

Behavioural Analysis in a 6-DoF VR System: Influence of Content, Quality and User Disposition

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Immersive experiences



Immersive experiences

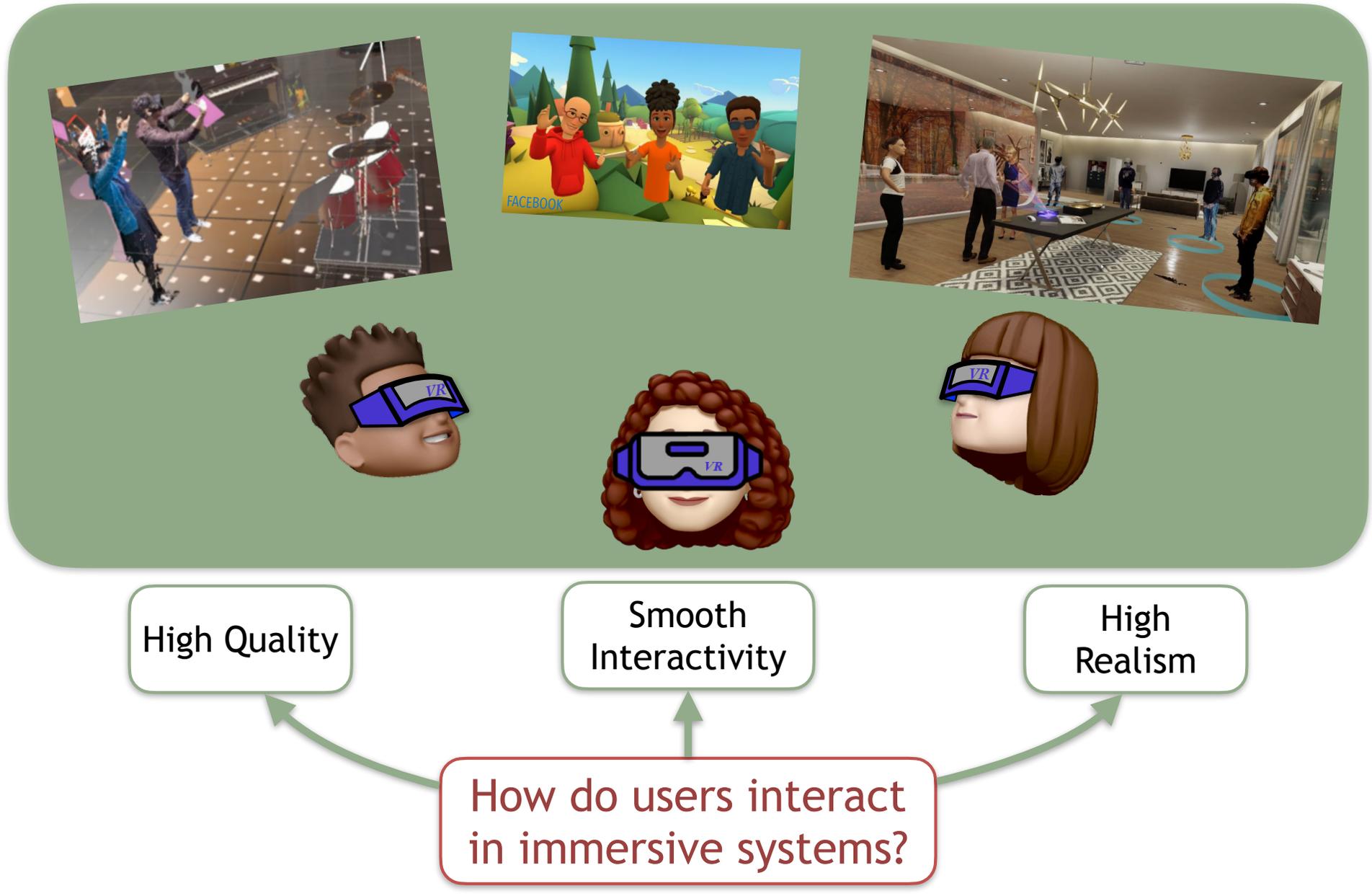


High Quality

Smooth
Interactivity

High
Realism

Immersive experiences



Virtual Reality (VR)

