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MRMAC : Mixed Reality Multi-user Asymmetric Collaboration


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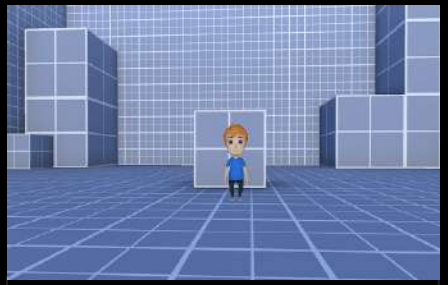
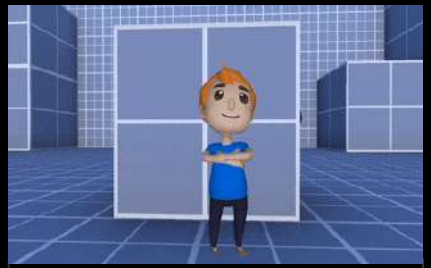
IEEE COMPUTER SOCIETY IEEE vgtc

Collaborative Tools



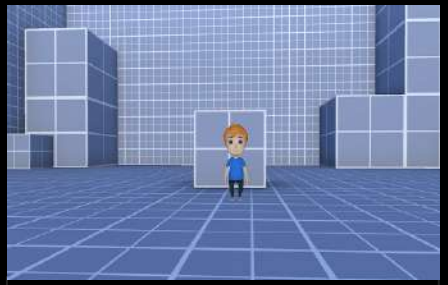
Limited Field of view

Barely see others' body language & gaze



Fixed viewpoint

Collaborative Tools



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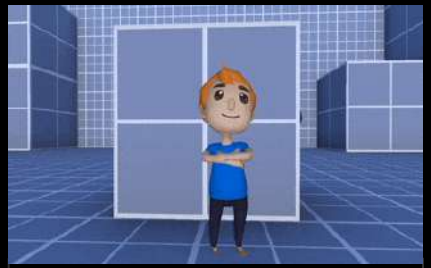
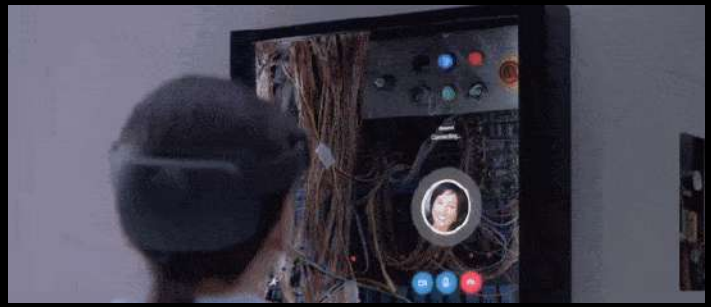


Fixed viewpoint

Collaborative XR Tools

Project starline, *Lawrence et al. 2021*

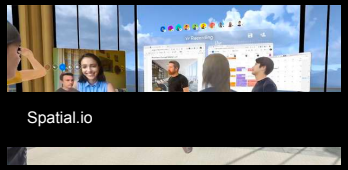


Microsoft Remote Assist

Spatial.io

Microsoft Mesh

Collaborative XR Tools



Spatial.io

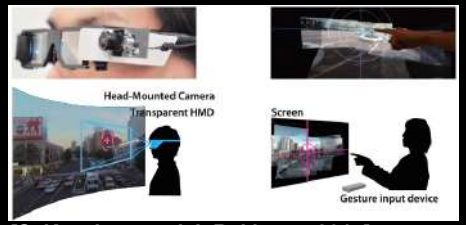
Project starline, *Lawrence et al. 2021*

Microsoft Remote Assist

Microsoft Mesh

?

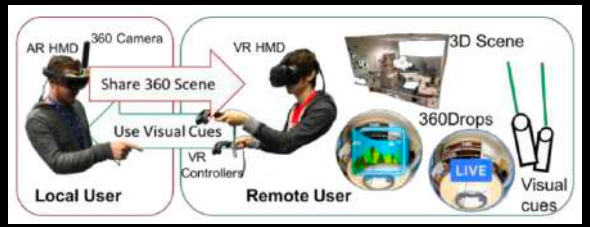
Related Work



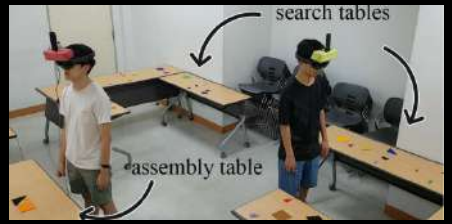
[S. Kasahara and J. Rekimoto 2014]

[S. Nagai et al. 2015]

[Lee et al. 2017]



[Teo et al. 2017]



[Lee et al. 2020]

[Rhee et al. 2020]

Only One-One & One-Many

No Audio-Visual Sync

Contributions

Mixed Reality Multi-user Asymmetric Collaboration (MRMAC) system that enables multiple remote users to virtually teleport into a real-world task space to collaborate with local users.

MRMAC

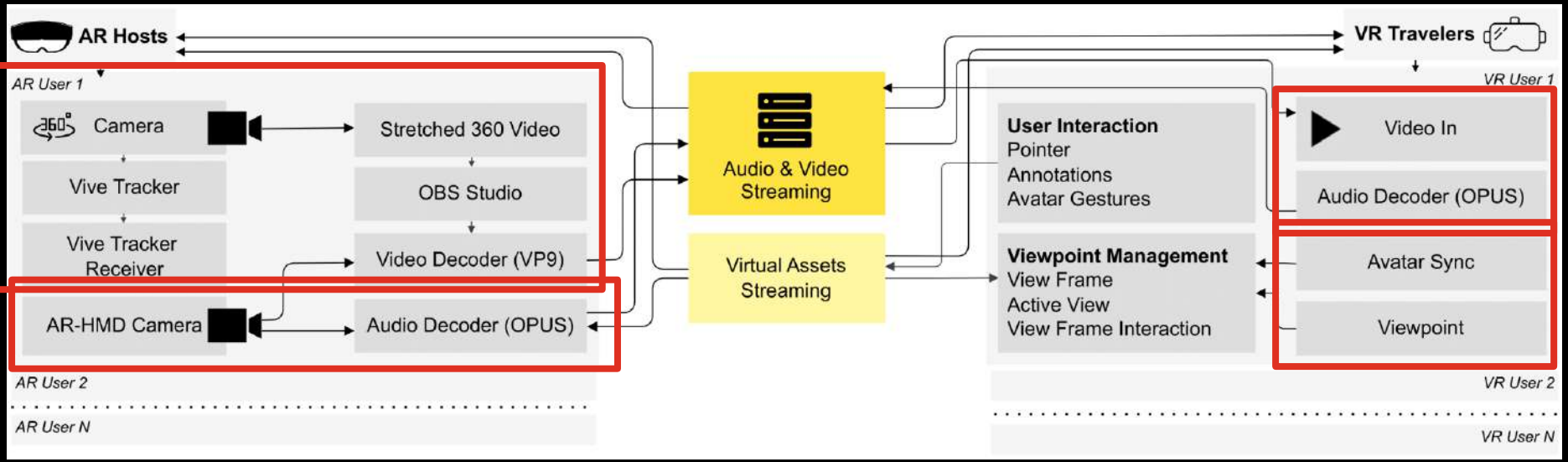
Design & Implementation

- Design concept for multi-user asymmetric remote collaboration
- Bidirectional face-to-face communication
- Synchronised audio-visual communication
- Client-server architecture for avatars, view controls, and asset streaming

