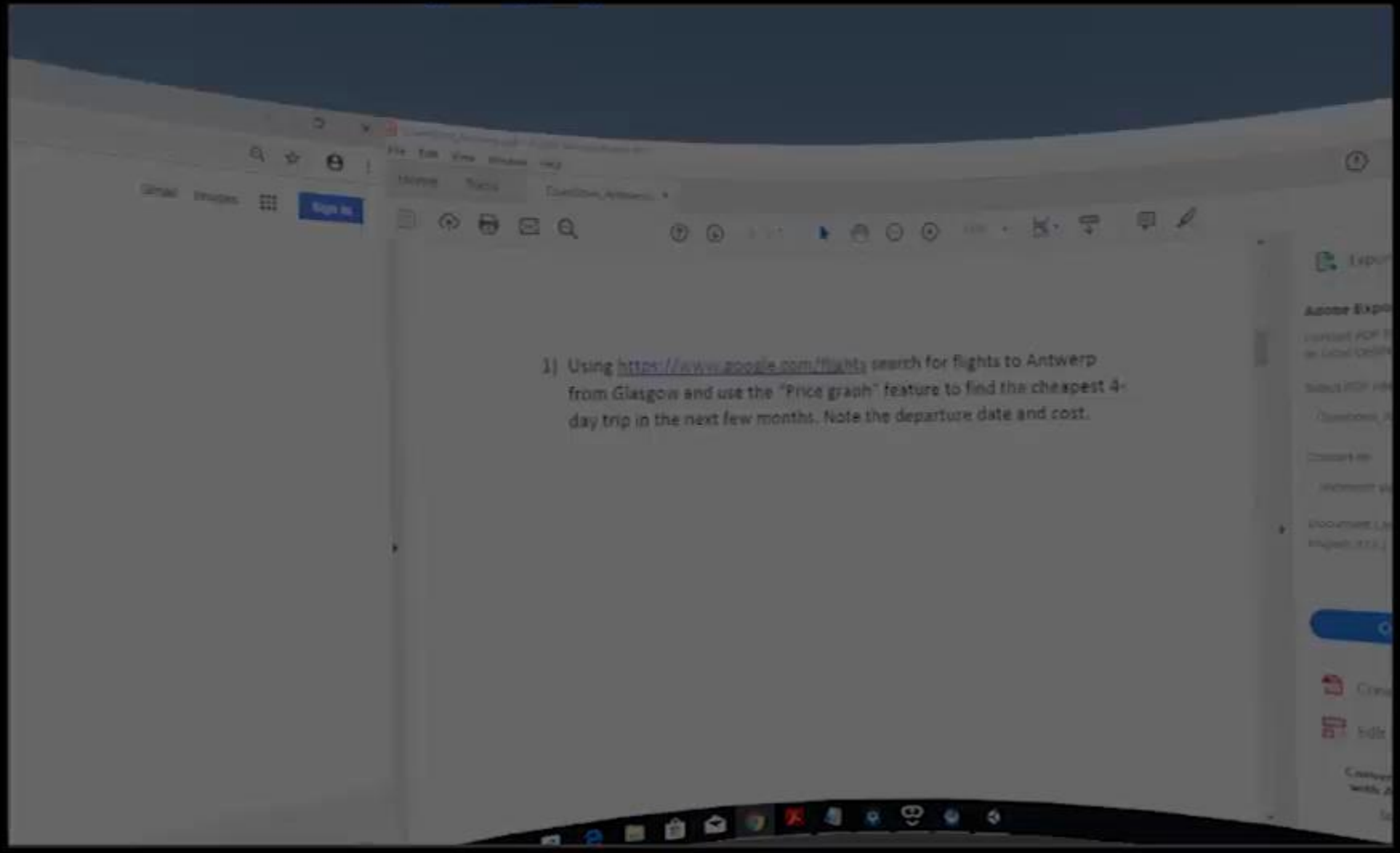


Results TLX Performance