A virtual - rather than physical - world in which any **user** can be fully ***immersed and interactive***

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3-DoF system



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3-DoF system

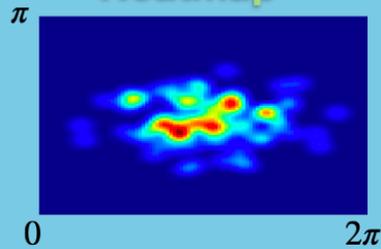


6-DoF system

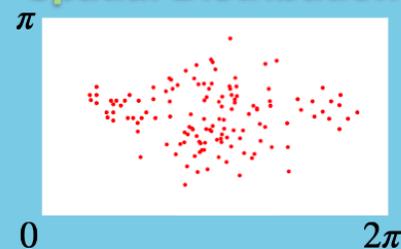


Traditional Data Analysis

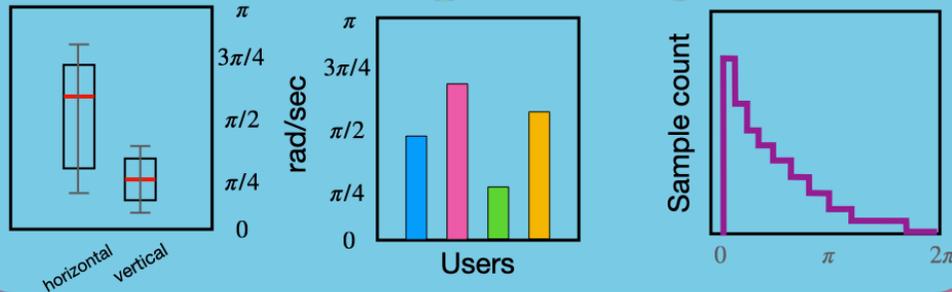
Heatmap



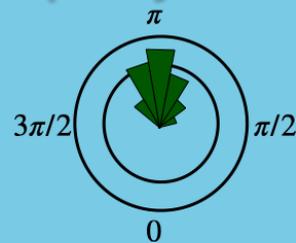
Spatial Distribution



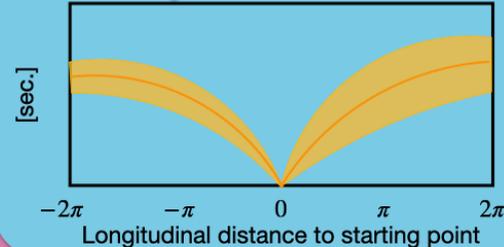
Mean angular velocity



Frequency Fixation

