CNS Cyberinfrastructure for Network Science Center

LUDDY
SCHOOL OF INFORMATICS, COMPUTING, AND ENGINEERING
Bloomington

Exploring Data in VR: Opportunities and Challenges

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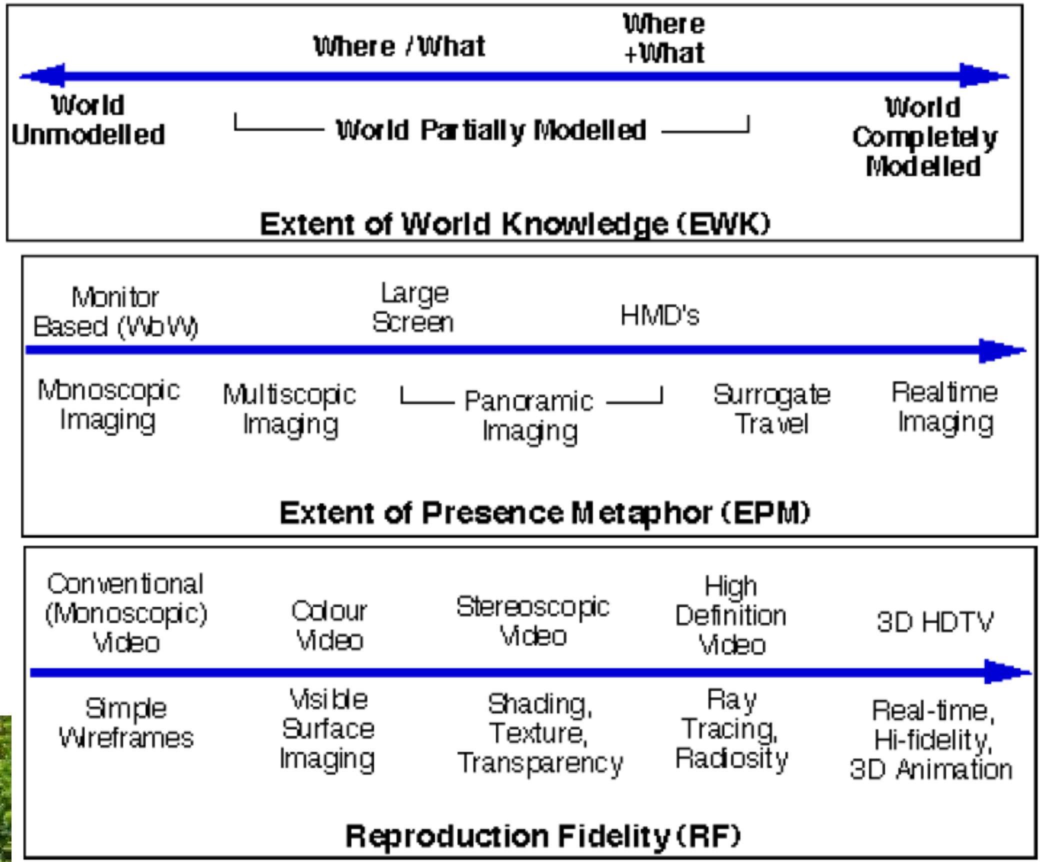
Tech Tuesday Series by IN3 and Midwest Tech Bridge | The Mill | Bloomington, IN | September 20, 2022

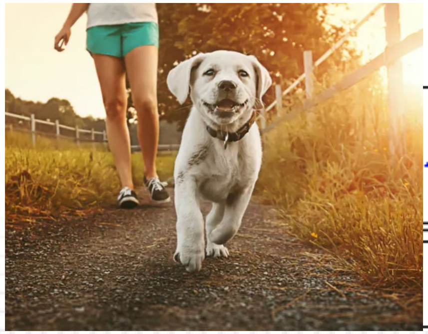
A Note on Nomenclature

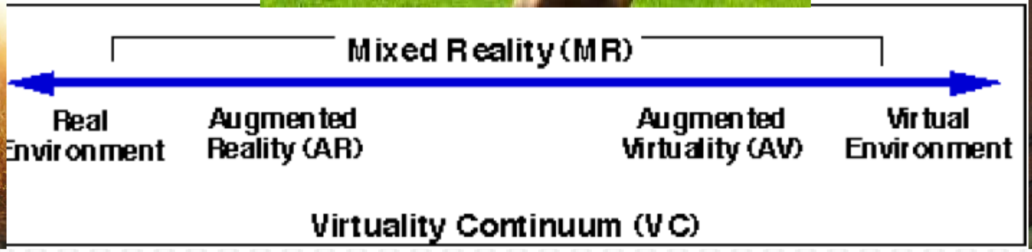
- Virtual reality, augmented reality, mixed reality, hybrid reality – what does it all mean?

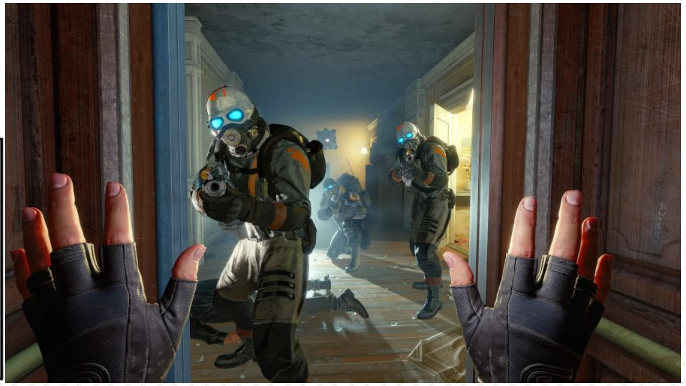
The Reality-Virtuality Continuum

- Milgram & Kishino (1994) proposed a spectrum to describe the **reality-virtuality continuum**
- Along three dimensions
  - Extent of World Knowledge (EWK)
  - Extent of Presence Metaphor (EPM)
  - Reproduction Fidelity (RF)







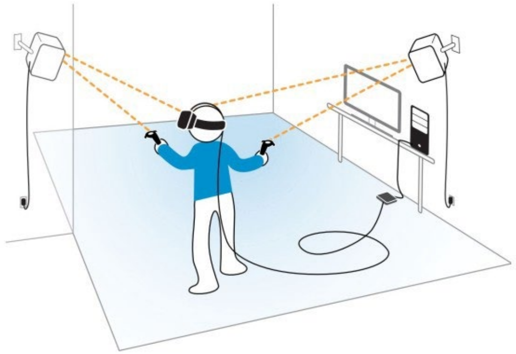


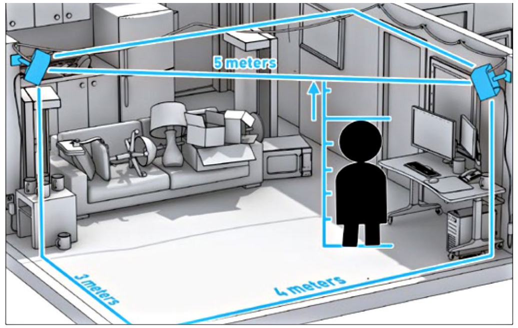
What We Mean by “VR” in This Talk

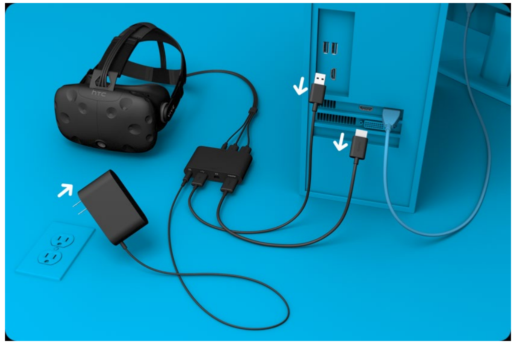
Introduction

- Recent rise of consumer-grade VR
- Many options
  - price
  - resolution
  - field of view
  - size
  - Tracking
- Content delivery platforms
  - Steam
  - Oculus Store
  - WebXR (browser)

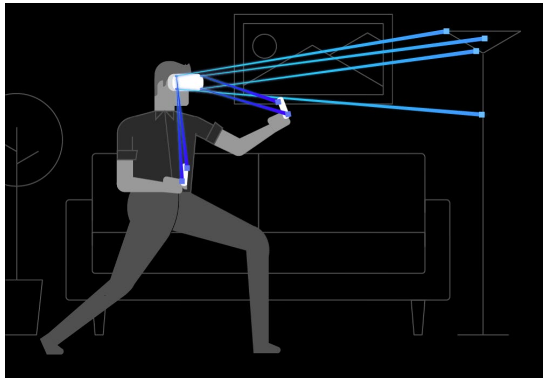
oculus







HTC Vive



Oculus Quest 2

Vision...

https://www.reddit.com/r/Thatsabooklight/comments/kf2ve0/the_medical_infusion_devices_center_background/

https://medcitynews.com/2019/09/the-benefits-of-ar-in-healthcare/

…and Reality

https://www.mobihealthnews.com/news/asia/ndmc-partners-htc-deepq-build-largest-mr-anatomy-classroom-taiwan

https://cgvr.cs.uni-bremen.de/research/atlas_19/

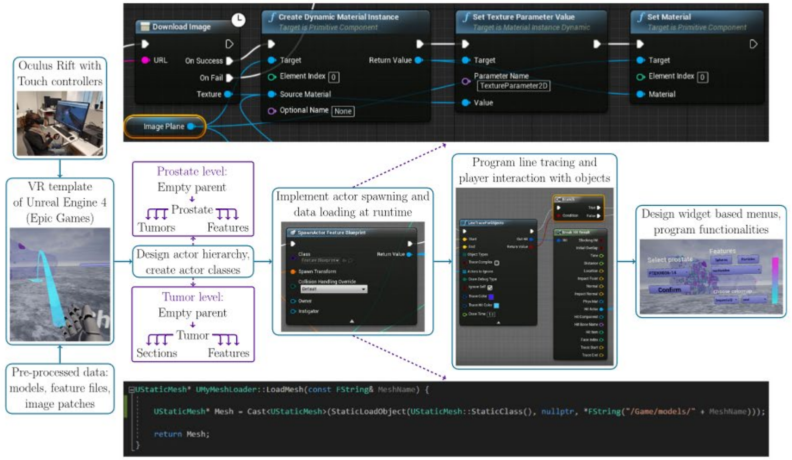
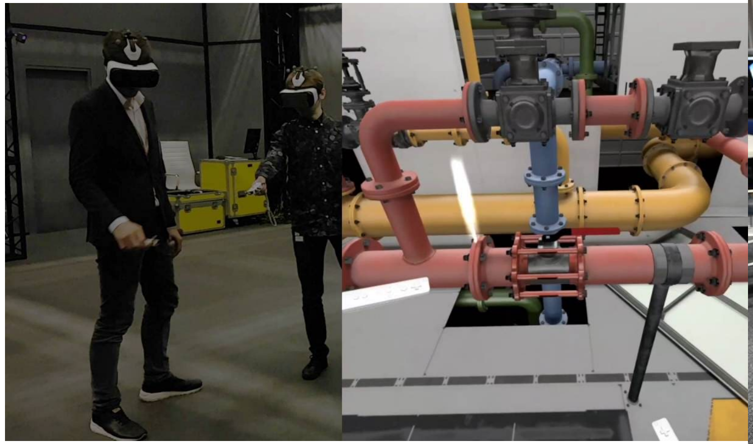


Fig. 3 VR implementation steps illustrated. The example on top shows how images (cropped serial sections) are loaded with Blueprint nodes. The example in bottom is the C++ function used for loading meshes

Liimatainen, Kaisa, Leena Latonen, Masi Valkonen, Kimmo Kartasalo, and Pekka Ruusuvuori. "Virtual Reality for 3D Histology: Multi-Scale Visualization of Organs with Interactive Feature Exploration." *BMC Cancer* 21, no. 1 (December 2021): 1133. https://doi.org/10.1186/s12885-021-08542-9.