Evaluation

- System evaluation
  - scalability and latency
- User evaluation
  - communication and awareness
  - compared against two baseline conditions

Architecture

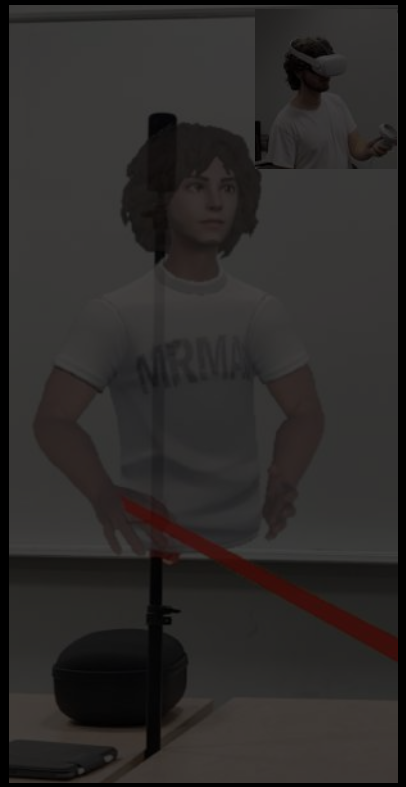


Communication Cues

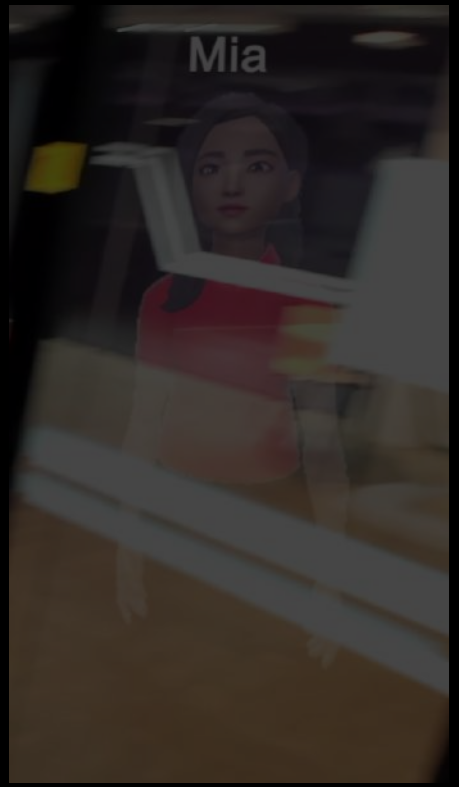
Viewpoint Sharing

Multiple Avatar Control

Personalised Avatar



Spatial Audio



Communication Cues

Viewpoint Sharing

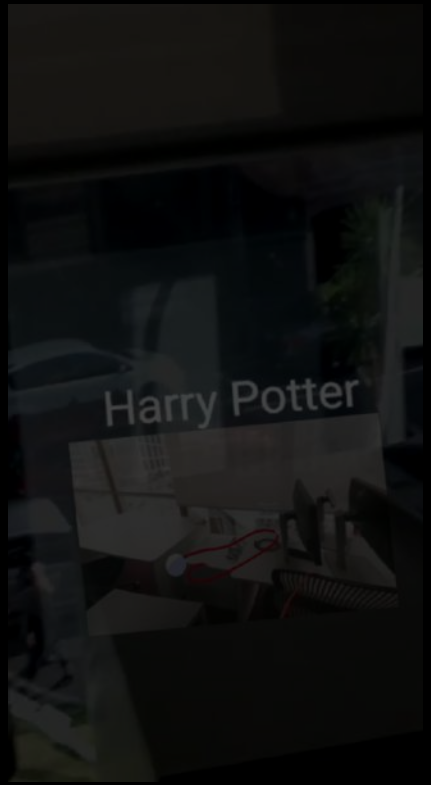
Vicarious: Context-aware Viewpoints Selection for Mixed Reality Collaboration

Faisal Zaman, Craig Anslow, Taehyun Rhee

F. Zaman, C. Anslow, T. Rhee. **Vicarious: Context-aware Viewpoints Selection for Mixed Reality Collaboration**. ACM VRST, 2023.

Communication Cues

Viewpoint Sharing



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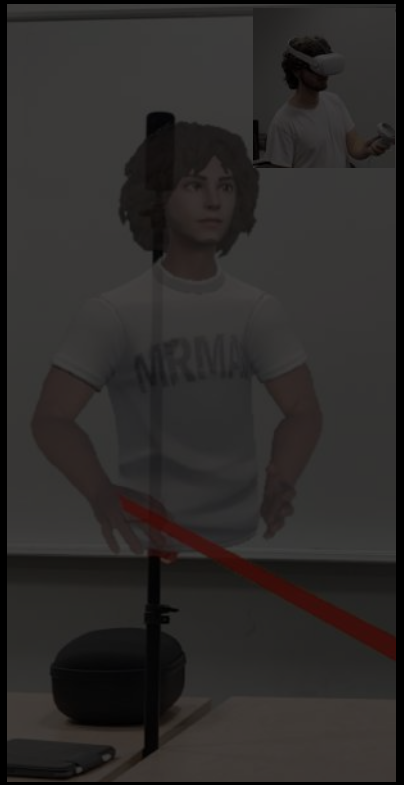

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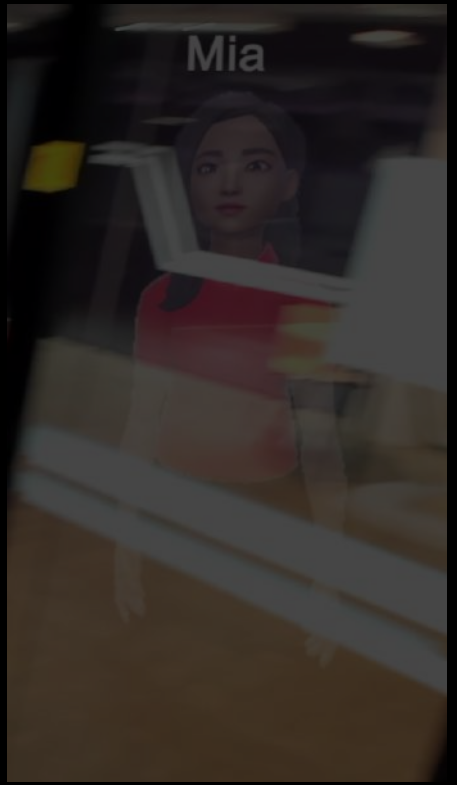