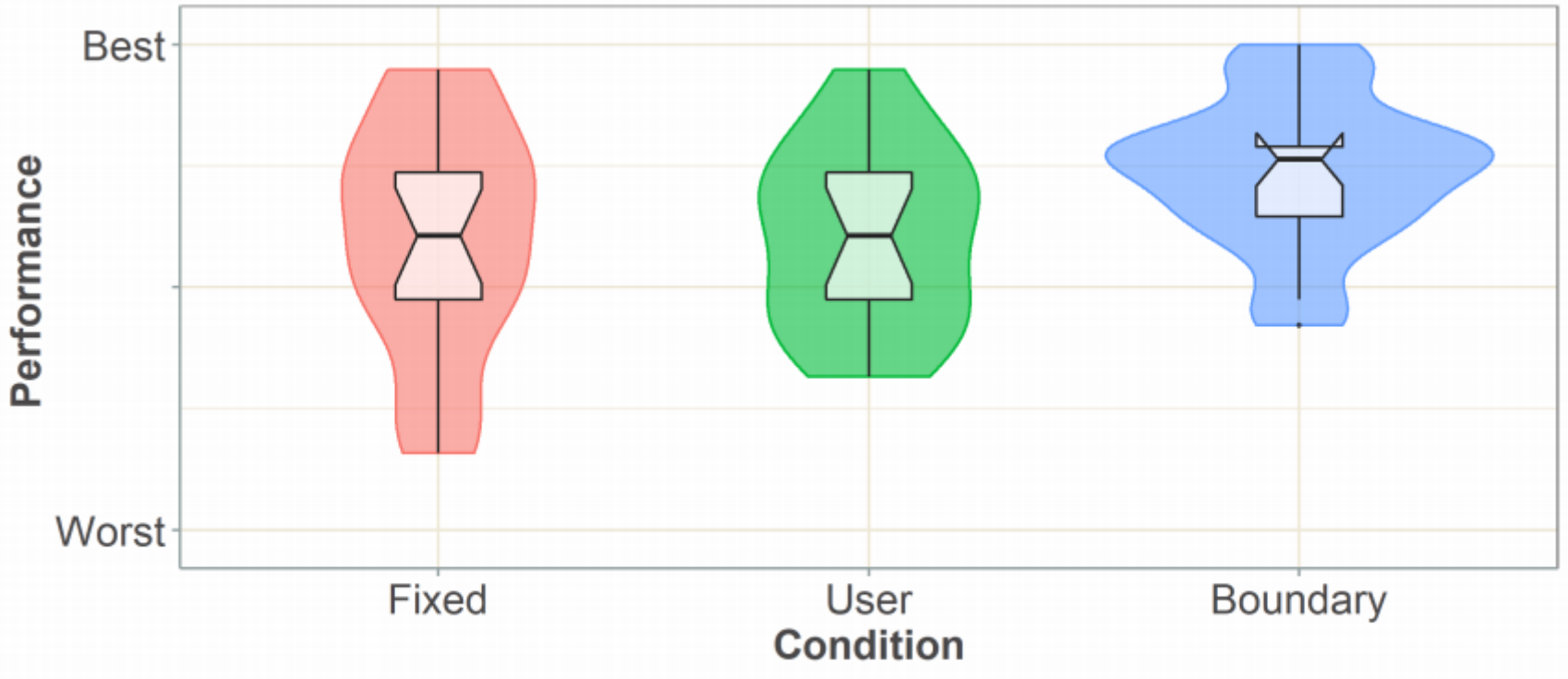