Use Cases

- Training
  - Vehicles
  - Machines
  - HUDs
  - Mission planning
  - Studying information processing and overload
- Tactical Augmented Reality (TAR)
  - Enhance what is already there
- Measuring and timing movement and interaction between user and environment



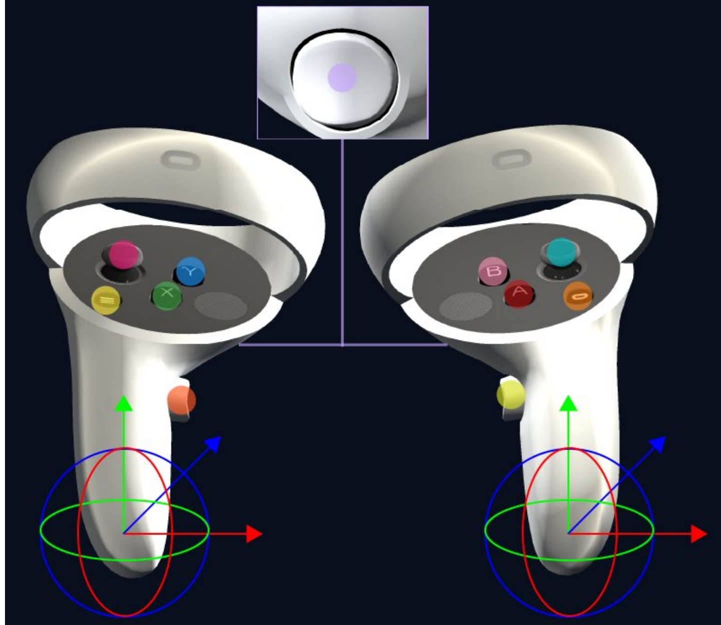
https://www.youtube.com/watch?v=0NormS9SIow

https://www.airforcetimes.com/news/your-air-force/2019/10/08/academy-brings-vr-pilot-training-to-cadets/

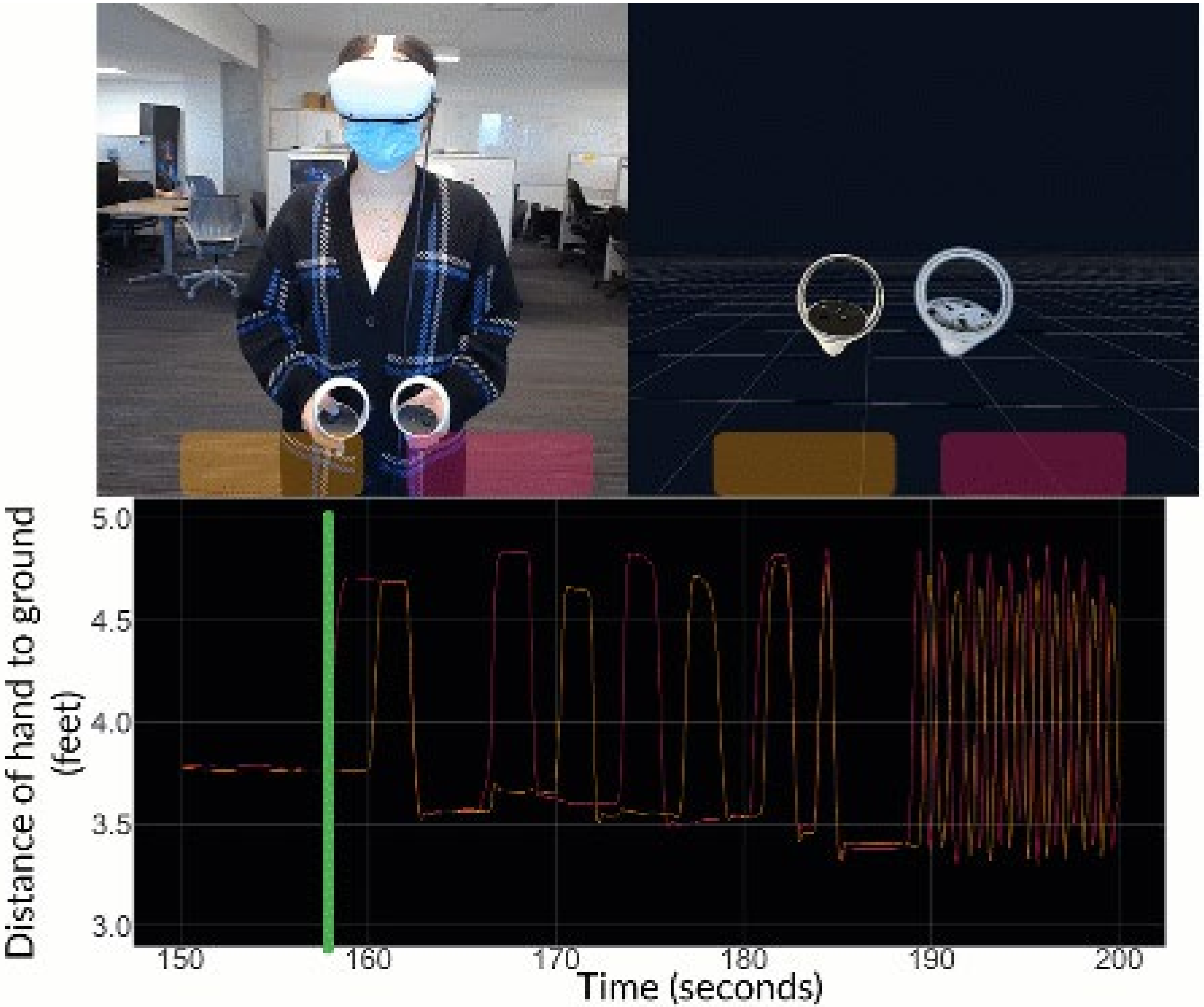
https://www.roadtovr.com/iti-vr-crane-training-simulator-test/

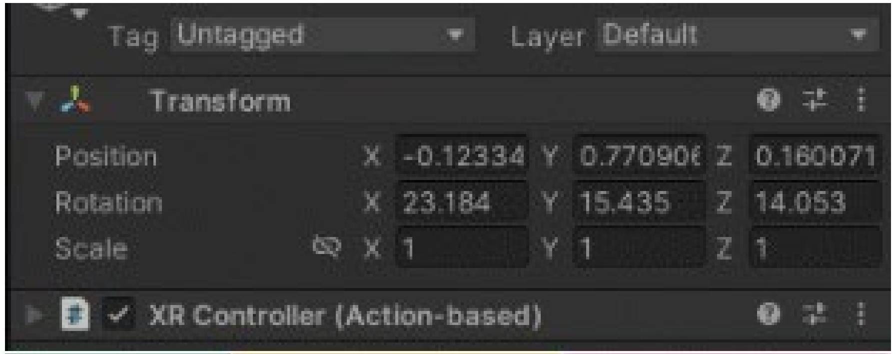
Input devices

Left mouse button
Right mouse button
Middle mouse button/wheel
x, y-position



Left analog stick
Menu button
X-button
Y-button
Left trigger button
Left grip button
Right analog stick
Oculus button
B-button
A-button
Right trigger button
Right grip button
x, y, z-position
x, y, z-rotation





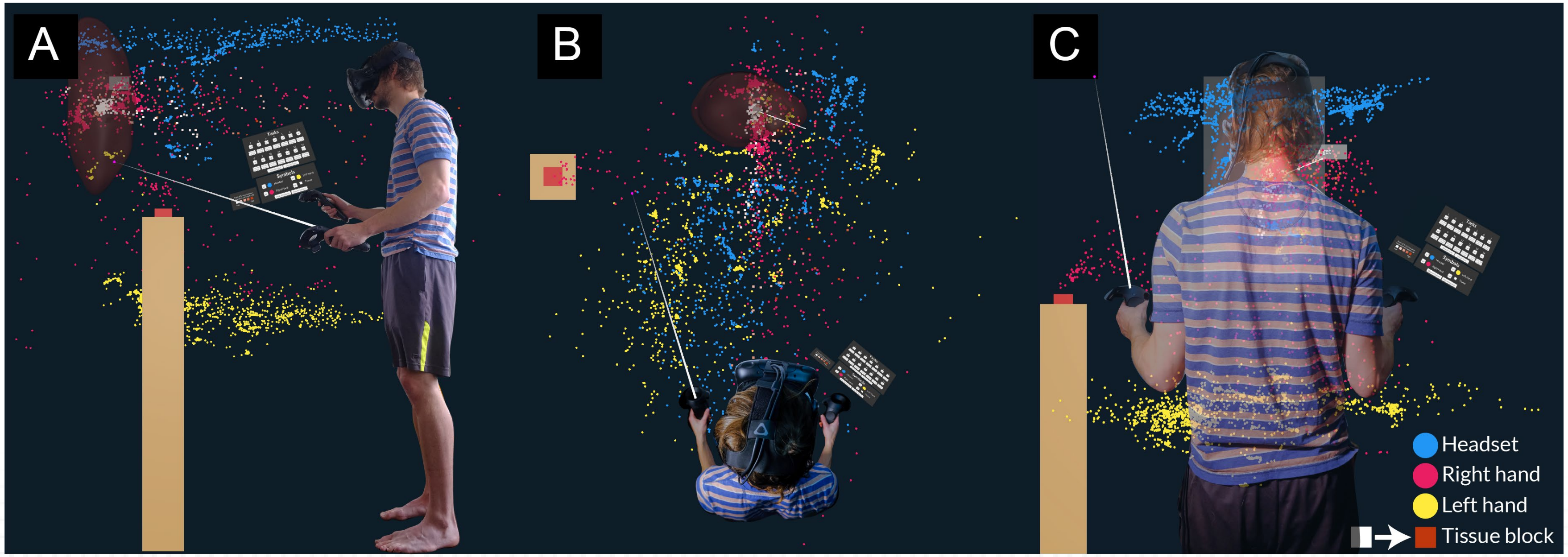
elapsedTime	ControllerLeftPosY	ControllerRightPosY
146.7885	1.145622	1.145195
146.9156	1.146054	1.145453
147.0404	1.146554	1.145594
147.166	1.146521	1.145718
147.2754	1.146712	1.146041
147.4028	1.147	1.146333
147.5262	1.147393	1.146196
147.6518	1.149418	1.146329
147.7639	1.150053	1.146693
147.8906	1.150788	1.146913
148.0158	1.150822	1.146652
148.1395	1.150867	1.147119
148.2646	1.1518	1.147748

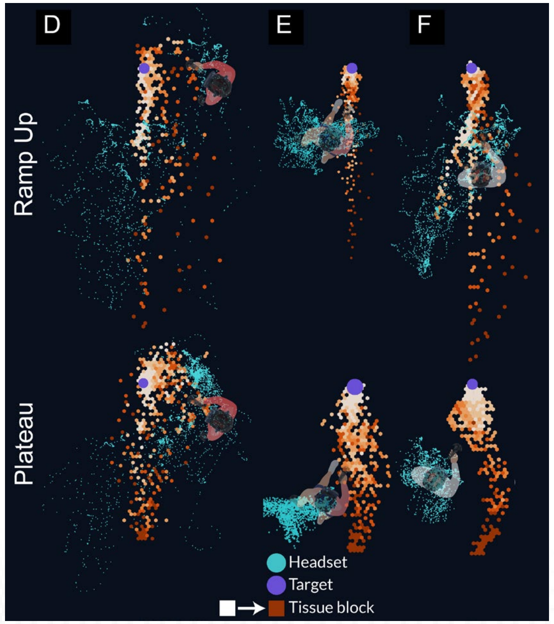
Where is the Data?

Data Visualization in VR: Vision

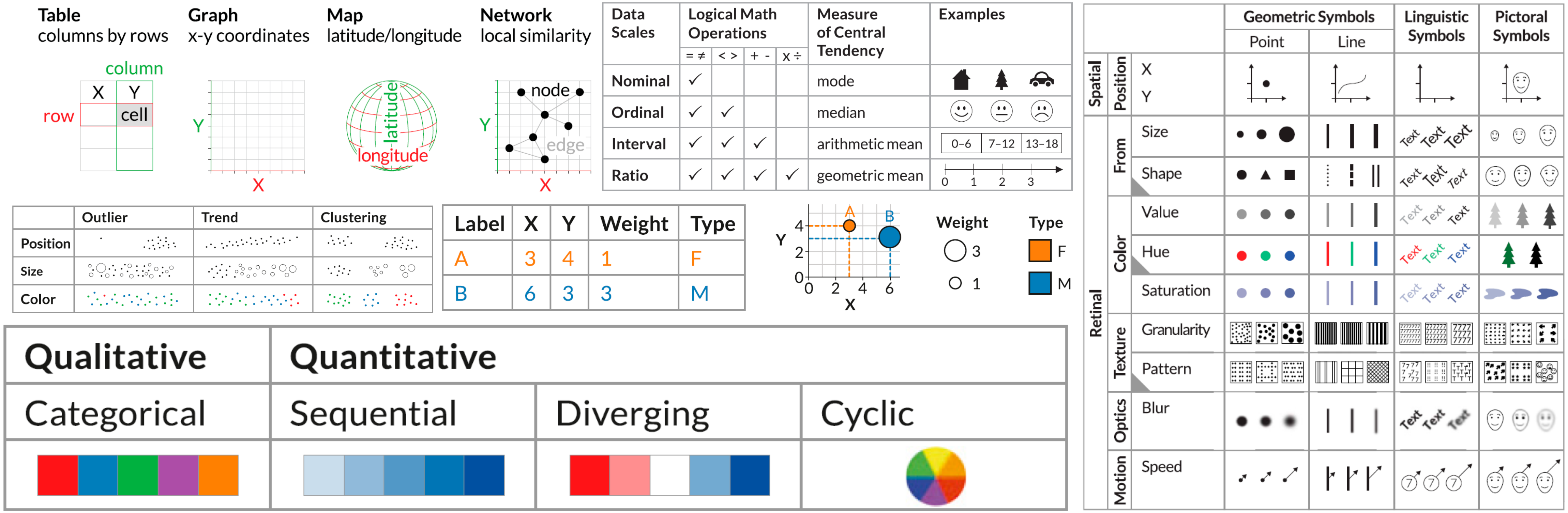
“Visual data exploration seeks to integrate humans in the data exploration process, applying their perceptual abilities [...]. The basic idea is to present the data in some visual form, allowing data analysts to [...] interact with it.” (Keim, 2001)

- Symbiosis of computers and humans
- Visualization is for humans only
- Many formalizations for making, interpreting, and teaching data visualization





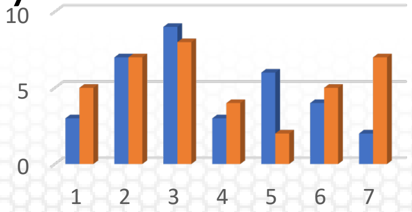
Data Visualization Literacy Framework



Börner, Katy, Andreas Bueckle, and Michael Ginda. "Data Visualization Literacy: Definitions, Conceptual Frameworks, Exercises, and Assessments." *Proceedings of the National Academy of Sciences* 116, no. 6 (2019): 1857–64. https://doi.org/10.1073/pnas.1807180116.