Communication Cues

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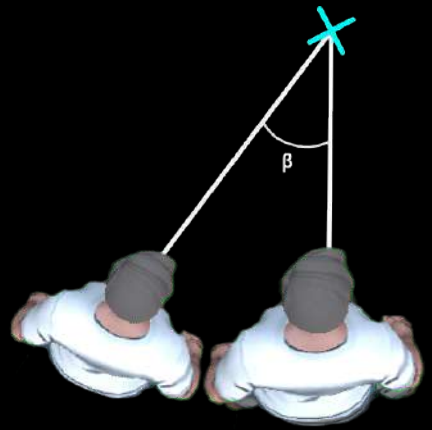

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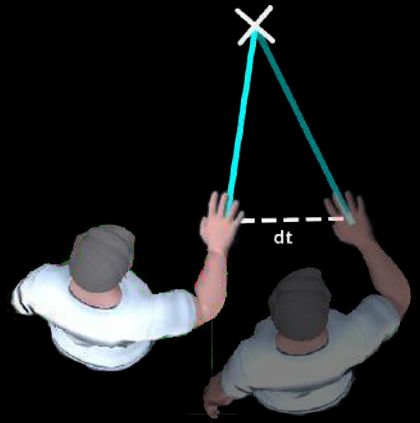

Communication Cues

Multiple Avatar Control

Communication Cues

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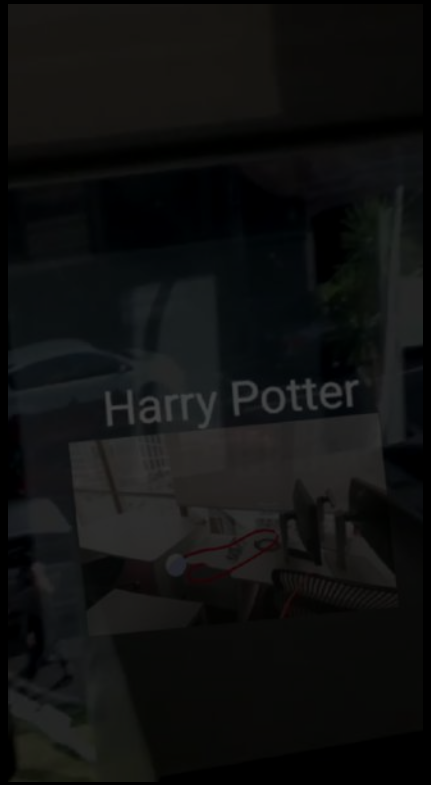

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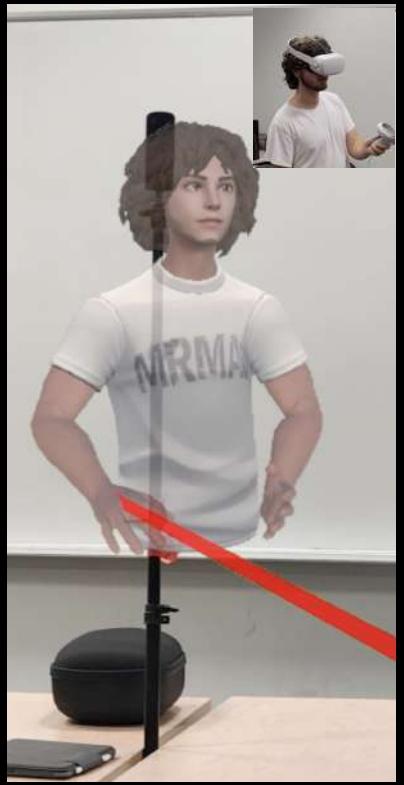
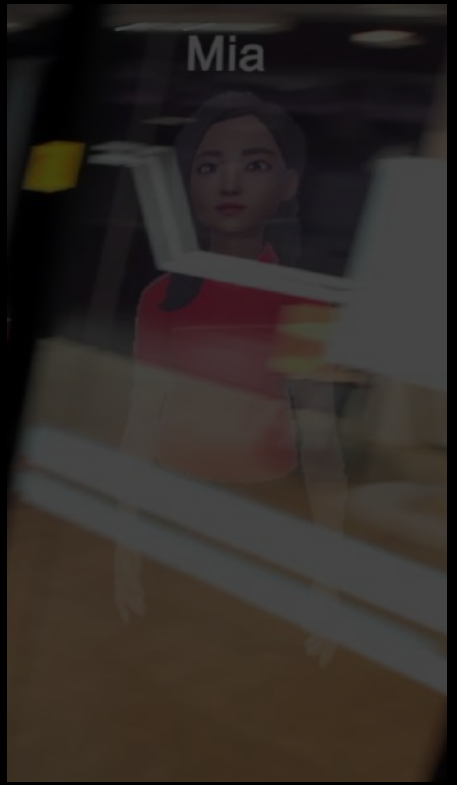
Personalised Avatar



Spatial Audio



Communication Cues

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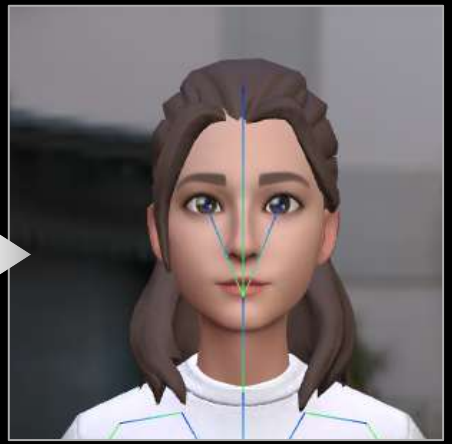
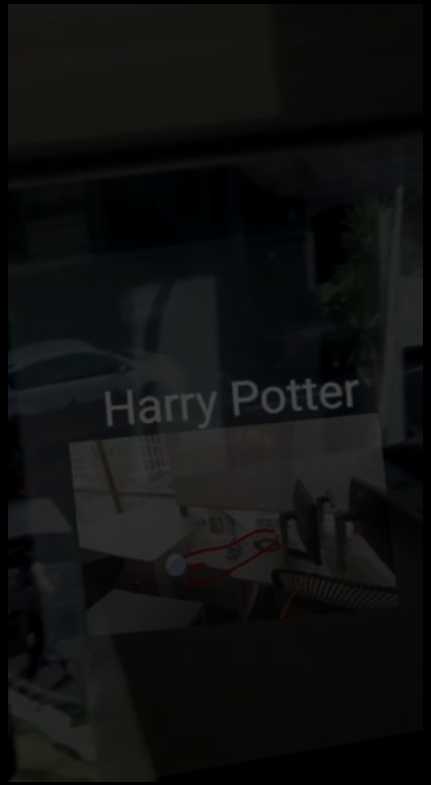