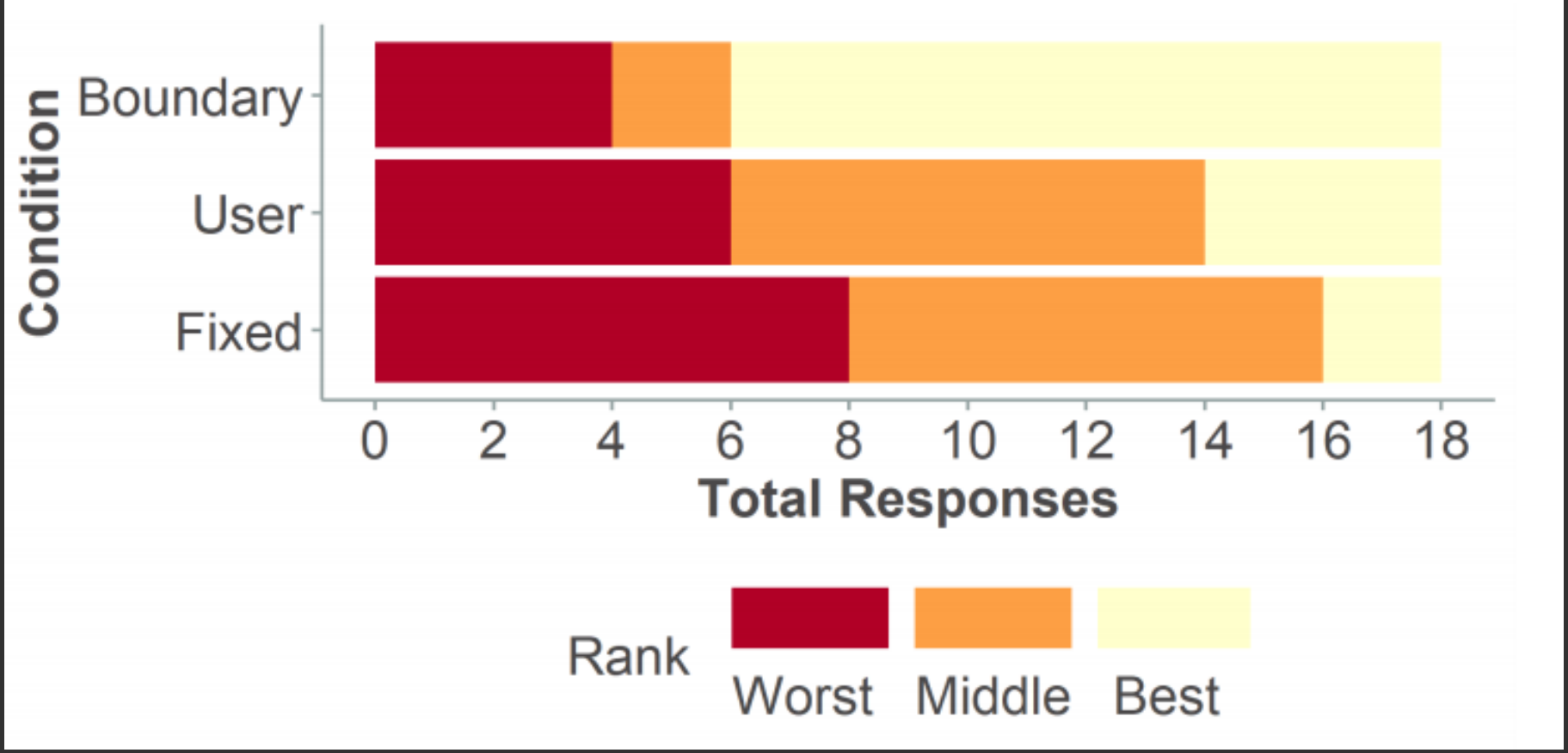
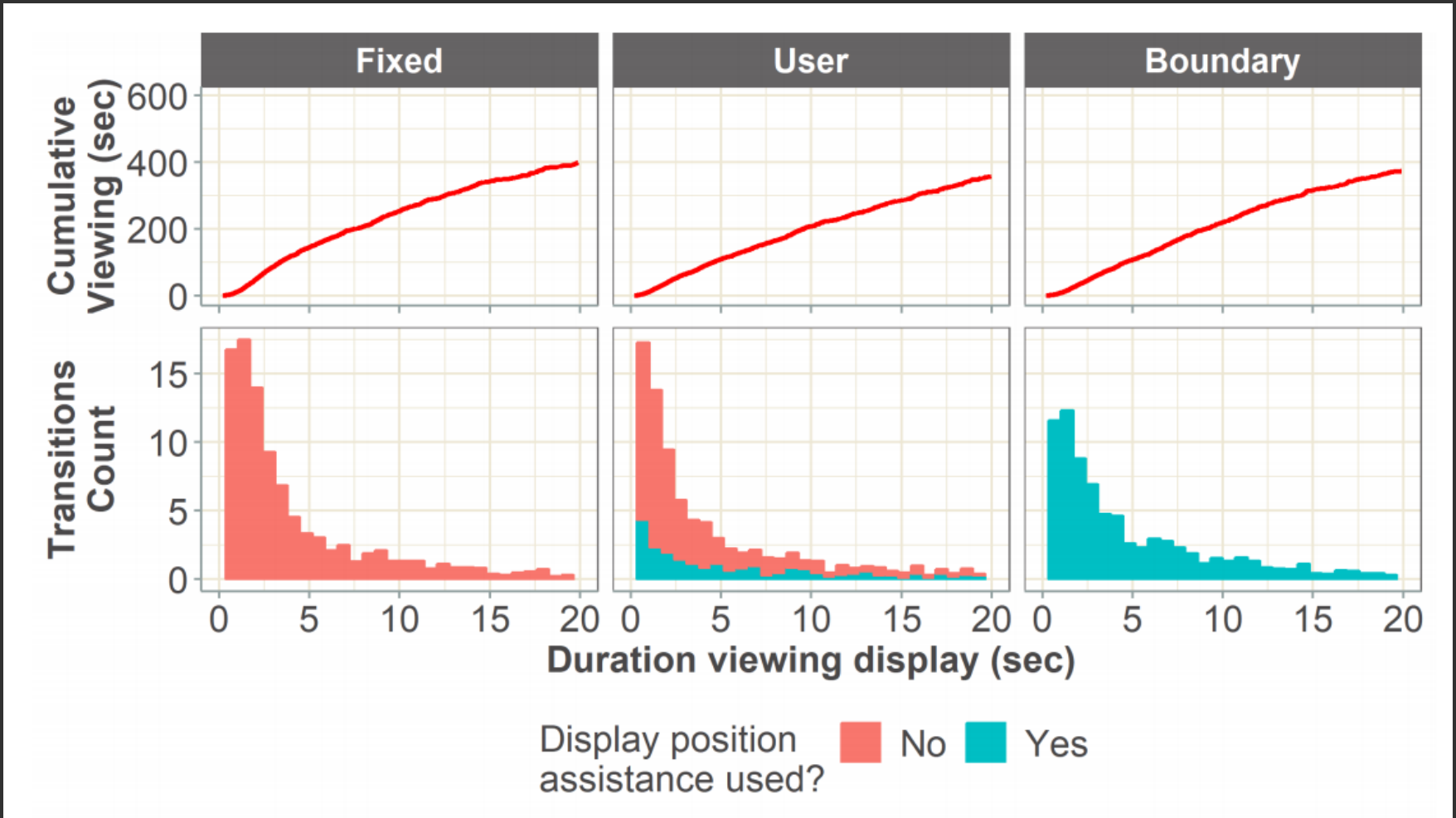