Perceptual Challenges for vis in VR

- 2D is simplicity
- VR is 3D by nature
- Occlusion
  - Depth cue -> limits what we can see in 3D
  - We experience the world in 2.05D (Munzner, 2014; Ware, 2008)
- Foreshortening
  - Shows size difference where there should be none
- 3D costs time and cognitive effort
  - No 3D as purely aesthetic choice! (Few, 2012)



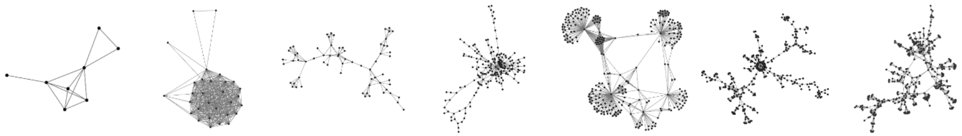
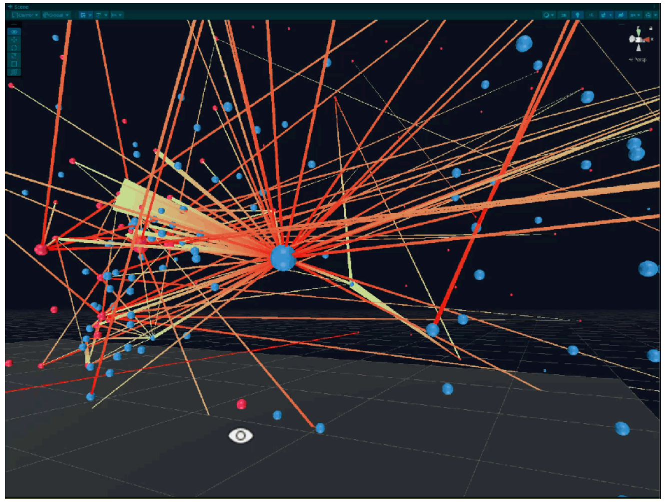
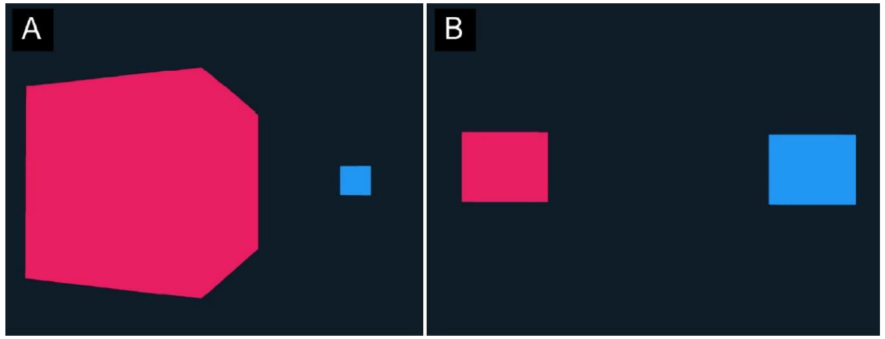


Figure 13. A visualization of each network layout, using the GEM layout.

From (Zoss, 2018)

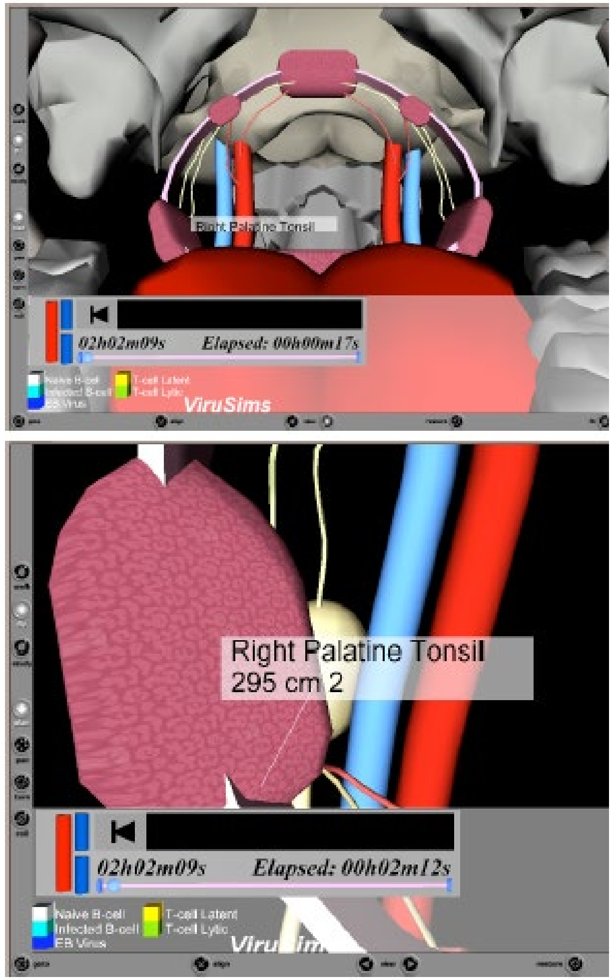




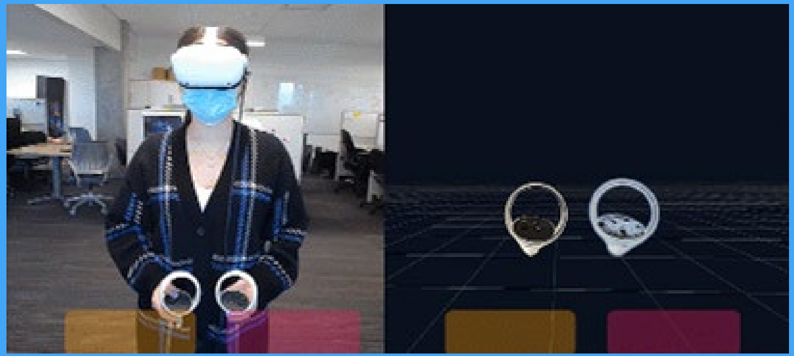
From (Bueckle, 2021)

Information-Rich Virtual Environments (IRVE)

- "An information-rich virtual environment (IRVE) is a realistic VE that is enhanced with the addition of related abstract information."
- Bowman, Doug A, Chris North, Jian Chen, Nicholas F Polys, Pardha S Pyla, and Umur Yilmaz. "Information-Rich Virtual Environments: Theory, Tools, and Research Agenda," 81–90. New York City, NY: ACM, 2003. https://doi.org/10.1145/1008653.1008669.



Project 1: Optimizing Movement in VR



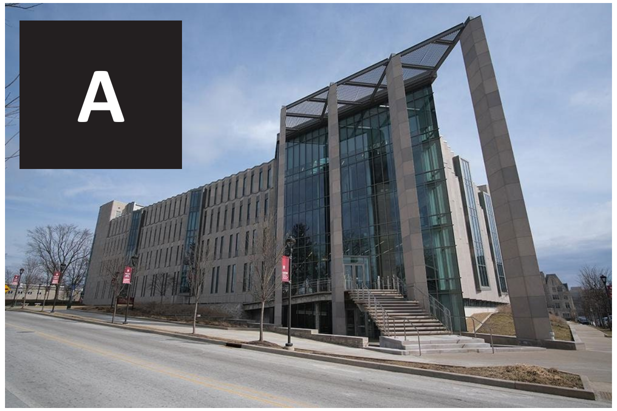
We can show someone in VR visualizations of their own movement data.

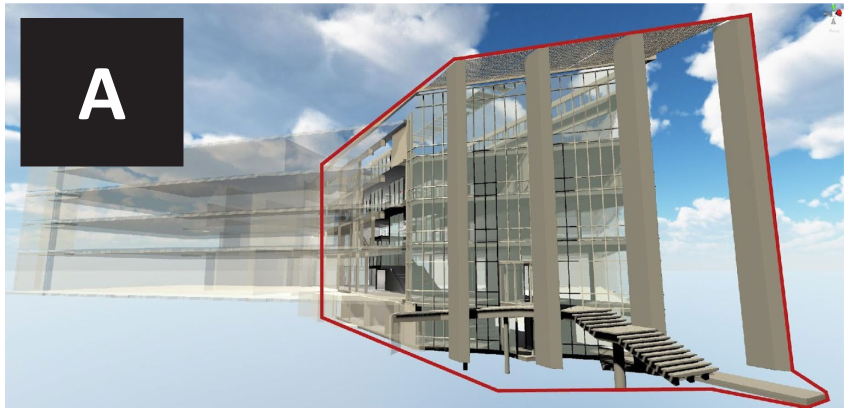
Then maybe they can learn from it.

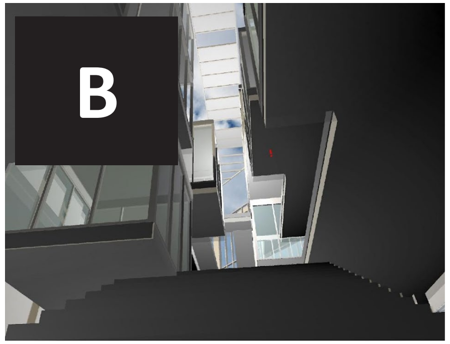
In a recent paper, we asked people to travel through a virtual building as fast as possible.

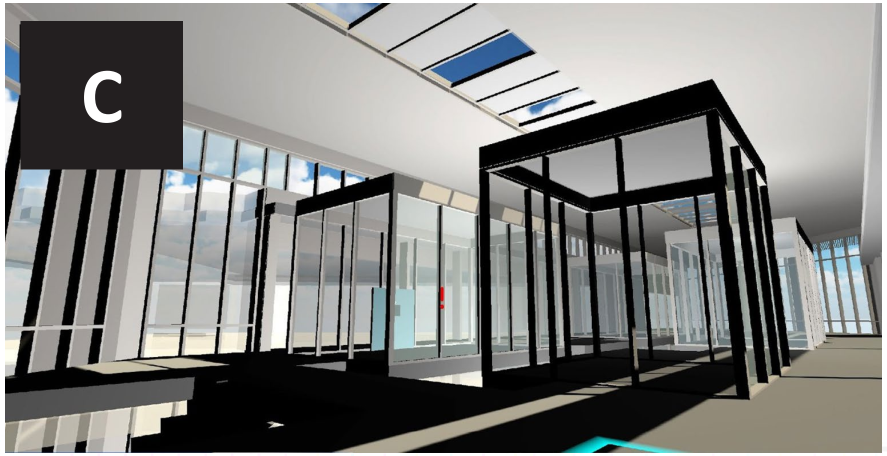
We wanted to check if they can beat their own time in a 2nd trial after having seen a visualization of their own movement.