READY PLAYER ME

HEADSHOT 2

Communication Cues

Viewpoint Sharing



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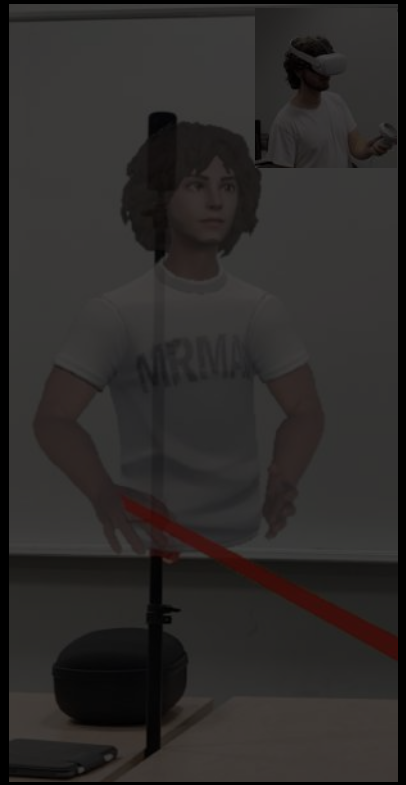
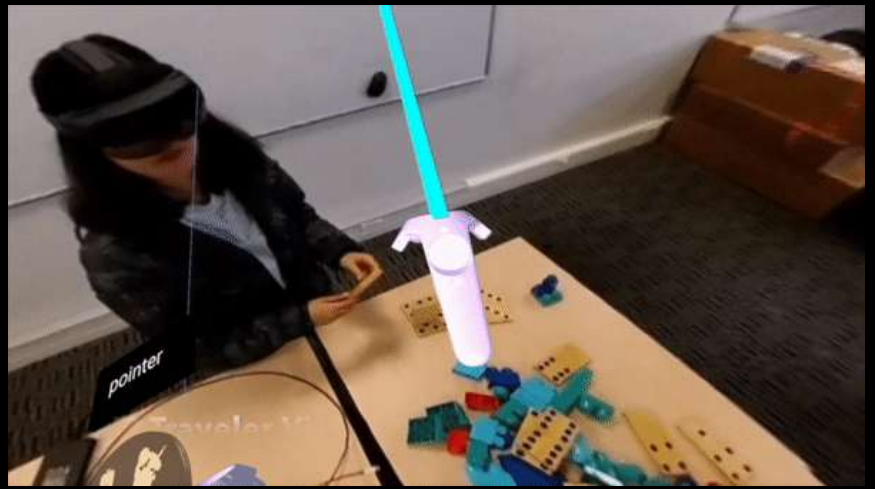


Spatial Audio

Interaction Cues

3D Pointer



Annotation

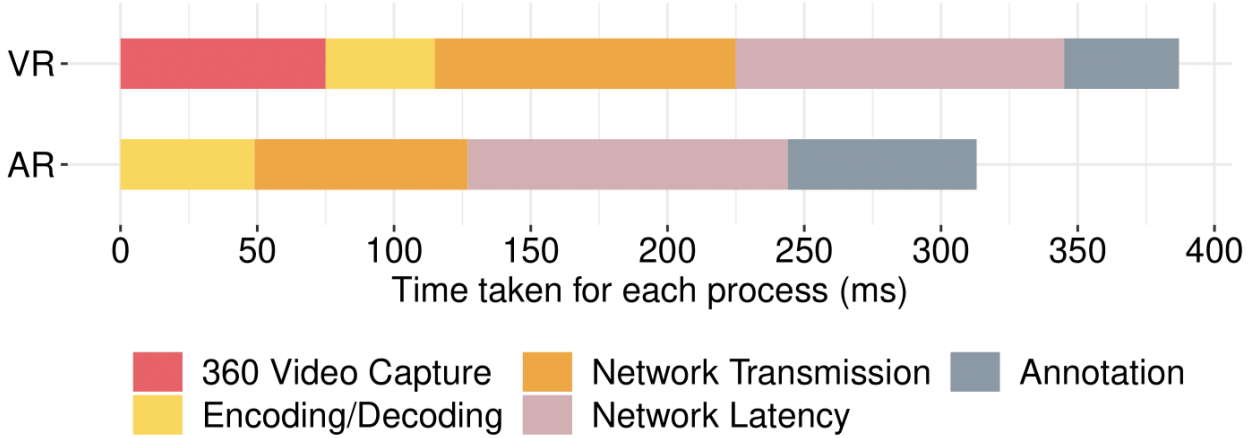
evaluation

Evaluation

System Evaluation: Latency

Average end-to-end latency

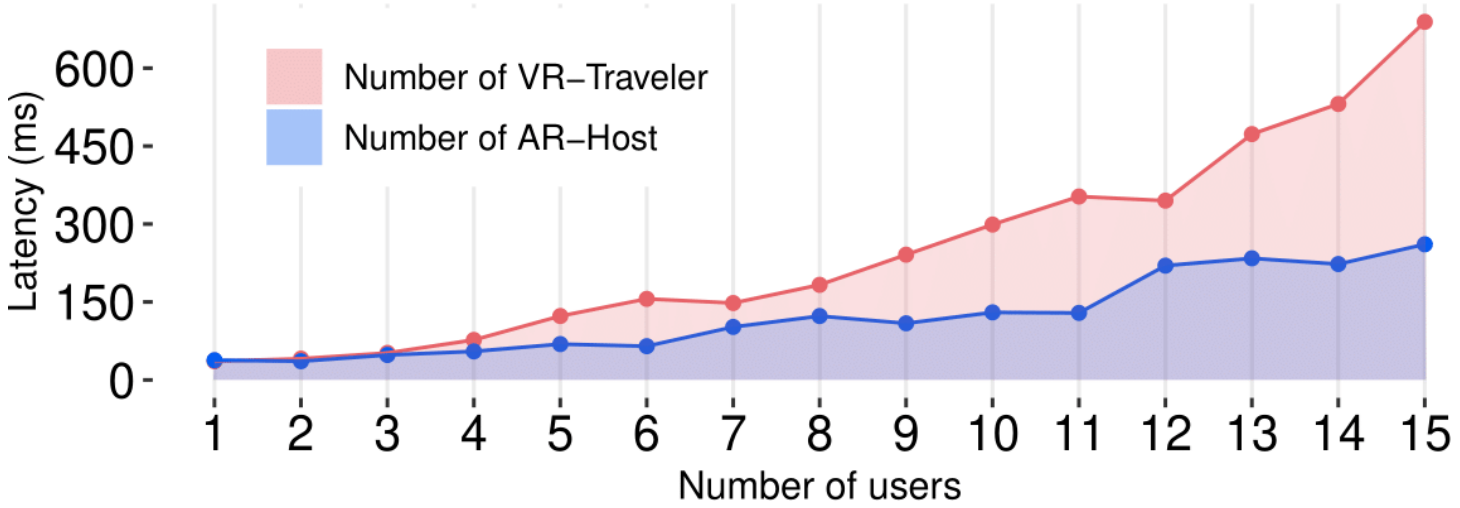
- Changes in the 360-degree video to show up on the local computer and in the VR/AR window.