Fig. 16. TLX Performance subscale for Study 2

Results User Preferences



Results Viewing Behaviour



Discussion

Over two studies we demonstrated the utility of dynamically manipulating the display position based on head/neck movement. Wide display spaces were made more comfortable and more accessible to users, allowing their use within a more ergonomic envelope of neck movement.

Virtual displays give us an opportunity not just to present *more* content, but to present it in ways that also better take into account ergonomics and the ability/range of motion of an individual, and adapt to changes in our context/posture/position, or any situational or permanent impairments.

But this is just scratching the surface…

Refinements to dynamic manipulation of display position

- Improving display boundary switching – e.g. preventing false positive transitions, using eye gaze rather than head orientation etc

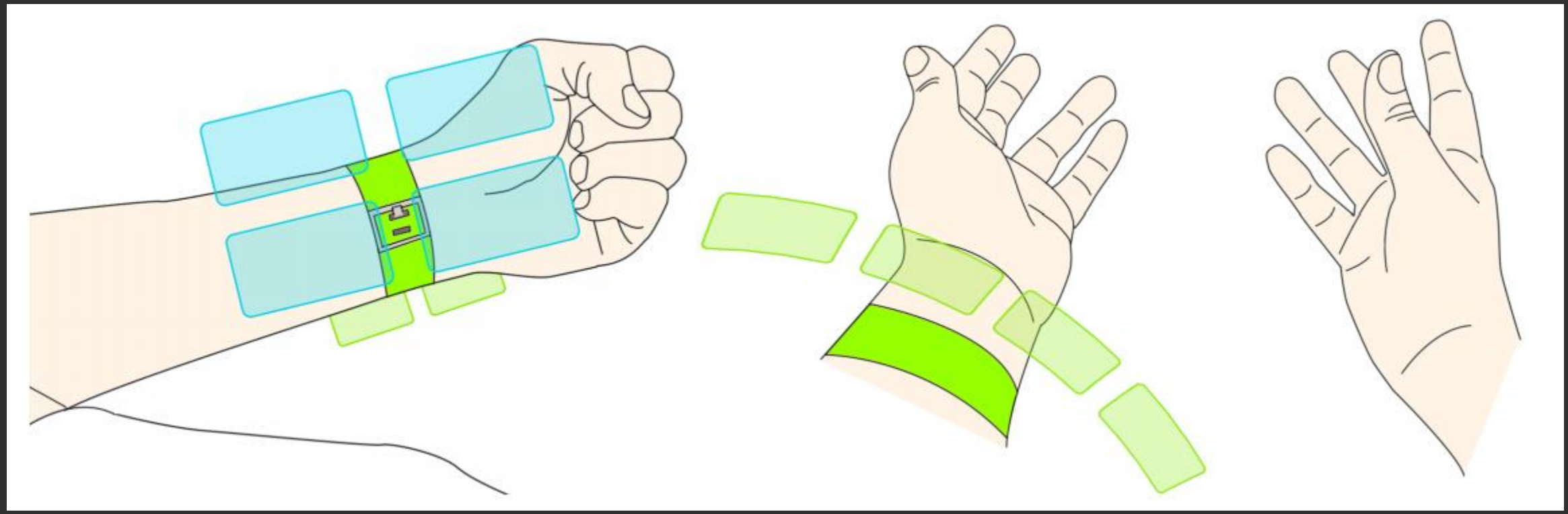
- Cursor management – we used a cursor relocation gesture to move the cursor to where the user's head orientation intersected the virtual displays, but better approaches will be needed

- Alternative display arrangements and anchor points – we looked only at horizontal, curved displays of fixed sizes, but work by Ens et al. hypothesized many other configurations (e.g. vertical, stacked etc).