Study design



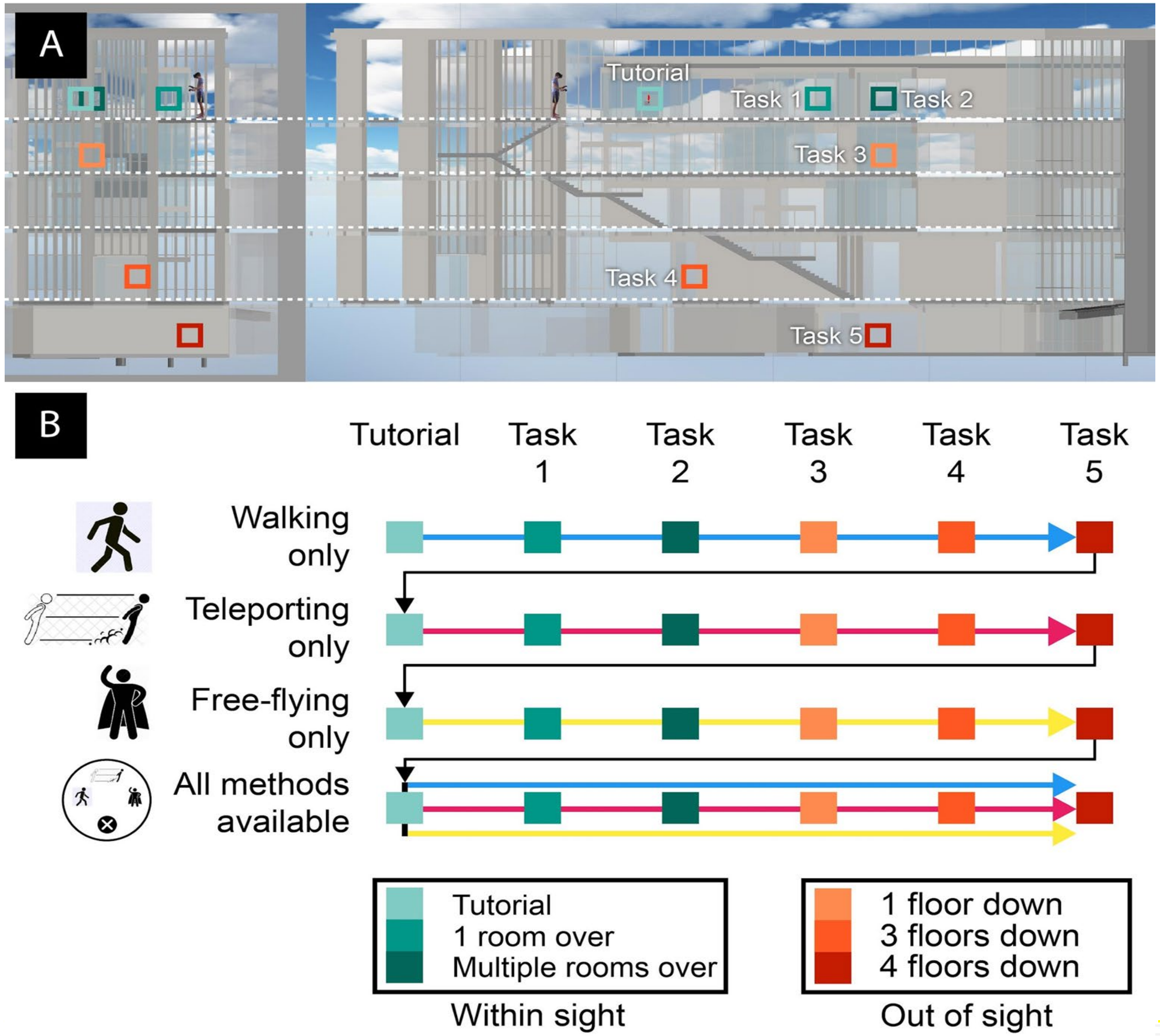




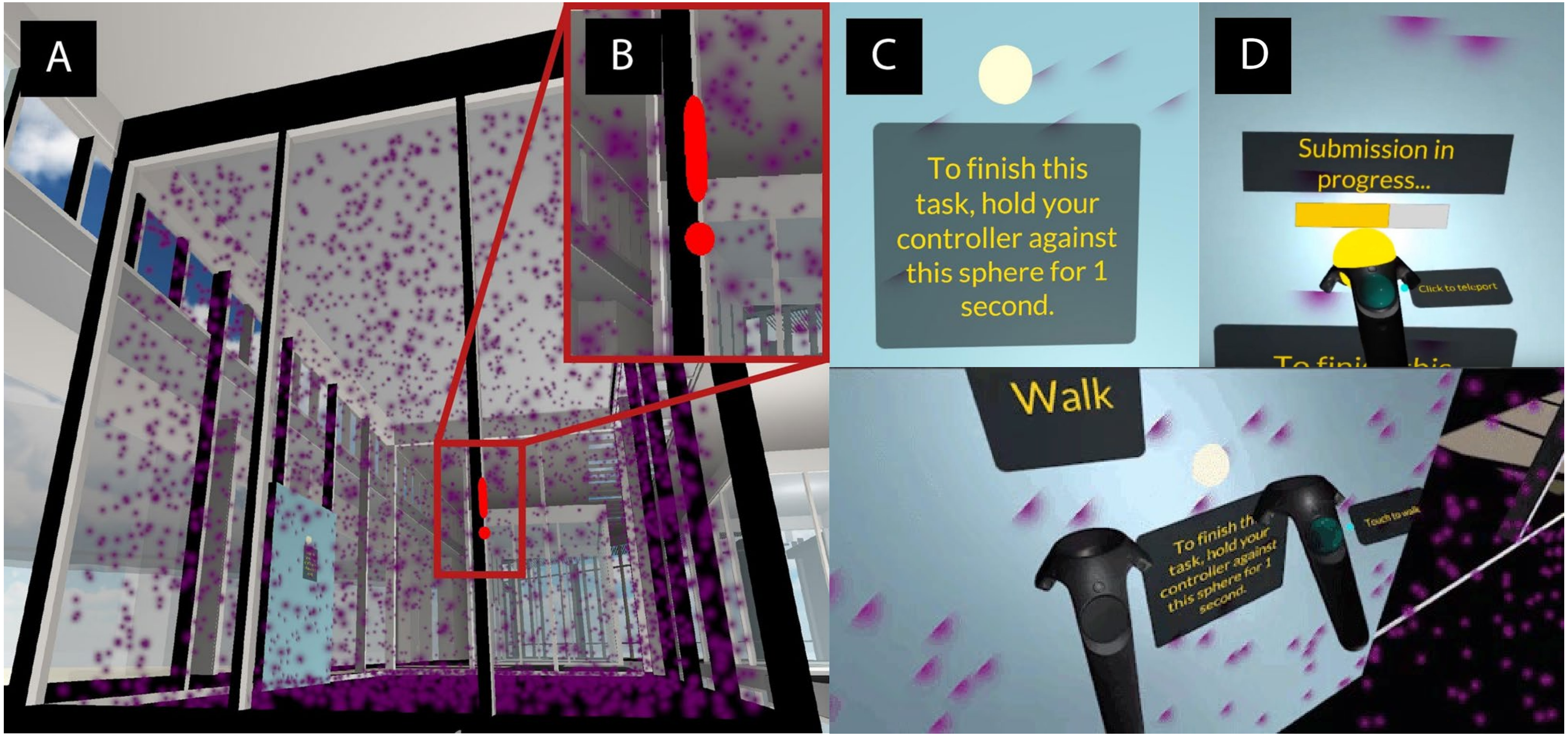


Study overview

- 4 x 6 tasks
- 1st task is practice
- Movement methods
- Tasks get harder

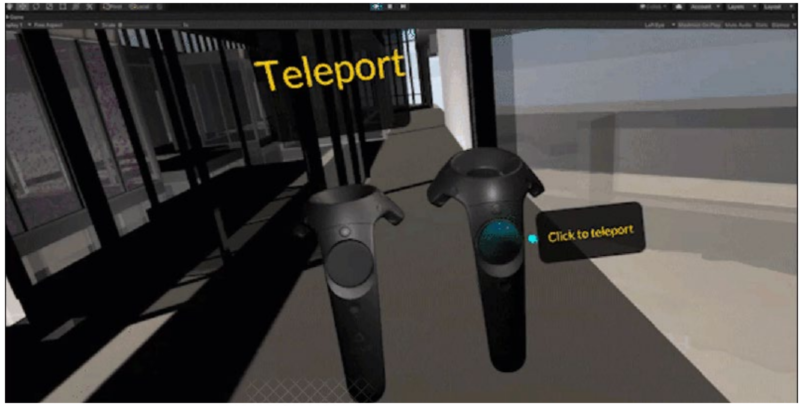


Study overview (cont’d)