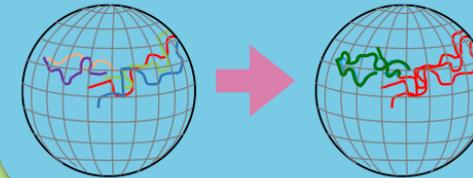


Exploration time

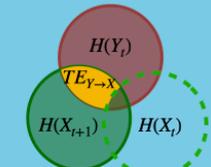


Trajectory-based Analysis

Clustering of Navigation Trajectories



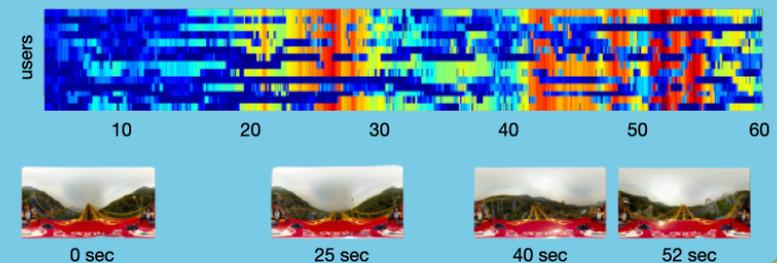
Information Theory tool



Graph modelling users interactivity

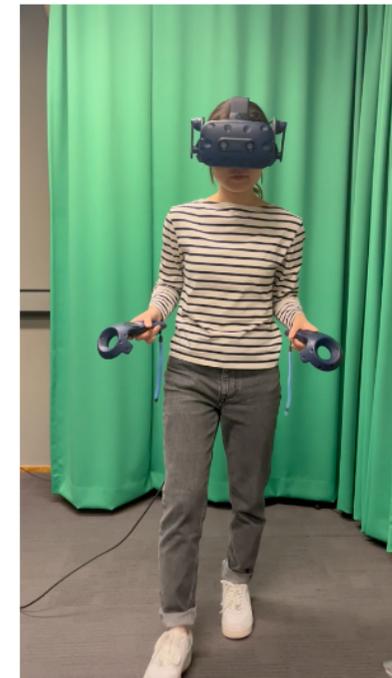
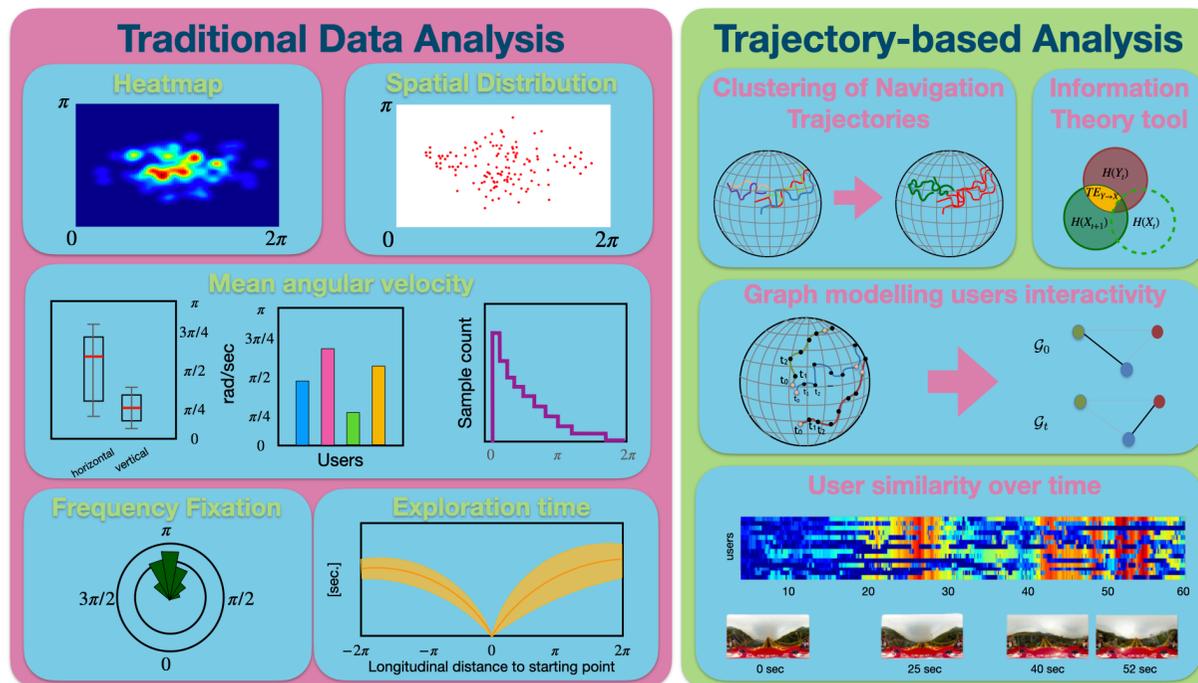


User similarity over time



Behavioural Analysis in a 6-DoF VR System

We propose an **exploratory behavioural analysis** in 6-DoF VR space aimed at detecting key aspects that influence the user navigation.