Detect & Influence Posture

Other applications of manipulating display-to-body mappings

E.g. imagine a wrist-based AR display where wrist rotation dictates which display is currently centered on the wrist for touch interaction. Low effort, small body movements could be utilized to make virtual UIs more accessible

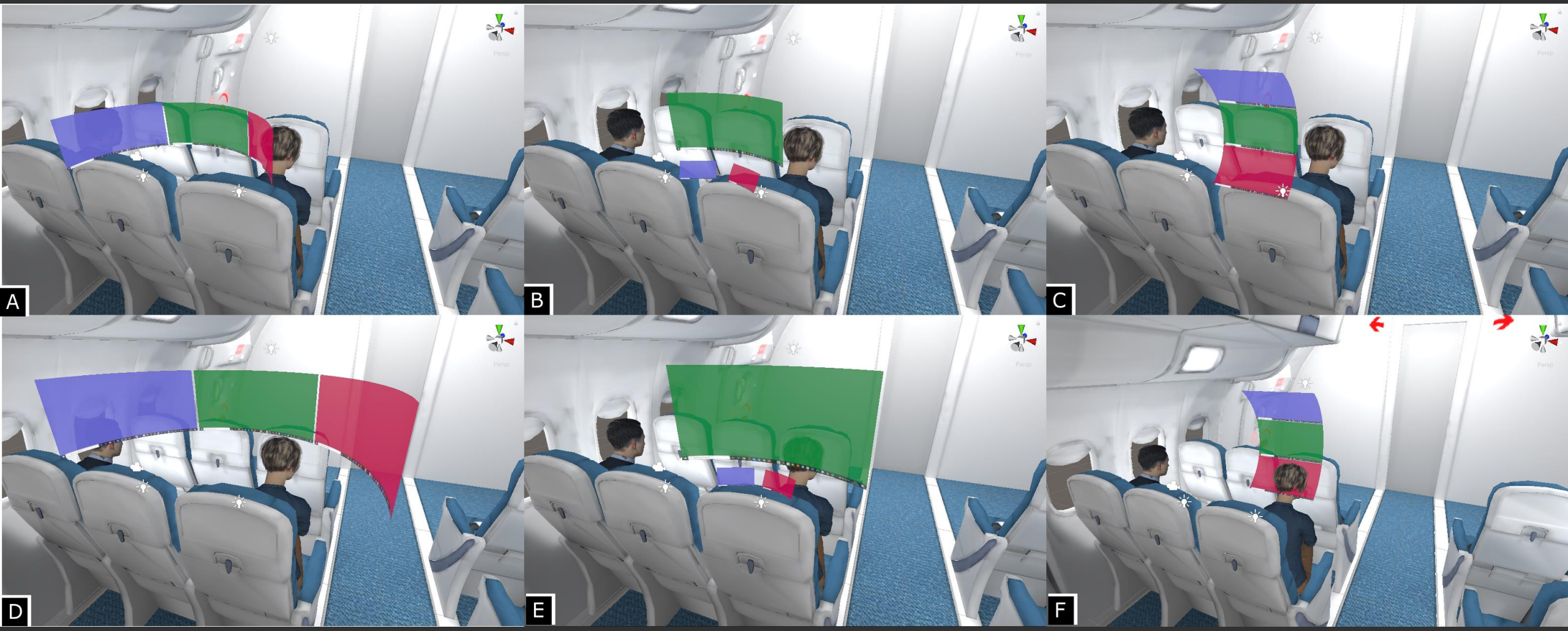


Use in confined spaces (e.g. plane)

Situational impairments (limited neck, head, torso movement), limited access to physical displays, size is restricted, ability to re-position limited