Movement methods

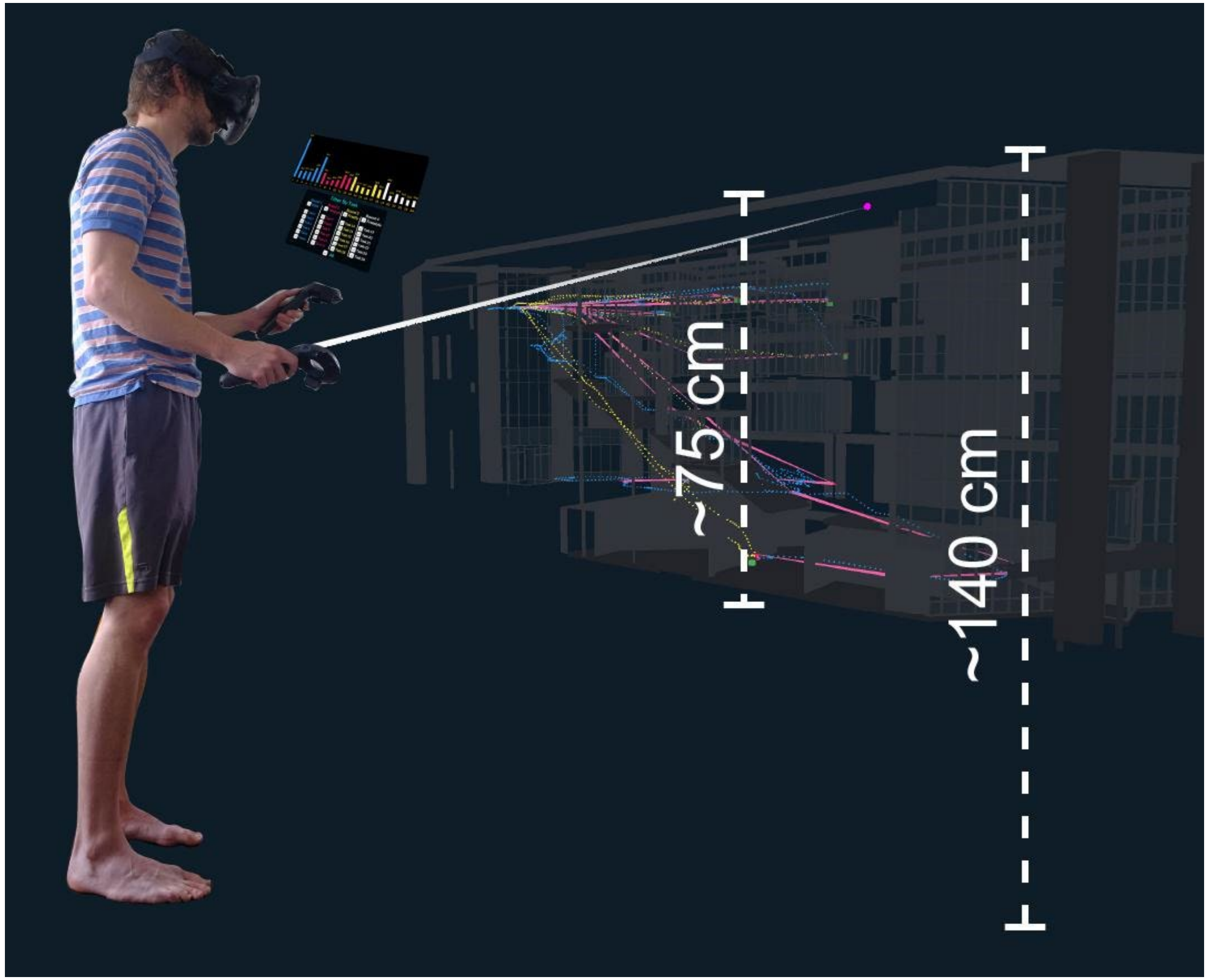
Walking



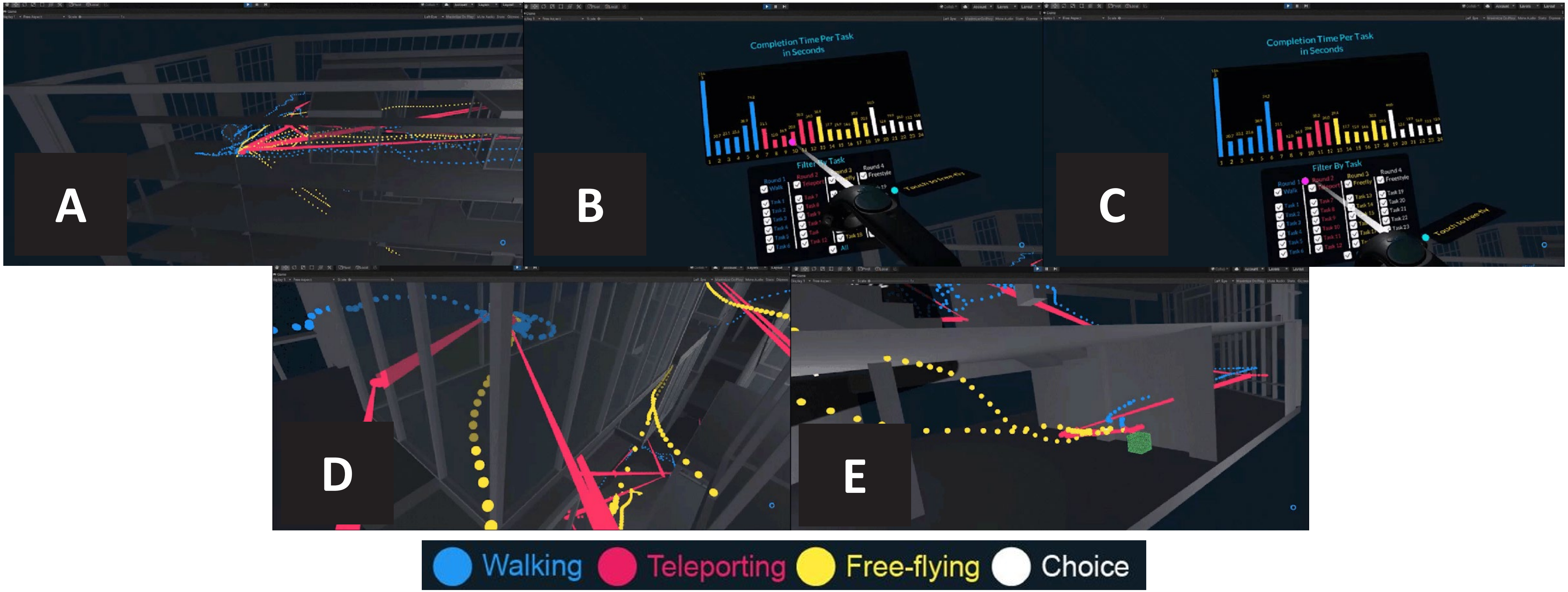
Teleport

Free-fly

Choice between all 3


~75 cm
~140 cm

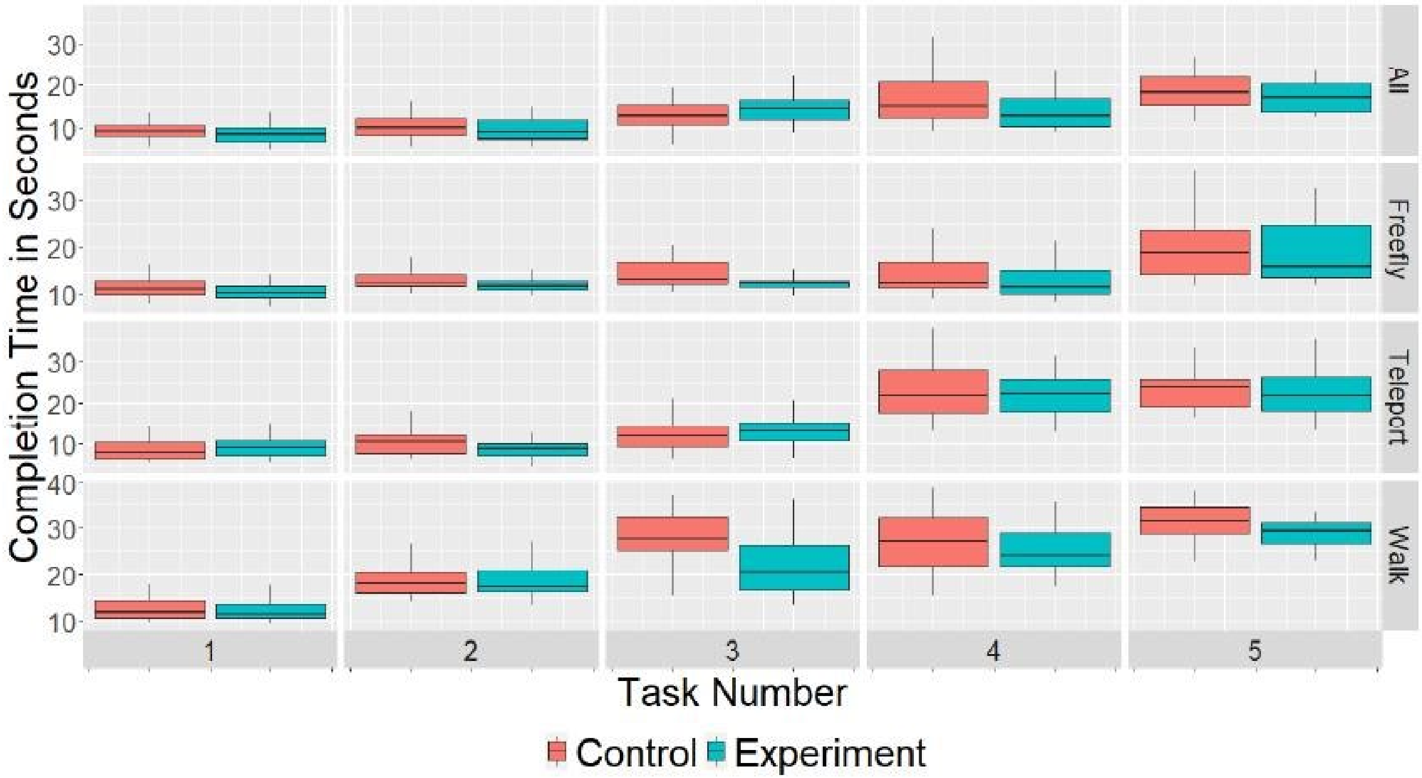
Data is beautiful



Did it work?

- **Yes!**
- People who saw their own data were faster by 1 second:
  - $m_{control}$ = 16.44 s
  - $m_{experiment}$ = 15.44 s

(*t* = 2.465, *p* = 0.01383) ✓

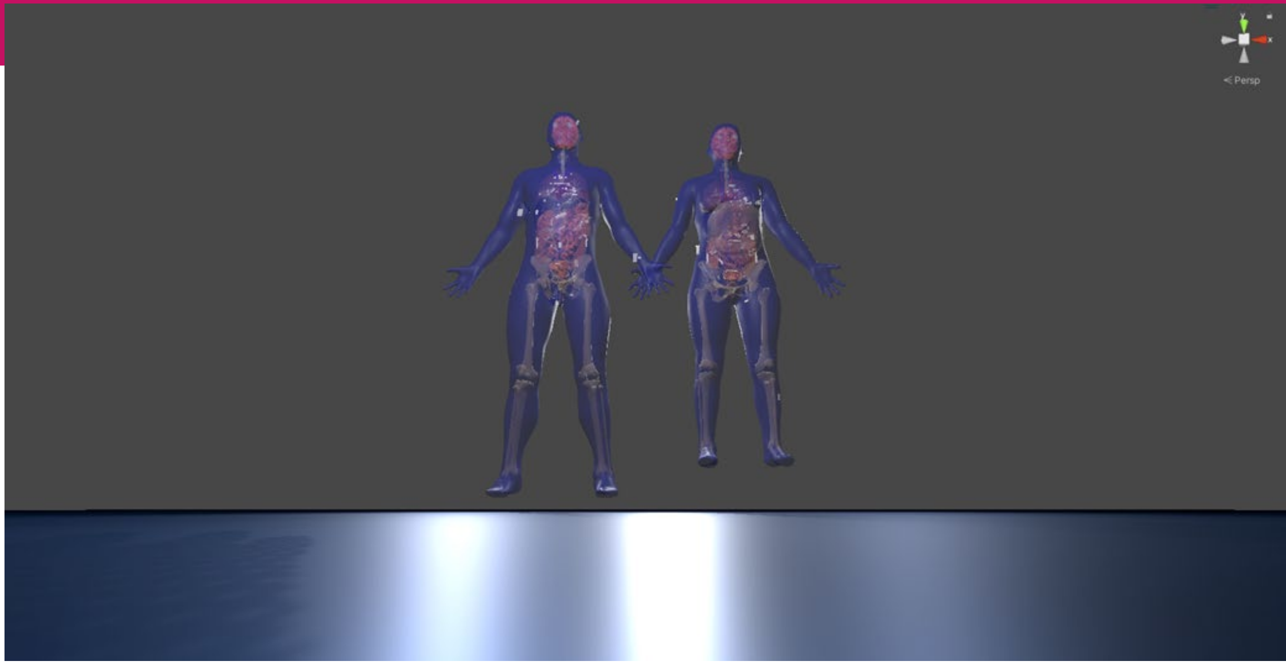


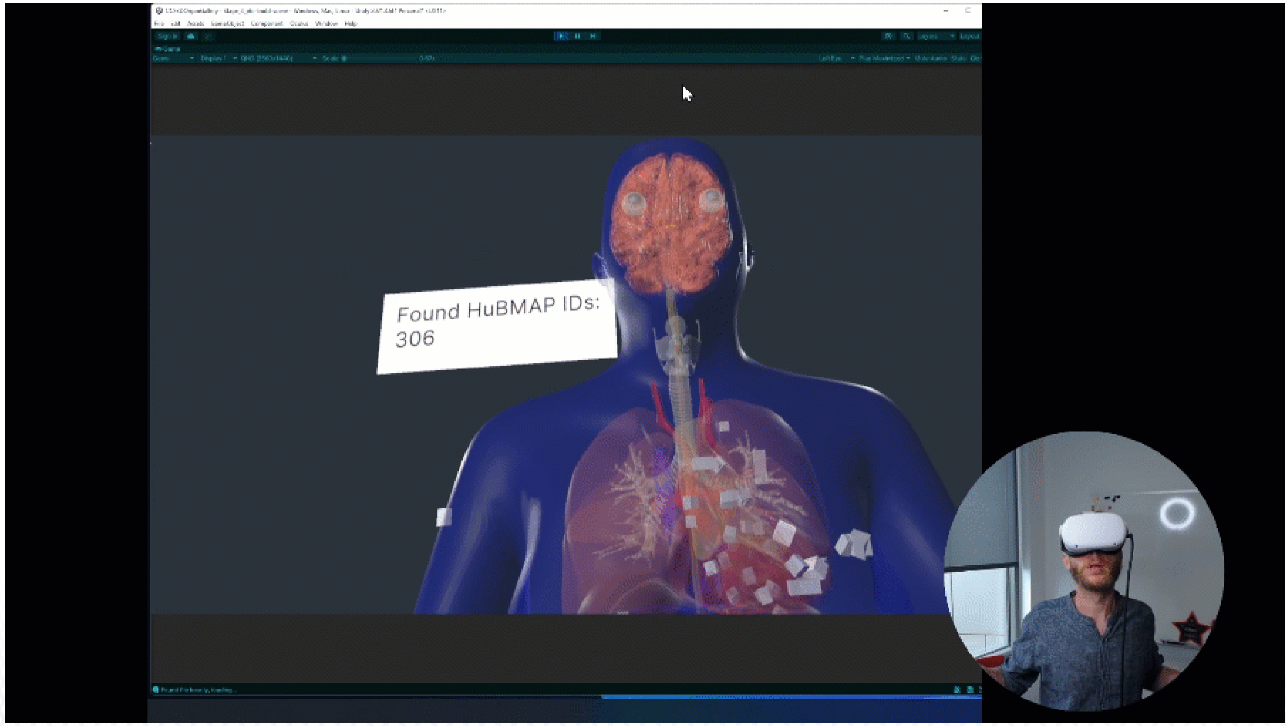
Project 2: The Common Coordinate Framework (CCF) Organ VR Gallery

Also called the “Human Reference Atlas in 3D VR”

The CCF Organ VR Gallery

- Human BioMolecular Atlas Program (HuBMAP) and other single-cell mapping efforts
- Integrates 3 data types for human tissue:
  - **Spatial**
  - **Biological structure**
  - Specimen/clinical metadata (not covered in this talk)
- Code: https://github.com/cns-iu/ccf-organ-vr-gallery
- Preprint: Bueckle, Andreas, Kristen M Browne, Bruce W Herr II, and Katy Börner. “The Common Coordinate Framework (CCF) Organ VR Gallery.” OSF, January 12, 2022. https://doi.org/10.31219/osf.io/z9gm3.