Challenges to understand user behaviour

Challenges to understand user behaviour



Volumetric Content

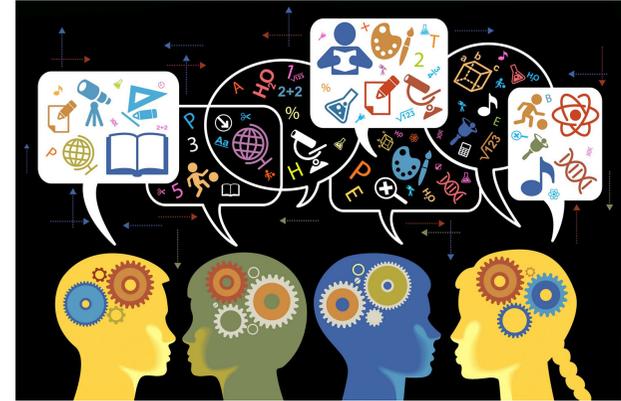


User Disposition

Challenges to understand user behaviour



Volumetric Content



User Disposition

- How does the **user behaviour** change based on the **dynamism** of volumetric content?
- Does the volumetric content **quality** have an impact on the **user navigation**?

Challenges to understand user behaviour



Volumetric Content



User Disposition

- How does the **user behaviour** change based on the **dynamism** of volumetric content?
- Does the volumetric content **quality** have an impact on the **user navigation**?
- Are **users consistent** in their navigation across different content (and quality)?

Methodology

1. Behavioural Analysis across Content
2. Behavioural Analysis across Content Quality
3. Behavioural Analysis across Users

1. Behavioural Analysis across Content

- ➔ **Spatial distribution** of users within the virtual space
- ➔ Distribution of user **viewing direction**
- ➔ **Spatial distance** between user and content

2. Behavioural Analysis across Users

3. Behavioural Analysis across Users

Methodology

1. Behavioural Analysis across Content

2. Behavioural Analysis across Content Quality

➔ Exploratory **velocity**

➔ Time of **interaction**

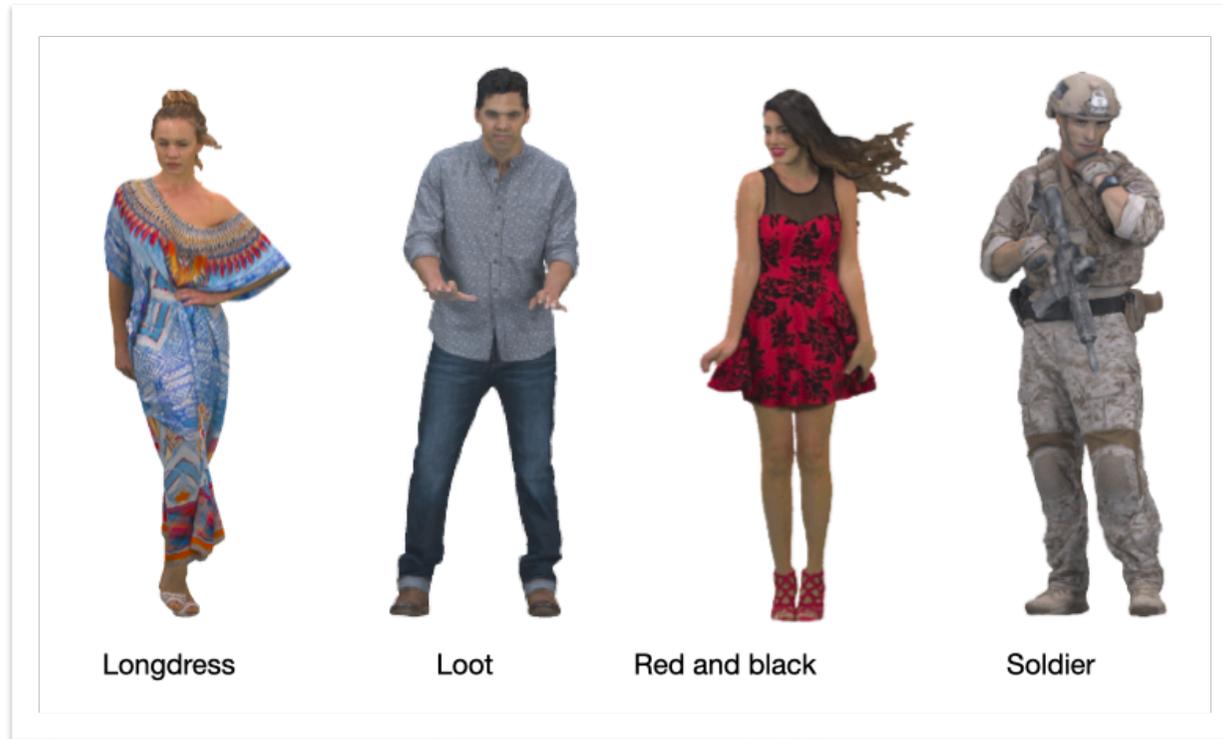
3. Behavioural Analysis across Users

1. Behavioural Analysis across Content
2. Behavioural Analysis across Content Quality
3. Behavioural Analysis across Users