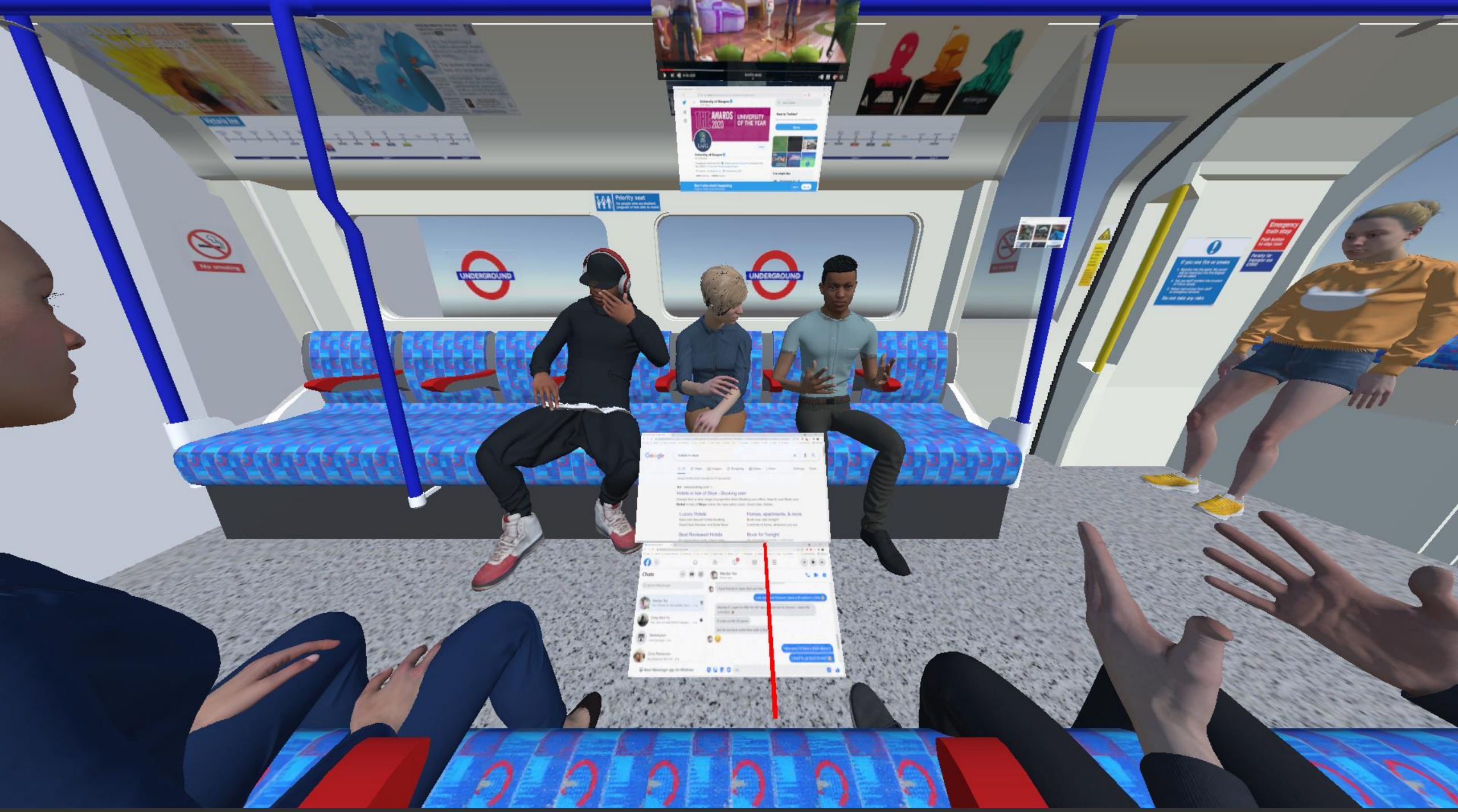
Could benefit significantly from VR/AR virtual displays

https://viajero-project.org/


A
B
C
D
E
F

Users were asked to position, rotate, and scale virtual displays to create their preferred productivity workspace layout


The tip of the iceberg
Catastrophe Theory
MATHS IS COOL
Victoria line
Priority seat
No smoking
UNDERGROUND
Toy Story 4 | Official Trailer
Chats
Instagram
Google
hotels in skye
Hotels in Isle of Skye - Booking.com
Homes, apartments, & more
Book for Tonight
THE AWARDS 2020
UNIVERSITY OF THE YEAR
University of Glasgow
New to Twitter?
Sign up
You might like
Don't miss what's happening


THE AWARDS 2020
UNIVERSITY OF THE YEAR
Priority seat
No smoking
UNDERGROUND
UNDERGROUND
Emergency
Google
Chats


Google
hotels in skye
Hotels in Isle of Skye - Booking.com
Luxury Hotels
Homes, apartments, & more
Best Reviewed Hotels
Book for Tonight
Chats
Marilyn Teo
Toy Story 4 | Official Trailer
THE AWARDS 2020
UNIVERSITY OF THE YEAR
Cola
Cola
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AWARDS 2020
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Chats
Marilyn Teo
hotels in skye
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New to Twitter?


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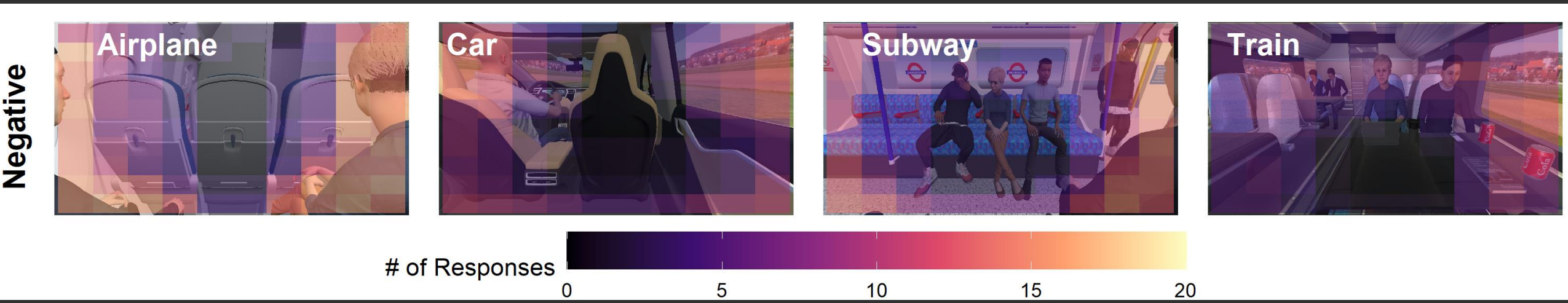
UNIVERSITY OF THE YEAR
Chats