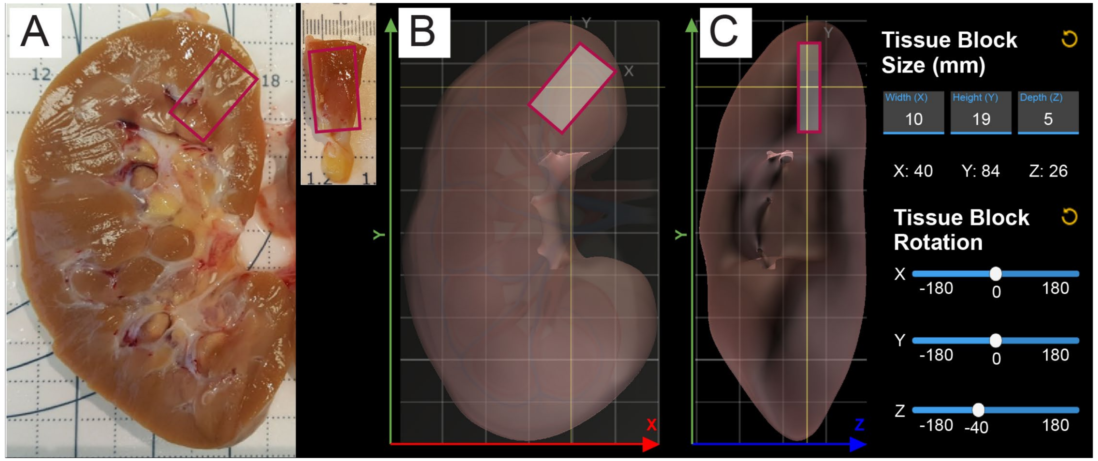


Spatial Data

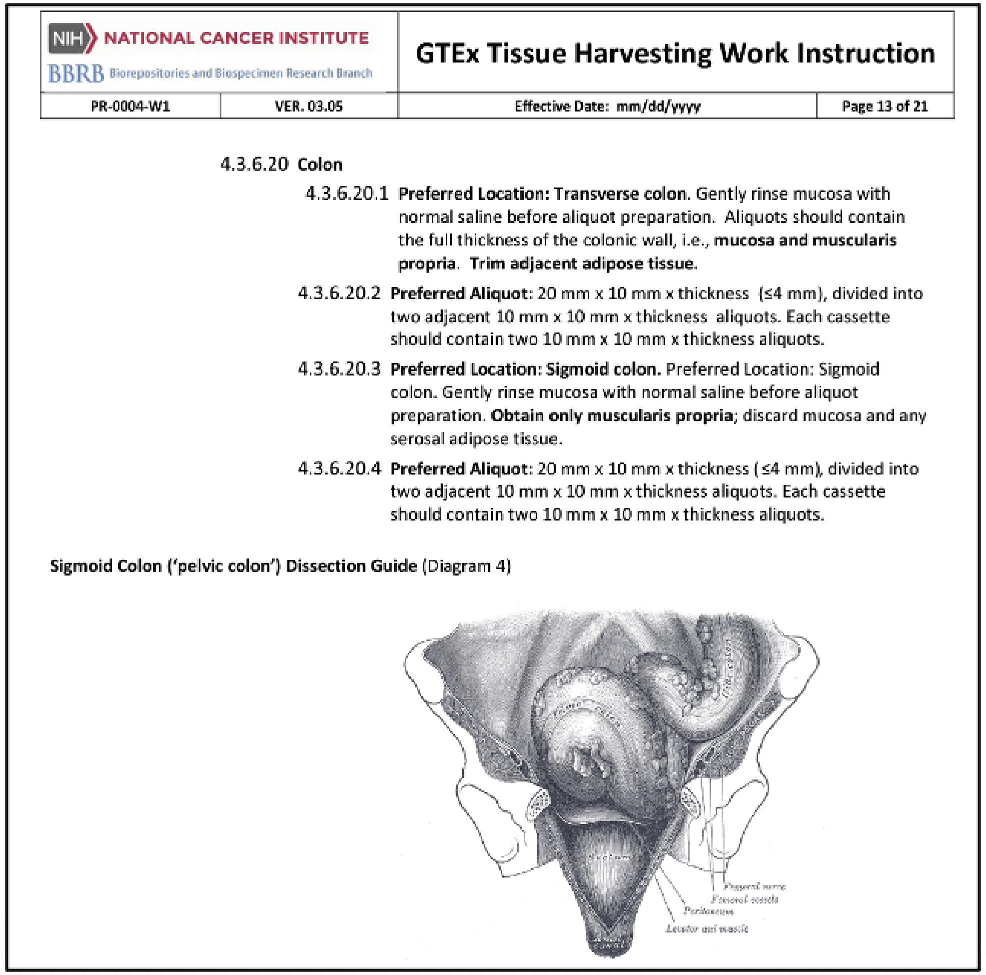
Warning: graphical image of a kidney coming up!

The Meat of the Matter

- Documenting tissue extraction sites is non-trivial
- Photos of reference organs (if available) on cutting boards with spatial markers
- We used the Visible Human male, left kidney (100 mm high, 60 mm wide, 40 mm deep)
- Spitzer, V., M. J. Ackerman, A. L. Scherzinger, and D. Whitlock. “The Visible Human Male: A Technical Report.” *Journal of the American Medical Informatics Association* 3, no. 2 (March 1996): 118–30. https://doi.org/10.1136/jamia.1996.96236280.



Mapping to the CCF



NIH NATIONAL CANCER INSTITUTE
BBRB Biorepositories and Biospecimen Research Branch

GTEx Tissue Harvesting Work Instruction

PR-0004-W1	VER. 03.05	Effective Date: mm/dd/yyyy	Page 13 of 21

4.3.6.20 Colon

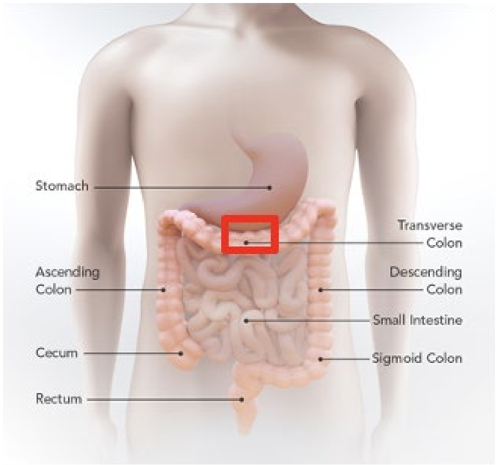
4.3.6.20.1 **Preferred Location: Transverse colon**. Gently rinse mucosa with normal saline before aliquot preparation. Aliquots should contain the full thickness of the colonic wall, i.e., **mucosa and muscularis propria**. **Trim adjacent adipose tissue.**

4.3.6.20.2 **Preferred Aliquot:** 20 mm x 10 mm x thickness (≤4 mm), divided into two adjacent 10 mm x 10 mm x thickness aliquots. Each cassette should contain two 10 mm x 10 mm x thickness aliquots.

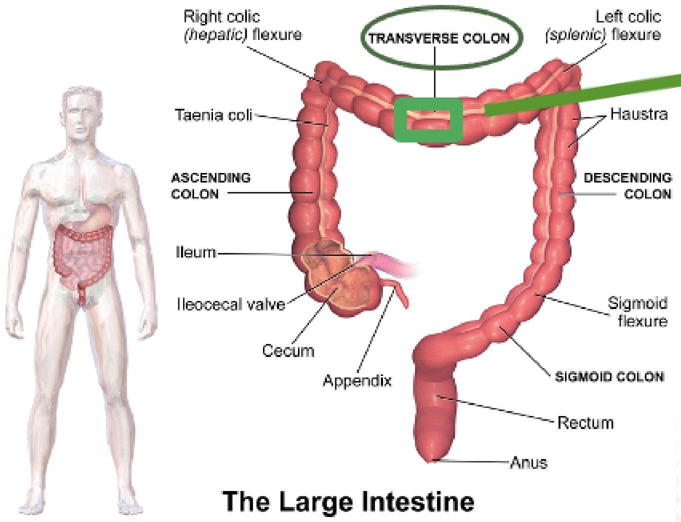
4.3.6.20.3 **Preferred Location: Sigmoid colon.** Preferred Location: Sigmoid colon. Gently rinse mucosa with normal saline before aliquot preparation. **Obtain only muscularis propria**; discard mucosa and any serosal adipose tissue.

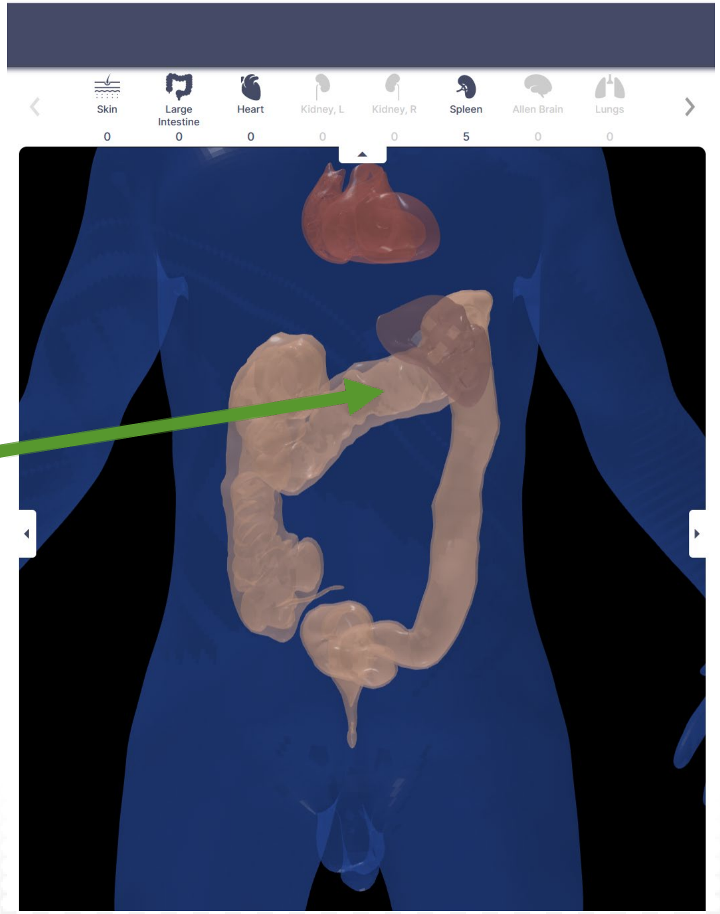
4.3.6.20.4 **Preferred Aliquot:** 20 mm x 10 mm x thickness (≤4 mm), divided into two adjacent 10 mm x 10 mm x thickness aliquots. Each cassette should contain two 10 mm x 10 mm x thickness aliquots.

Sigmoid Colon ('pelvic colon') Dissection Guide (Diagram 4)



Recover the transverse colon starting 10 cm back from the right colic (hepatic) flexure.





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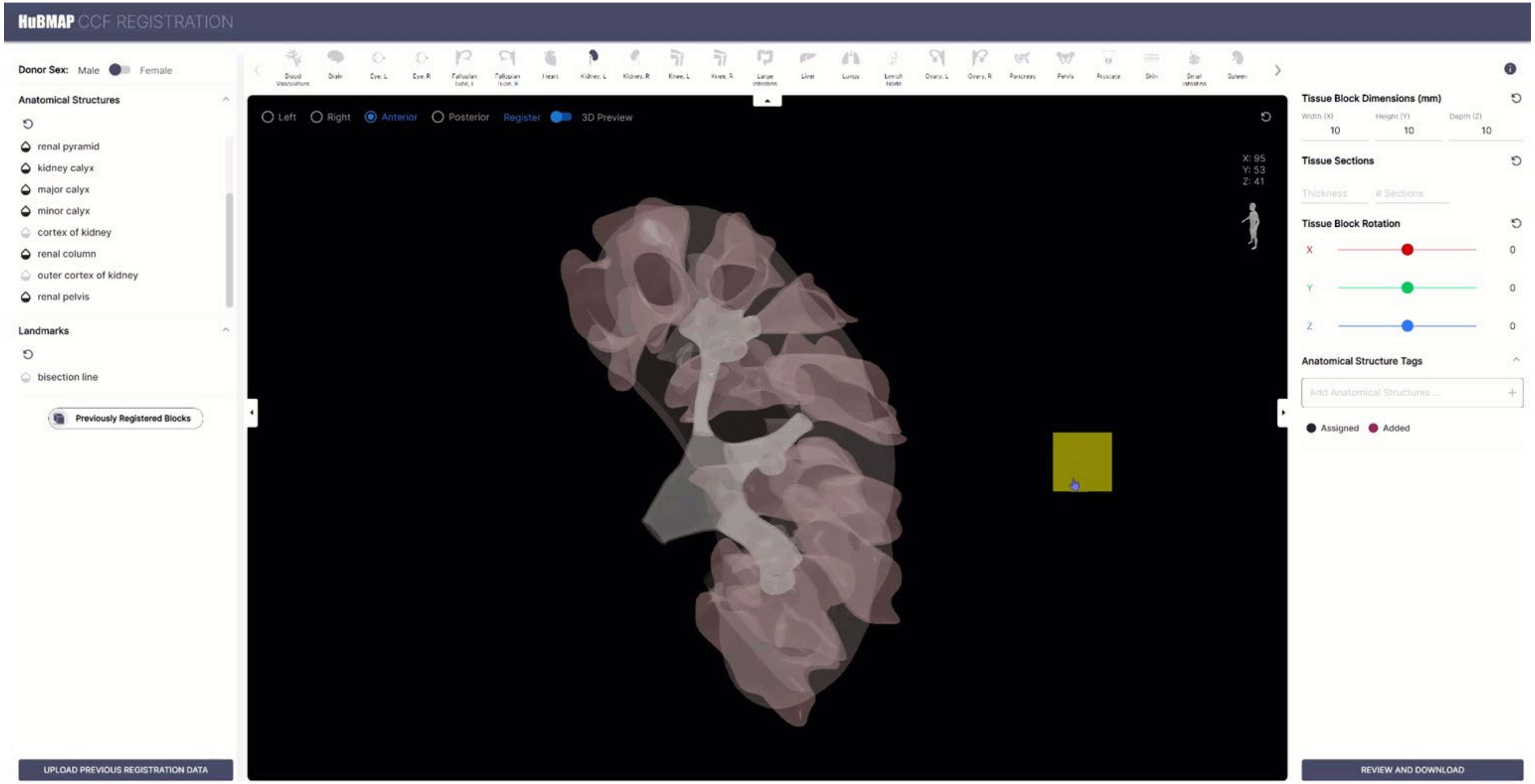
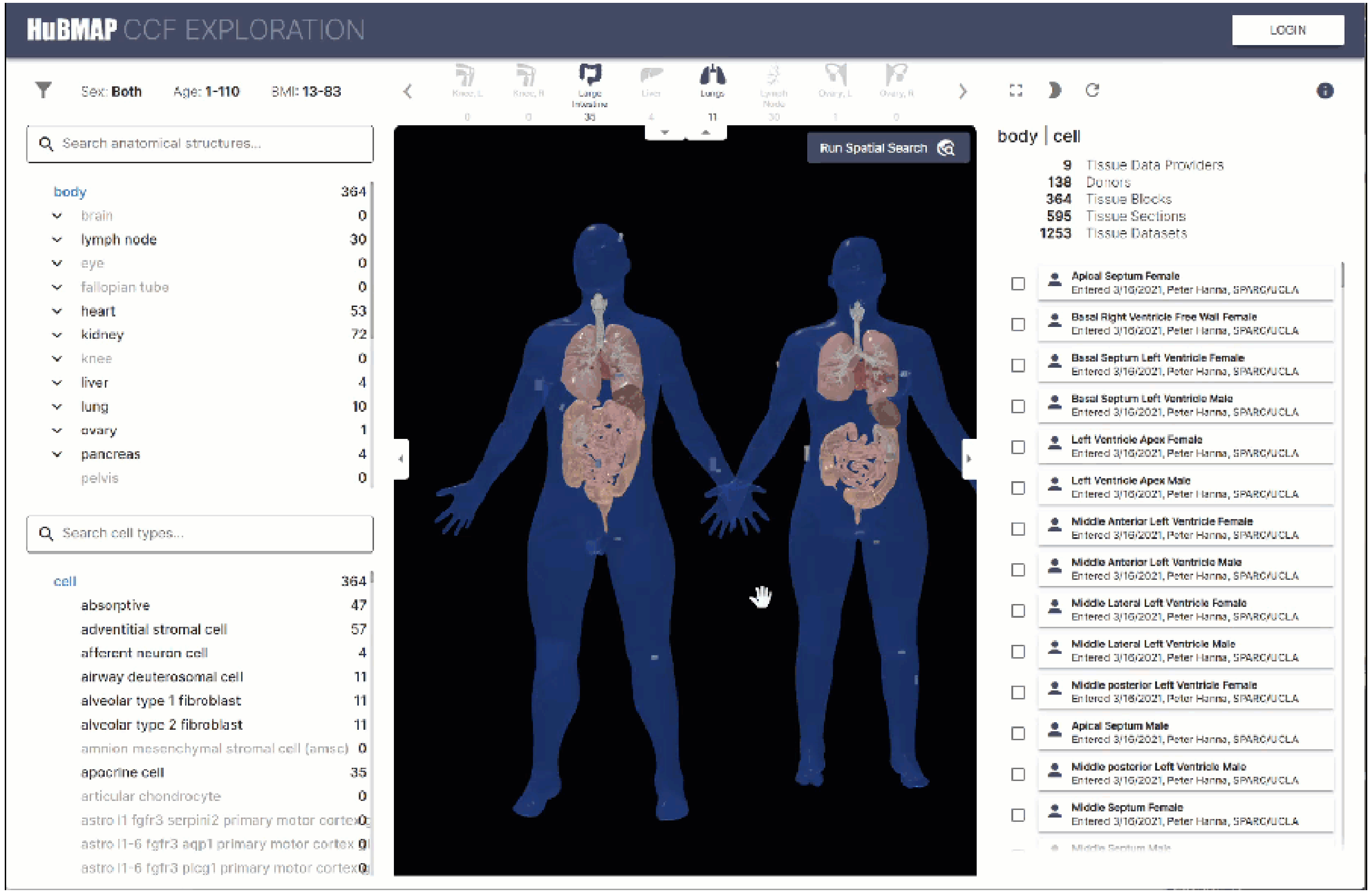
CCF Registration User Interface (RUI)