System Evaluation: Scalability

Network latency as the number of users increases

- average frame rate = video streaming 30FPS
- audio streaming 44.1kHz
- rendering time of 60±10 FPS.



User Evaluation

36 participants

18—81 years
μ = 30.83, σ = 14.10

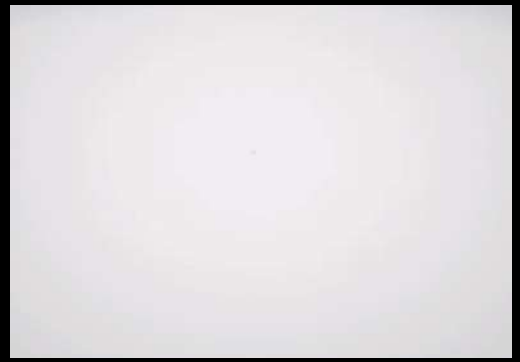
3×2 mixed factorial design

between-subjects factor:
local vs. remote

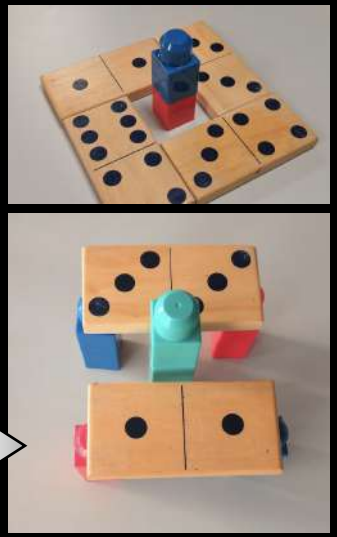
within-subjects factor:
C1 vs. C2 vs. C3

VR Users

AR Users



Virtual replica



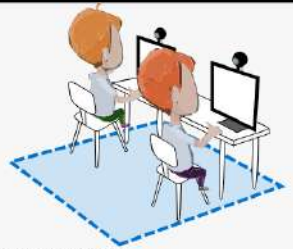
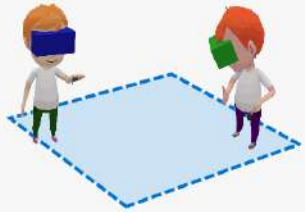
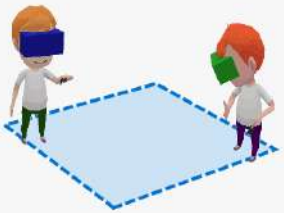
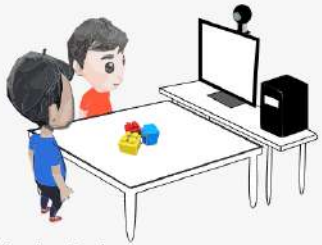
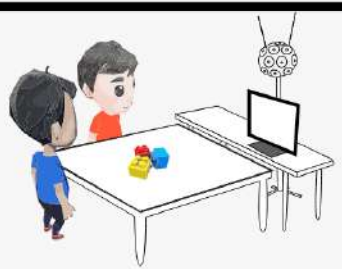
Physical model

User Evaluation

3×2 mixed factorial design

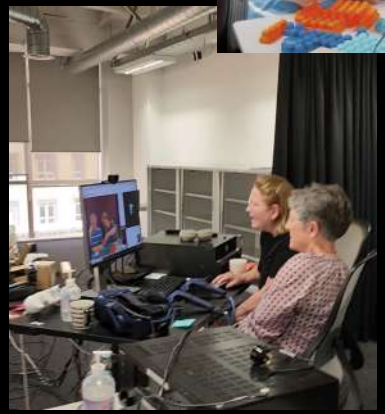
between-subjects factor:
local vs. remote

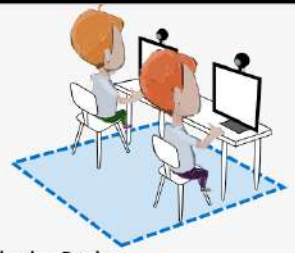
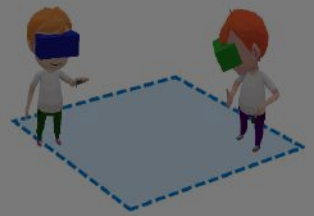
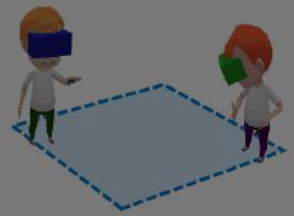
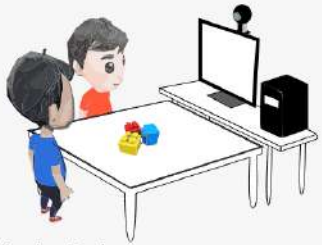
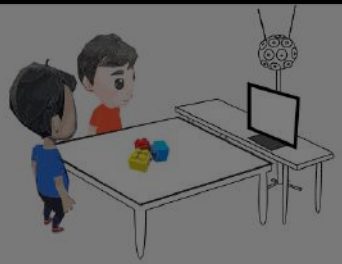
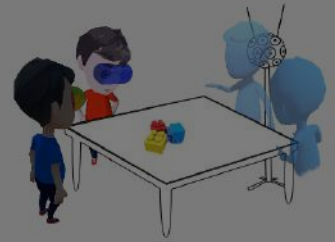
within-subjects factor:
C1 vs. C2 vs. C3

	1 Condition 1 Conventional video with 2D annotation	2 Condition 2 360 Video without augmented visual cues	3 Condition 3 360 video with augmented visual cues
VR-Travelers			
	Viewing Device: Desktop Monitor **Camera control:** N/A **Interaction:** Mouse for 2D Annotation **Representation:** Appears in 2D video	VR HMD (Viewing 360 Video) Camera Control by VR HMD N/A No Visual, Voice Only	VR HMD (Viewing 360 Video) Camera Control by VR HMD VR Controller 3D Avatar
AR-Hosts			
	Viewing Device: Desktop Monitor **Camera control:** N/A **Interaction:** N/A **Representation:** Appears in 2D video	Desktop Monitor N/A N/A Appears in 360-degree Video	AR HMD N/A N/A Appears in 360-degree Video