- ➔ **Actual entropy** of navigation trajectories [3]
- ➔ **Viewing direction** changes
- ➔ **Clustering analysis** for a a single user across different quality stimuli [4]

[3] S. Rossi, and L. Toni. Understanding user navigation in immersive experience: An information-theoretic analysis. *Proceedings of the 12th ACM International Workshop on Immersive Mixed and Virtual Environment Systems*. (2020).

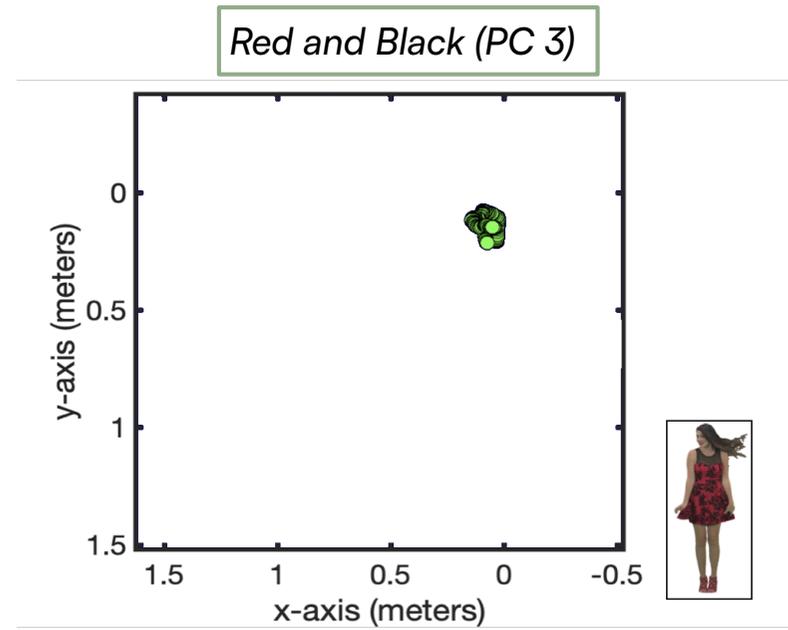
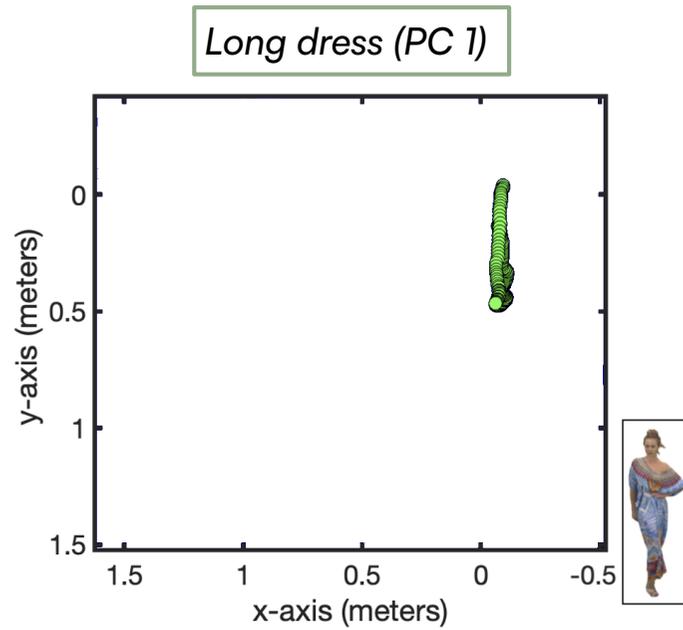
[4] S. Rossi, F. De Simone, P. Frossard, and L. Toni. Spherical Clustering of Users Navigating 360° Content. In *IEEE International Conference on Acoustics, Speech and Signal Processing* (2019)



We based our investigations on a publicly available dataset of **dynamic Point Clouds** with collected navigation trajectories of 27 users participating in a **visual quality assessment** study in **6-DoF VR** [5].