https://hubmapconsortium.github.io/ccf-ui/rui/

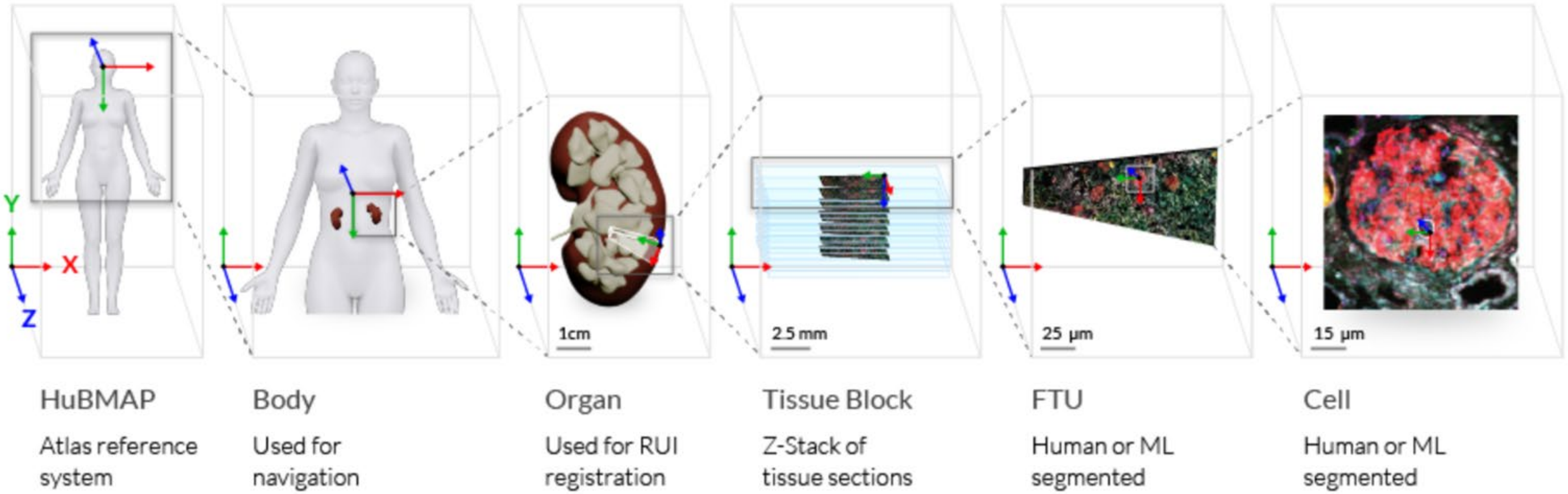
CCF Exploration User Interface (EUI)



https://portal.hubmapconsortium.org/ccf-eui

CCF

Allows us to 3D register tissue and explore tissue blocks spatially and semantically across macro-, meso-, and micro-scale.



Biological Structure

Linked Open Data (LOD)

Anatomical Structure, Cell Type, Plus Biomarker (ASCT+B) Table

Background–Structuring Knowledge: What does an ASCT+B Table Do?

Unstructured knowledge sources ~80% of biomedical knowledge

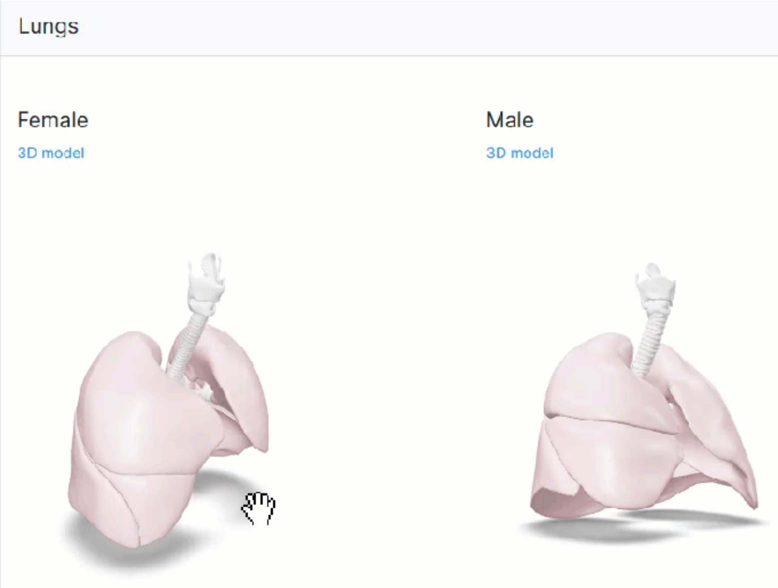
→ Standardize how information is captured, formatted, labeled

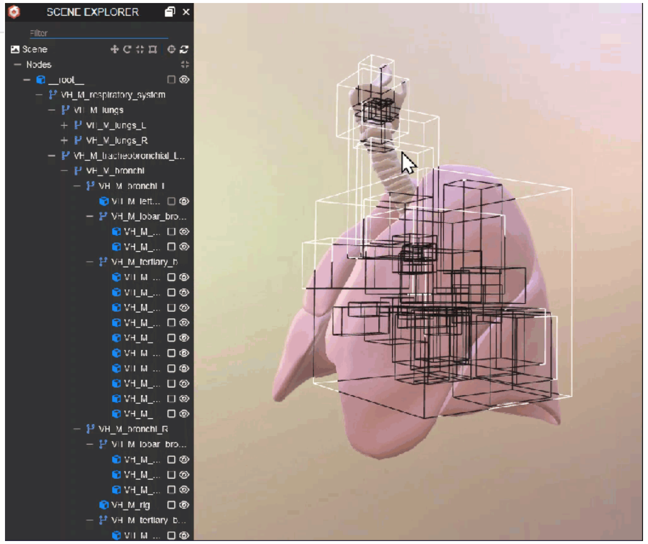
→ Knowledge about organs, anatomical structures, cell types, biomarker sets that uniquely define cell types

→ Ontologies like the multi-species Uber Anatomy (Uberon) and Cell Ontology (CL) capture nomenclature, synonyms, descriptions, relationships between entities, provenance for knowledge, assigns unique ID for this unit of knowledge

Structured knowledge unifies nomenclature that describes datasets so we are all speaking in the same language