User Evaluation

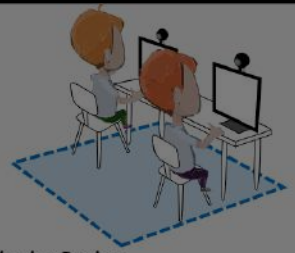
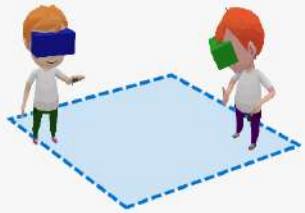
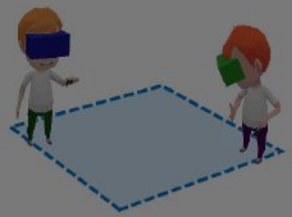
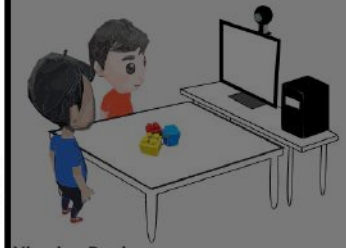
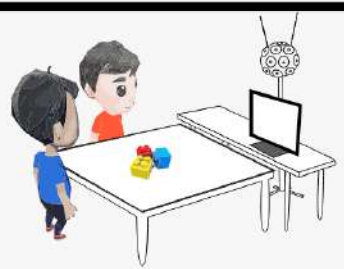
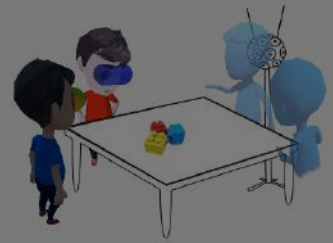
Condition 1



	1 Condition 1 Conventional video with 2D annotation	2 Condition 2 360 Video without augmented visual cues	3 Condition 3 360 video with augmented visual cues
VR-Travelers	 **Viewing Device:** Desktop Monitor **Camera control:** N/A **Interaction:** Mouse for 2D Annotation **Representation:** Appears in 2D video	 VR HMD (Viewing 360 Video) Camera Control by VR HMD N/A No Visual, Voice Only	 VR HMD (Viewing 360 Video) Camera Control by VR HMD VR Controller 3D Avatar
AR-Hosts	 **Viewing Device:** Desktop Monitor **Camera control:** N/A **Interaction:** N/A **Representation:** Appears in 2D video	 Desktop Monitor N/A N/A Appears in 360-degree Video	 AR HMD N/A N/A Appears in 360-degree Video

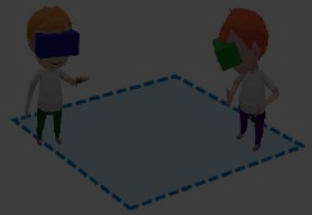
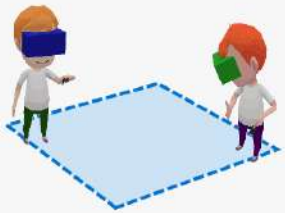
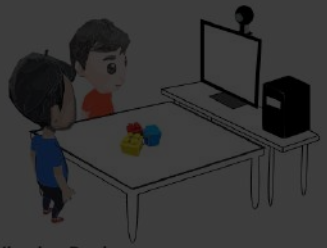
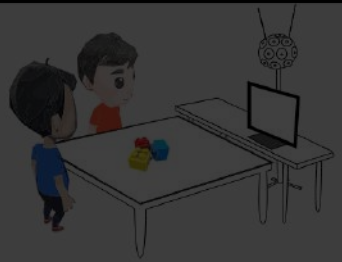
User Evaluation

Condition 2

	1 Condition 1 Conventional video with 2D annotation	2 Condition 2 360 Video without augmented visual cues	3 Condition 3 360 video with augmented visual cues
VR-Travelers			
	Viewing Device: Desktop Monitor **Camera control:** N/A **Interaction:** Mouse for 2D Annotation **Representation:** Appears in 2D video	VR HMD (Viewing 360 Video) Camera Control by VR HMD N/A No Visual, Voice Only	VR HMD (Viewing 360 Video) Camera Control by VR HMD VR Controller 3D Avatar
AR-Hosts			
	Viewing Device: Desktop Monitor **Camera control:** N/A **Interaction:** N/A **Representation:** Appears in 2D video	Desktop Monitor N/A N/A Appears in 360-degree Video	AR HMD N/A N/A Appears in 360-degree Video

User Evaluation

Condition 3

	1 Condition 1 Conventional video with 2D annotation	2 Condition 2 360 Video without augmented visual cues	3 Condition 3 360 video with augmented visual cues
VR-Travelers	 **Viewing Device:** Desktop Monitor **Camera control:** N/A **Interaction:** Mouse for 2D Annotation **Representation:** Appears in 2D video	 VR HMD (Viewing 360 Video) Camera Control by VR HMD N/A No Visual, Voice Only	 VR HMD (Viewing 360 Video) Camera Control by VR HMD VR Controller 3D Avatar
AR-Hosts	 **Viewing Device:** Desktop Monitor **Camera control:** N/A **Interaction:** N/A **Representation:** Appears in 2D video	 Desktop Monitor N/A N/A Appears in 360-degree Video	 AR HMD N/A N/A Appears in 360-degree Video

Results

results

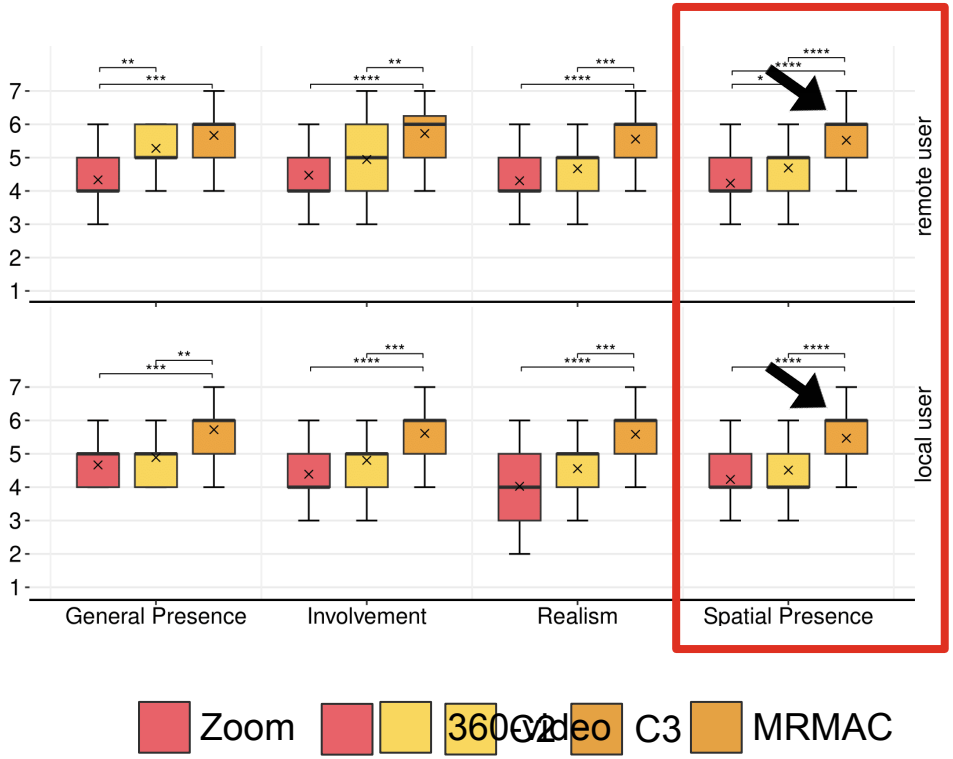
Results: Spatial Presence

H1: Spatial presence would be significantly higher in MRMAC.