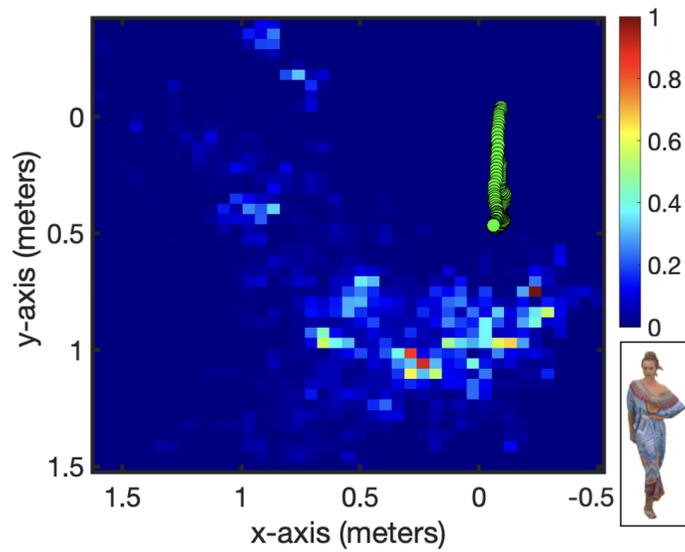
[5] S. Subramanyam, I. Viola, A. Hanjalic, and P. Cesar, **User Centered Adaptive Streaming of Dynamic Point Clouds with Low Complexity Tiling**, in Proceedings of the 28th ACM International Conference on Multimedia, 2020.

Behavioural Analysis across Content

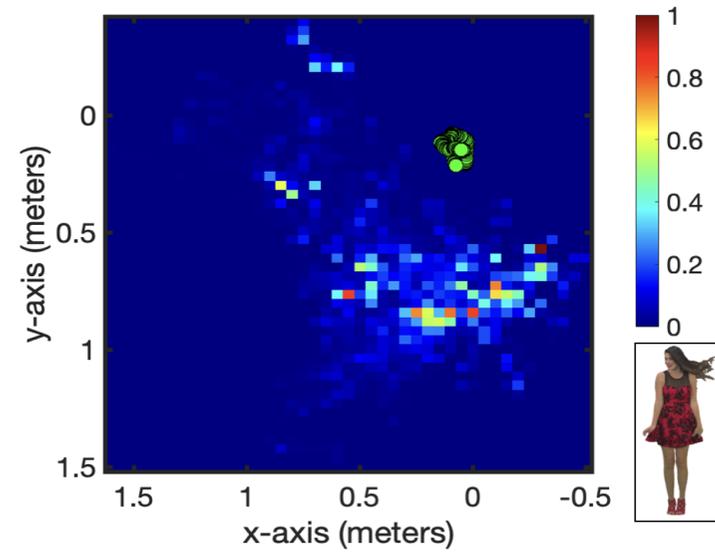


Behavioural Analysis across Content

Floor Heatmap Long dress (PC 1)

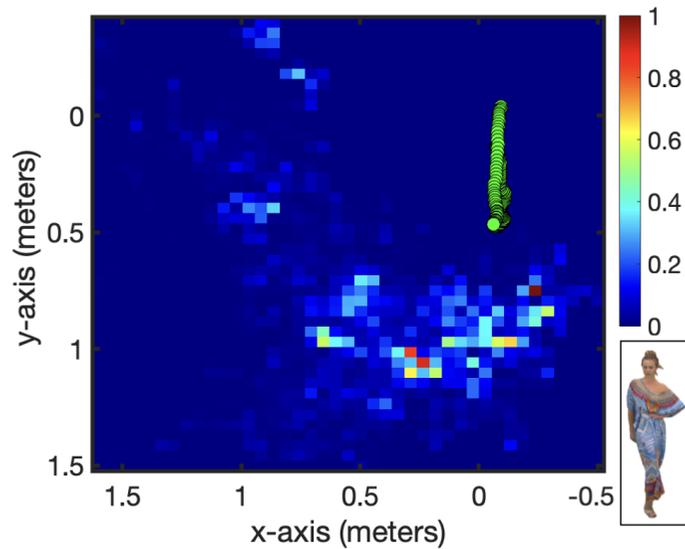


Floor Heatmap Red and Black (PC 3)