Display layout preferences




Cola
Cola
Cola


UNDERGROUND
UNDERGROUND

For (Simulated) Travel Contexts…

Comfort is not the only, nor even potentially the primary, concern

The social presence of others impacts user attitudes and behaviour for simulated AR productivity in train, plane, subway.

Challenge here is subtly different as there is an additional constraint – how can we make *socially acceptable* display configurations more ergonomic?

This could include:

- applying our suggested approaches to vertical arrangements of content

- carefully motivating some variety of neck/head movements, avoiding the typical long periods fixated on a real seatback display that is small and extremely close

Summary - VR/AR for Virtual Productivity

Many benefits…

Ergonomics and usability – unlimited wider, taller, dynamic, adjustable layouts operating within the usable envelope of head/neck/body movement – and this could adapt to different envelopes based on situational or permanent impairments.

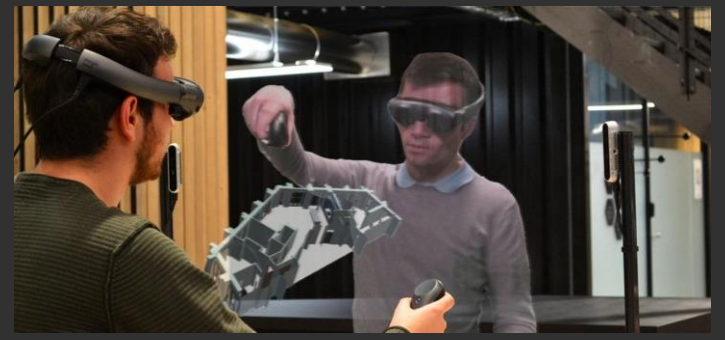
Mobility – Your workspace can travel with you, and can adapt to the physical environment you are in

Physical infrastructure – Lower energy usage and consequently heat emissions (benefits for large, shared offices). Remove the physical barriers of walls of displays in shared offices, erecting virtual barriers to your view of others only when necessary. For home working, your office can recede into the background at the end of the day, with only a few physical artefacts (e.g. keyboard, mouse) needing to be removed.

Summary - VR/AR for Virtual Productivity (cont)

Environment - Augment or supplant reality with virtual content that creates a more calming or enjoyable office – particularly potentially beneficial for open-plan offices or working at home. Have a virtual window to your home garden, or have your "work" related augmentations disappear from your home at the end of the work day.

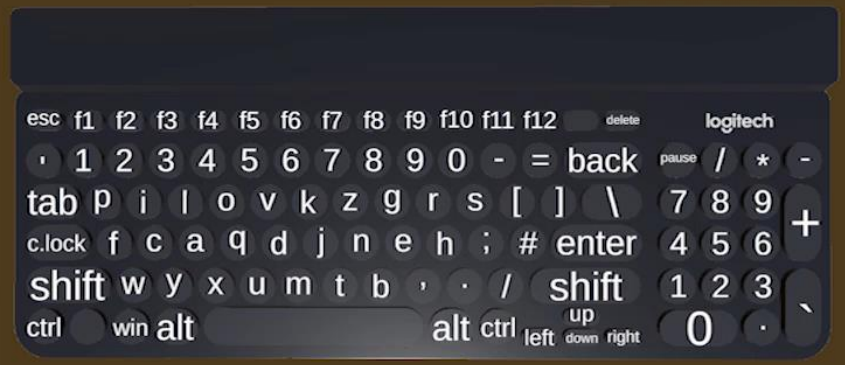
Communication & Collaboration – If we're using AR/VR, we're one step closer to facilitating embodied, 3D, telepresent comms, collaboration around 3D artefacts etc.



Summary - VR/AR for Virtual Productivity (cont)

Personal sensing – Posture, electroencephalogram (EEG), electromyography (EMG), physiological data, eye tracking etc. Many possibilities e.g. monitoring cognitive load or stress, detecting when mistakes are made.

Interaction - XR Headsets can also sense, track and augment physical environments/objects (e.g. supporting augmentation of physical keyboards, right), and the user's body (e.g. for hand tracked mid-air interactions)



Given trackable keyboards, it becomes possible to create augmented keyboard interactions where an XR headset visually augments the keyboard, and can support new interactions and key states (e.g. through hand tracking)

When will this impact practice?