Tie to Spatial Data: 3D Reference Models

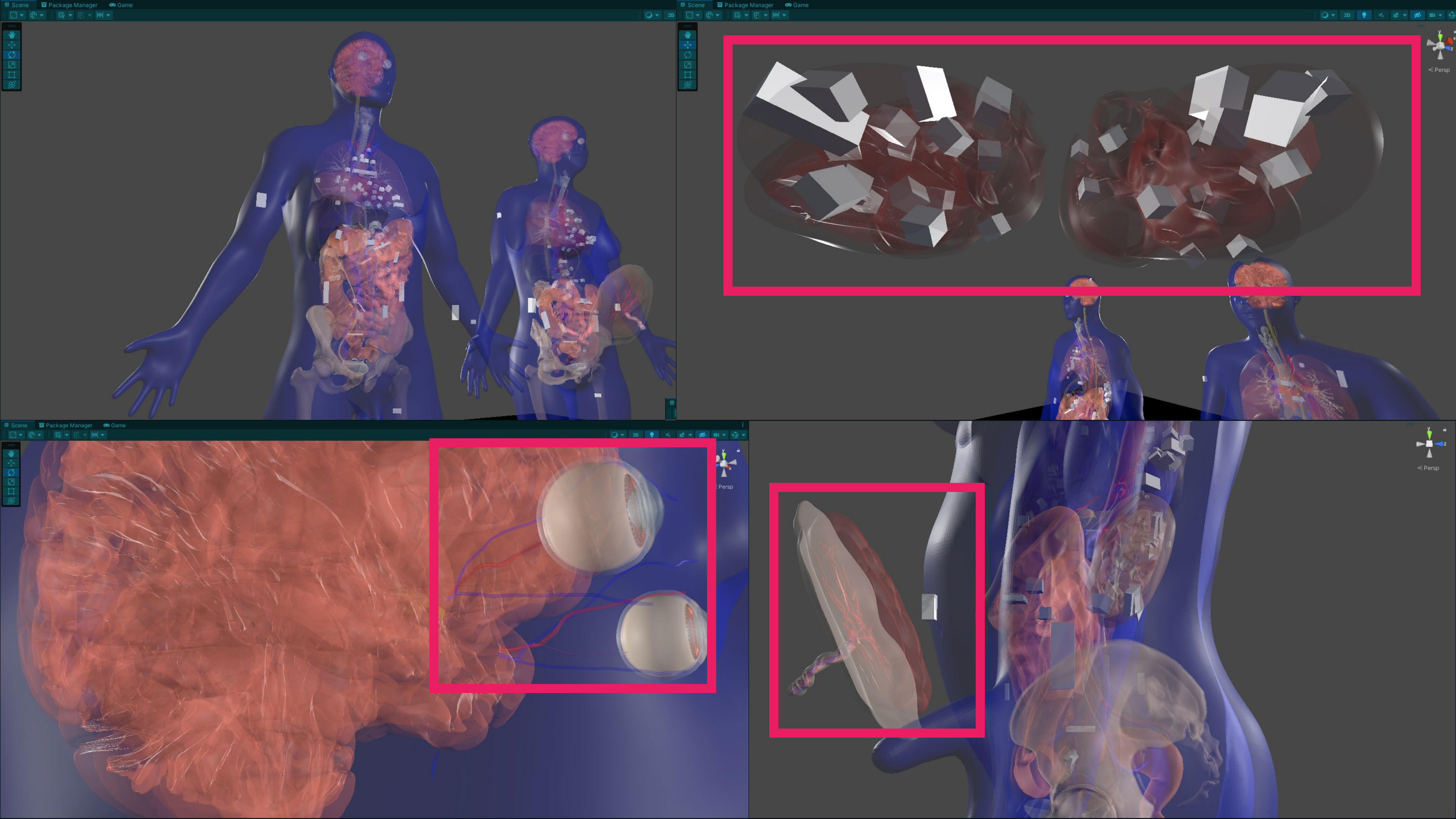


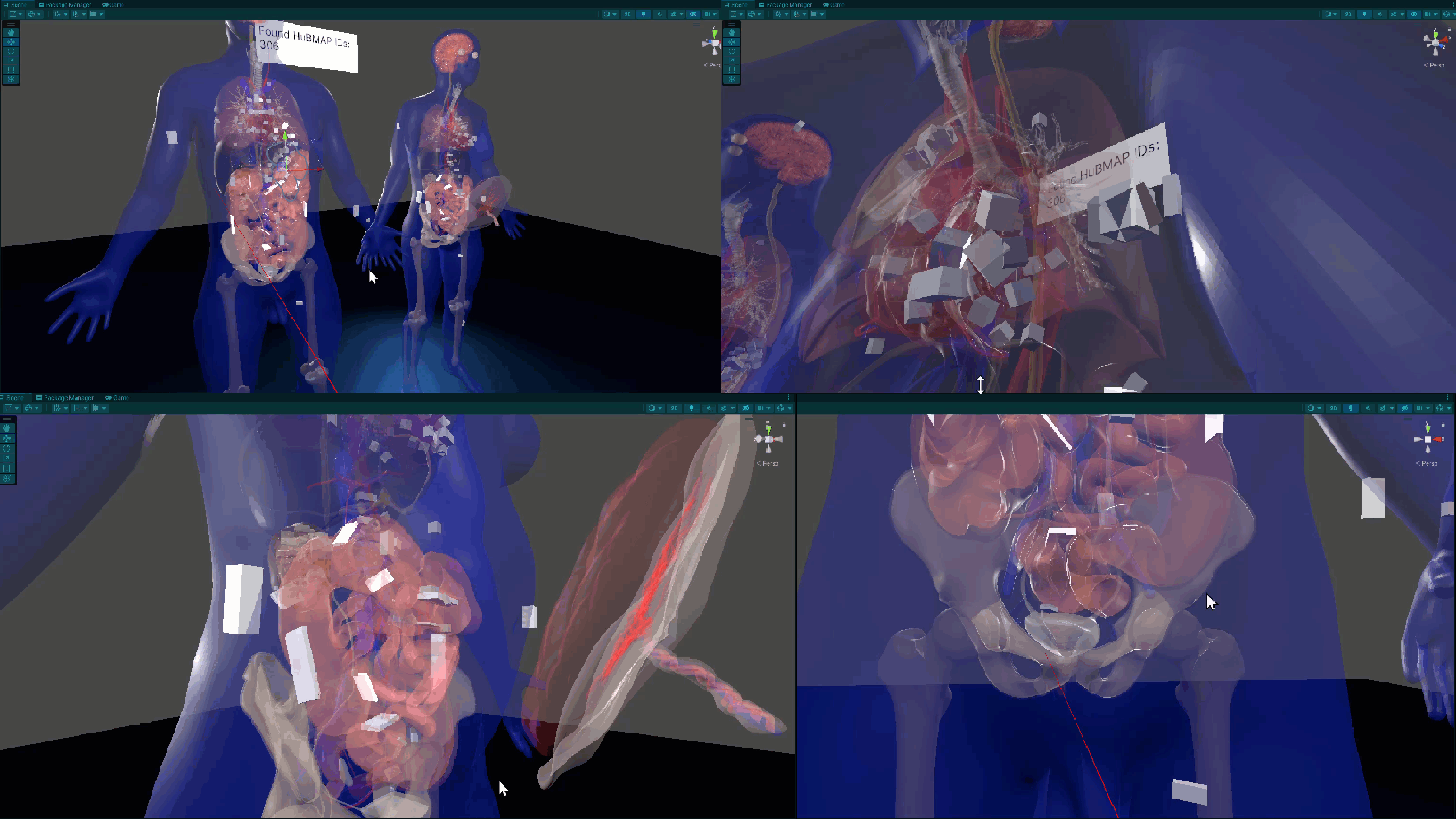


https://hubmapconsortium.github.io/ccf/pages/ccf-3d-reference-library.html

- Custom built by our medical illustrator team with input from subject matter experts
- Support the RUI, EUI, and CCF Organ VR Gallery
- Anatomical structures labeled with ontology IDs

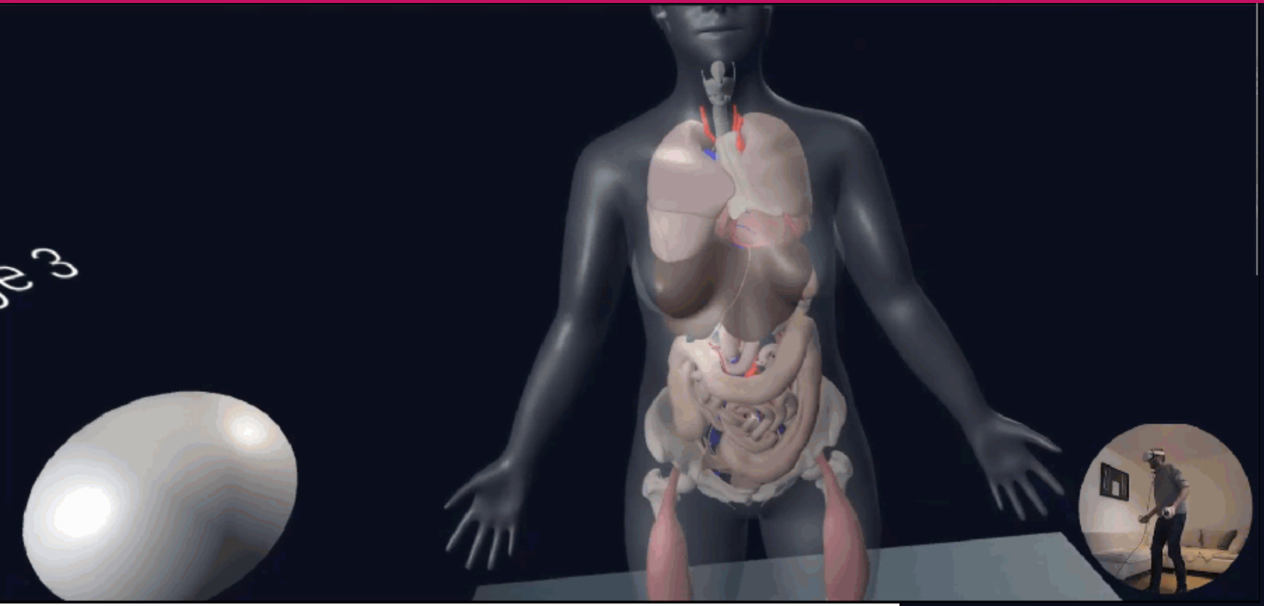
A Closer Look at the Gallery

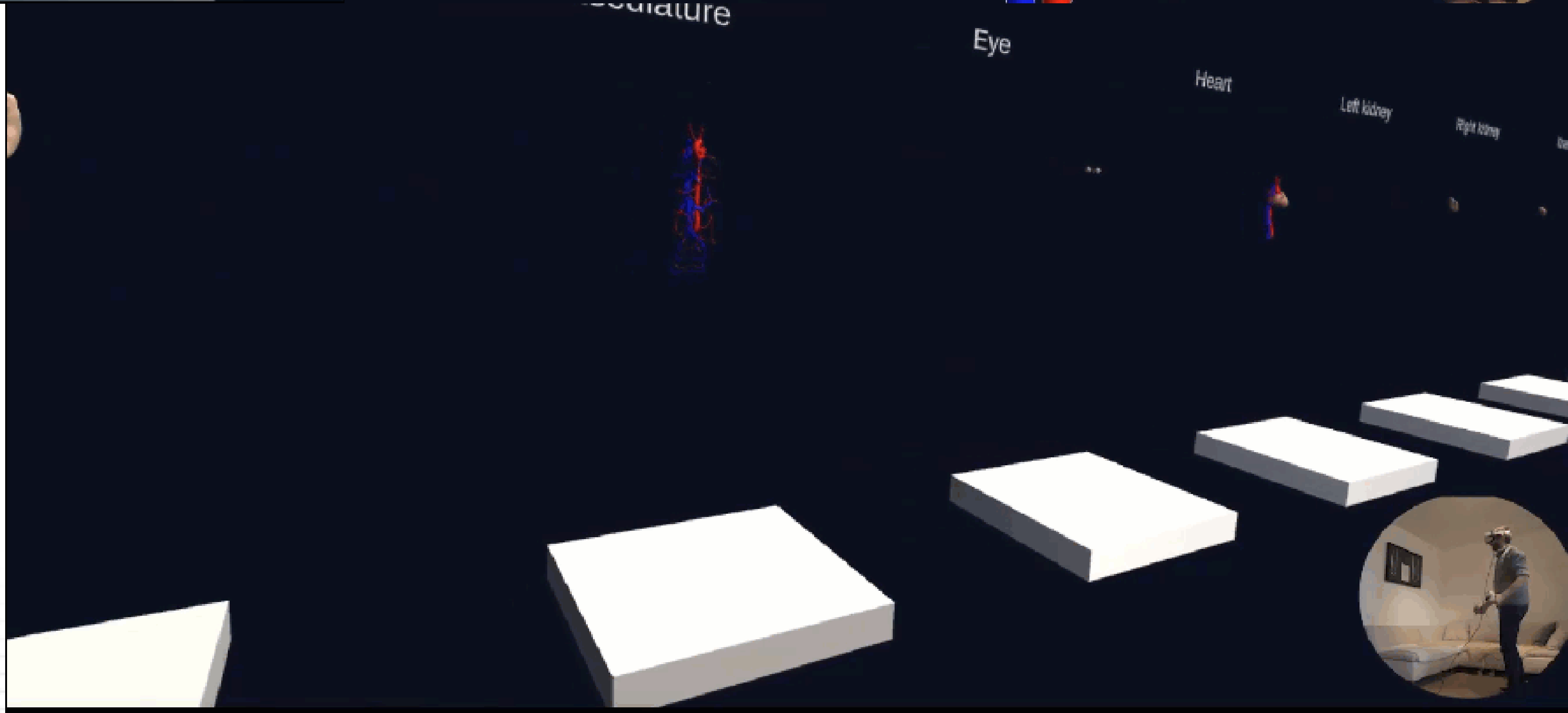

Scene
Package Manager
Game
2D
Persp



Found HuBMAP IDs:
306
Found HuBMAP IDs:
306

CNS Cyberinfrastructure Network Science C





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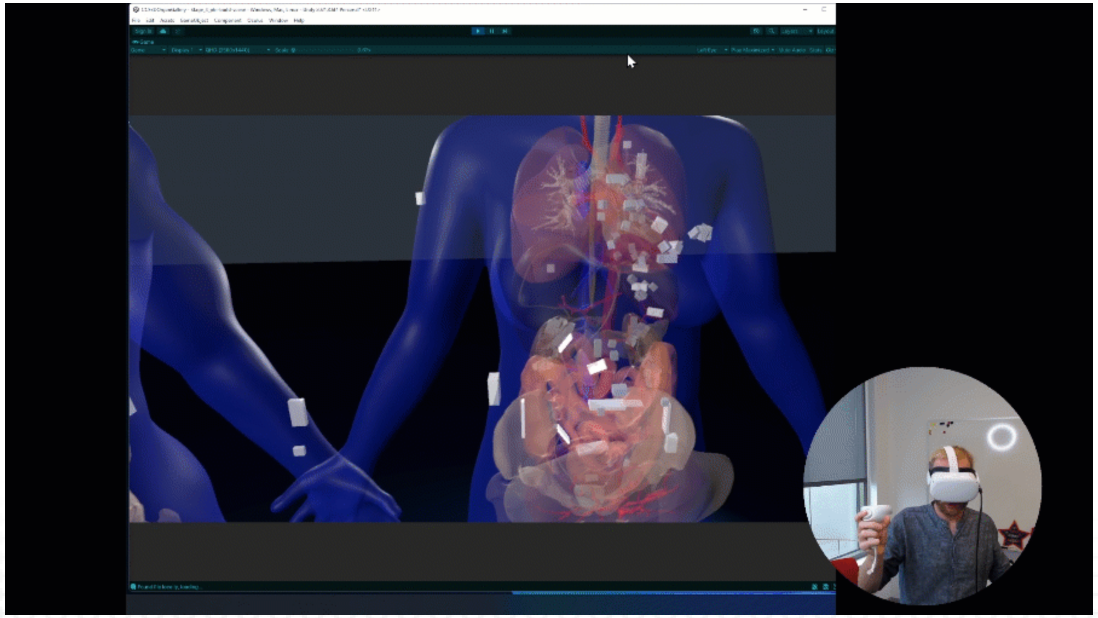
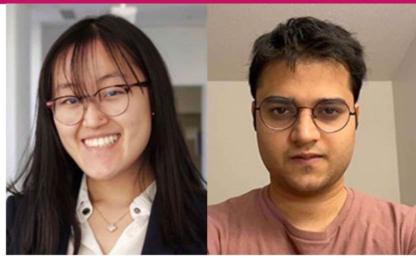
Conclusion

- VR + data visualization = superpower
- Challenges:
  - Perception
  - Complexity
  - Use cases
  - AR hardware
- Information-Rich Virtual Environments in VR
- Integrate spatial and abstract data in one continuous immersive environment



Become a Tester!



- Documentation: https://www.figma.com/file/TopdFvriKNcV9Af2Hgo8aK/Documentation-Organ?node-id=0%3A1
- Feedback: https://forms.gle/wnGnZLyDvU9MEs5o8
- Meta Quest 2 setup (general introduction): https://www.figma.com/file/0MgWkoPyuWLWb8esFsYya5/CNS-Documentation?node-id=0%3A1
- GitHub issues: https://github.com/cns-iu/ccf-organ-vr-gallery/issues
- Please contact Andreas Bueckle at abueckle@iu.edu!

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