Accepted

Justification:

Our system allow users to see each other and explore the real environment of users, social presence and spatial presence should be higher between AR and VR users.



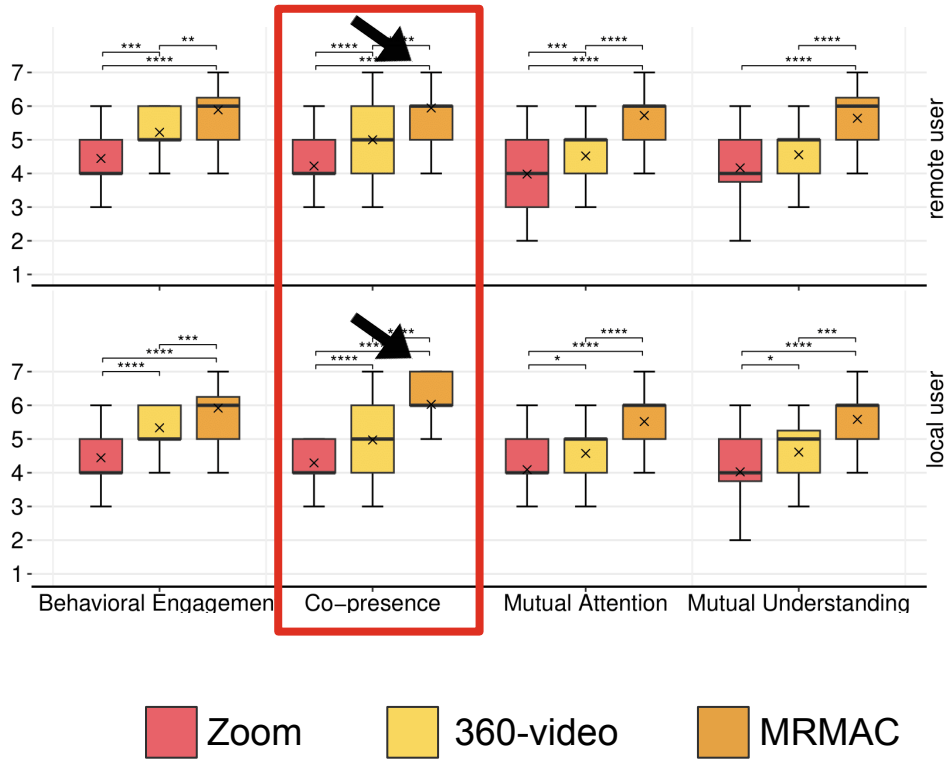
Results: Social Presence

H1: Social presence would be significantly higher in MRMAC.

Accepted

Justification:

Our system allow users to see each other and talk to each other.



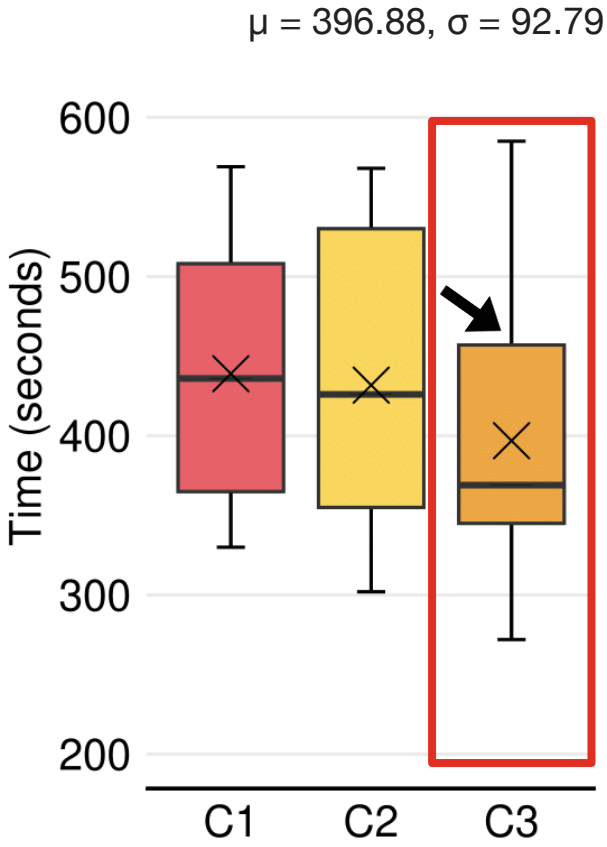
Results: Task Completion Time

H2: With MRMAC participants will complete the task faster.

Partially Accepted

Justification:

Available communication and awareness tools in MRMAC made it significantly easier for remote and local users to complete the task faster.



Results: Work Load (TLX)

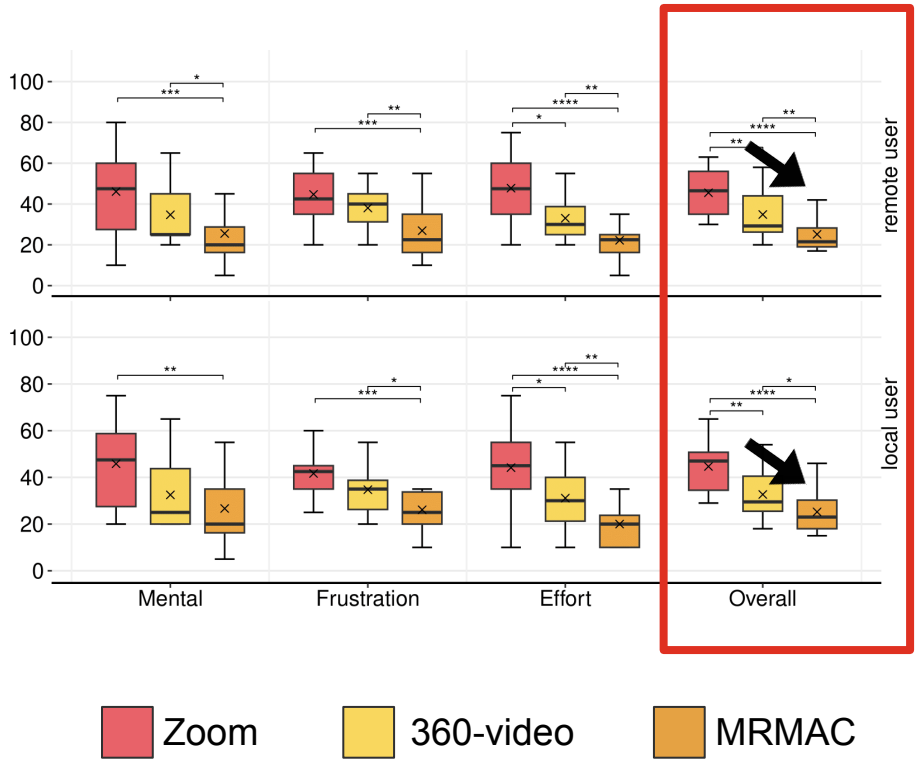
H2: With MRMAC participants will have less workload.