Contingent on hardware advances pushed by Facebook, Apple, Google, Microsoft etc.

Microsoft Hololens 2 – limited field of view, not particularly fashionable, expensive

Facebook / Oculus Quest 2 – affordable, but uncomfortable for long periods of usage, heavy, resolution/fidelity/field of view not quite there.

We're awaiting advances in terms of optics, resolution, field of view, form factor, comfort and price. It's inevitable we'll get there however e.g. Apple heavily rumoured to have an AR/VR headset by 2022, Glasses by 2025 (https://www.macrumors.com/roundup/apple-glasses/)

So we need to be in a position to take full advantage of these technologies when they mature…

Expanding the Bounds of Seated Virtual Workspaces

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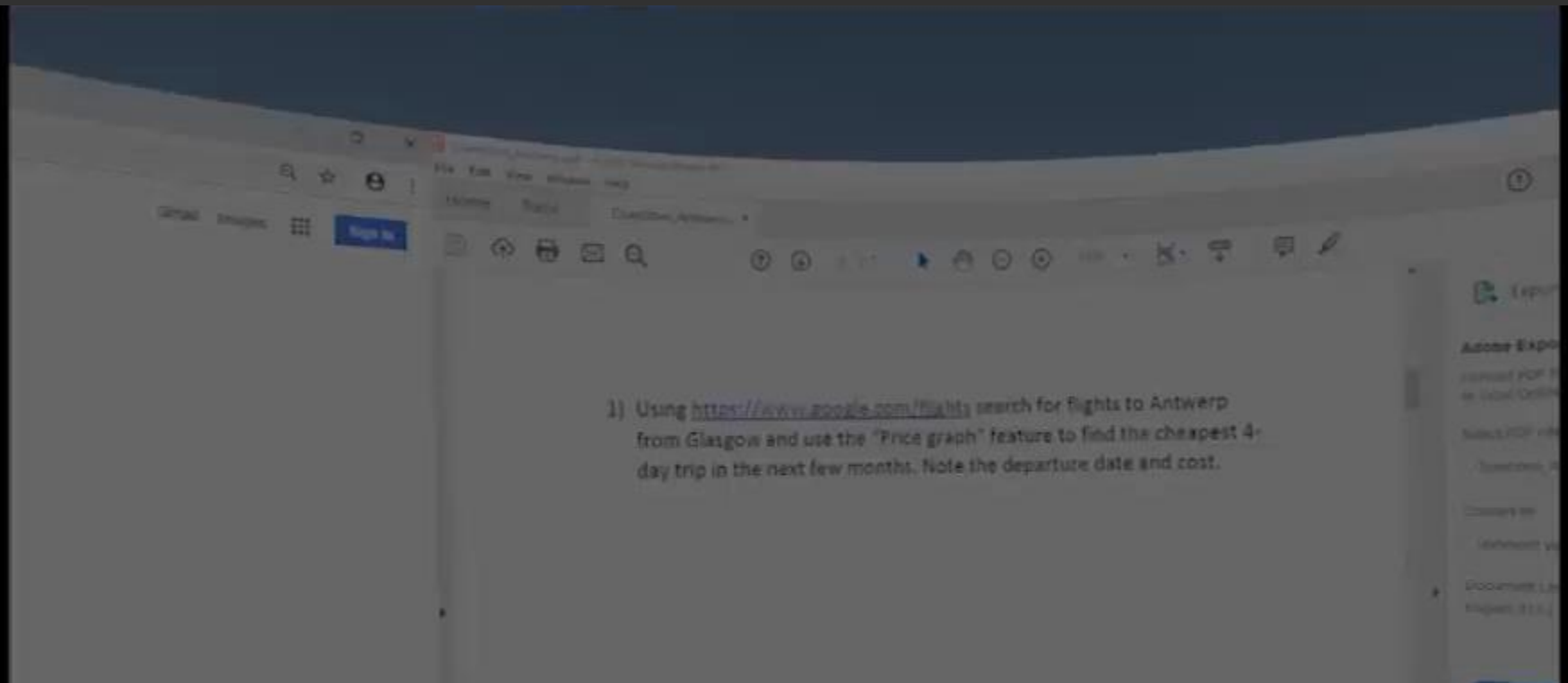

Some useful references

https://www.mdpi.com/2414-4088/5/4/15 - examines rear-seat productivity, and muses on the impact of virtual environment in mobility contexts

https://conferences.computer.org/vrpub/pdfs/VR2021-2AyvgnPUHcYon9QQHz6BPD/255600a750/255600a750.pdf - demonstrates the particular benefits of multiple virtual displays and augmenting existing physical displays

https://dl.acm.org/doi/10.1145/3380959 / https://www.youtube.com/watch?v=aR_Elxqa5-0 – our own work, emphasizes the enhanced ergonomics offered by manipulating displays