Accepted

Measured by: TLX

Justification:

Available communication and awareness tools in MRMAC made it significantly easier for remote and local users to complete the task faster.

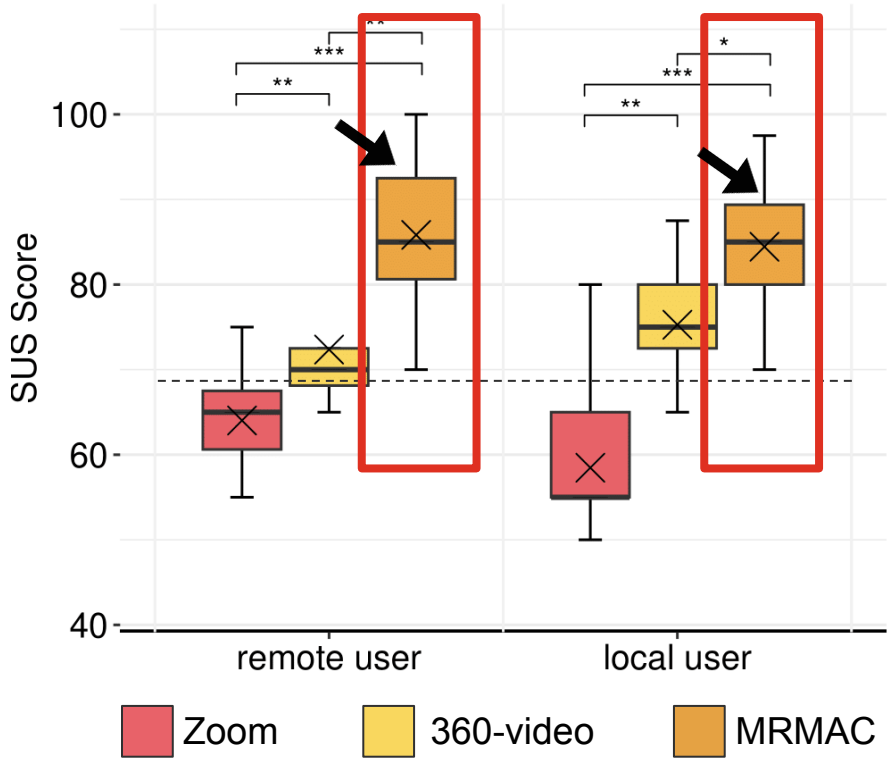


Results: Usability

H3: System usability would be significantly higher in MRMAC.

Accepted

Measured by: SUS

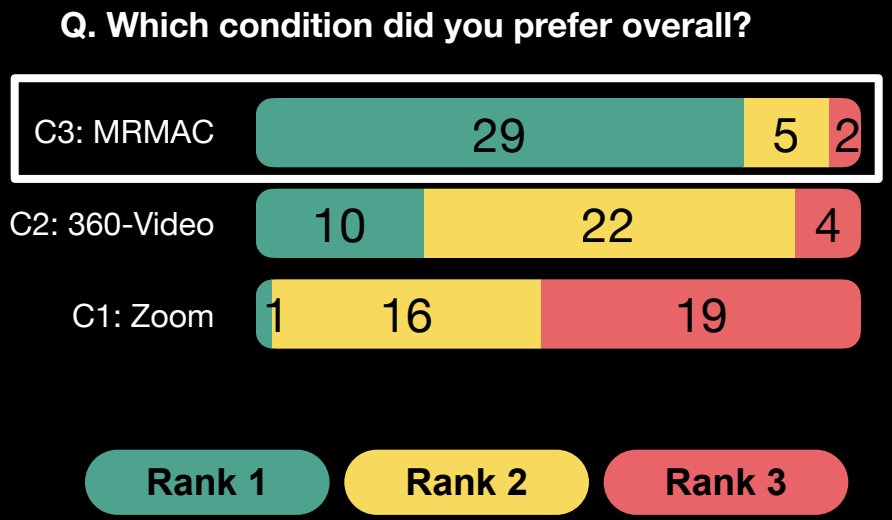


Results: Preference

H4: Participants would prefer MRMAC more.

[...] live-streaming the physical environment and blending 3D virtual assets really amps up the collaboration experience

[...] it feels like we're all in the same room. I can hear everyone's voices coming from different directions, it even more realistic



Limitation and Future Work

Explore more capture modalities

- Integrate depth information.
- Teleoperate robots.

System adaptability in challenging environment

Conduct more in-depth user studies.

Conclusion

Summary

Fully bidirectional asymmetric collaboration system

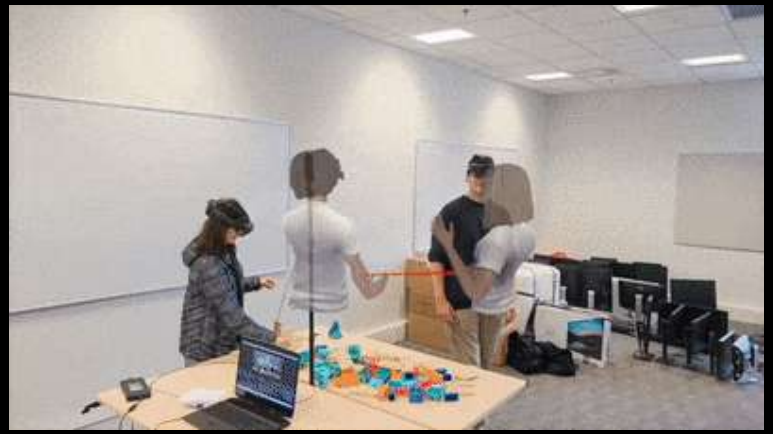
- Real-time collaboration
- Audio-visual synchronisation
- Virtual assets blending

System evaluation

- Reasonably Scalable
- Low-latency

User evaluation

- MRMAC *performed* collaborative tasks faster
- MRMAC *preferred* over conventional 2D and traditional 360



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