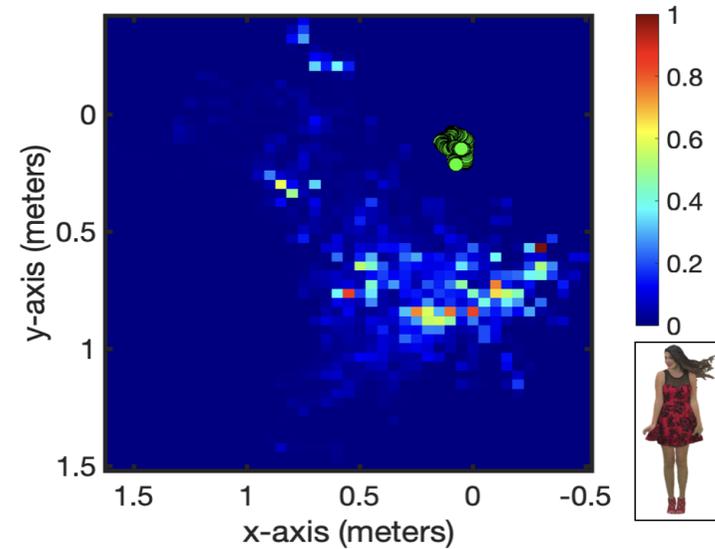


Behavioural Analysis across Content

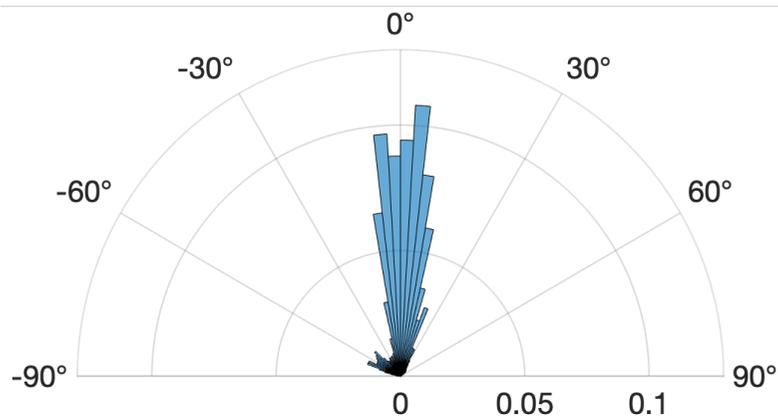
Floor Heatmap Long dress (PC 1)



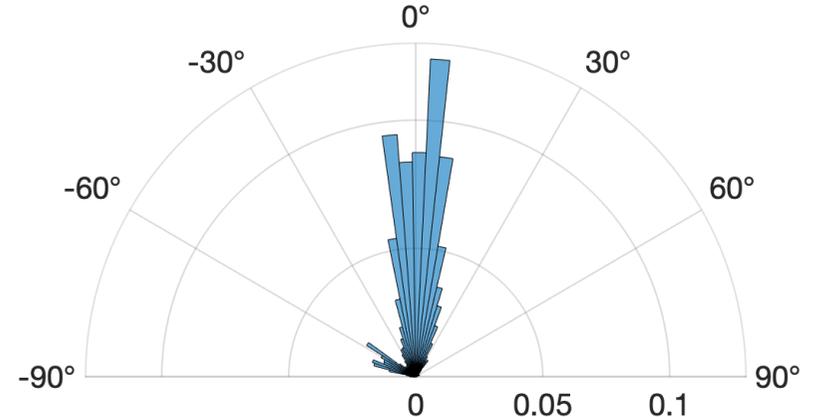
Floor Heatmap Red and Black (PC 3)



Viewing direction distribution in PC 1

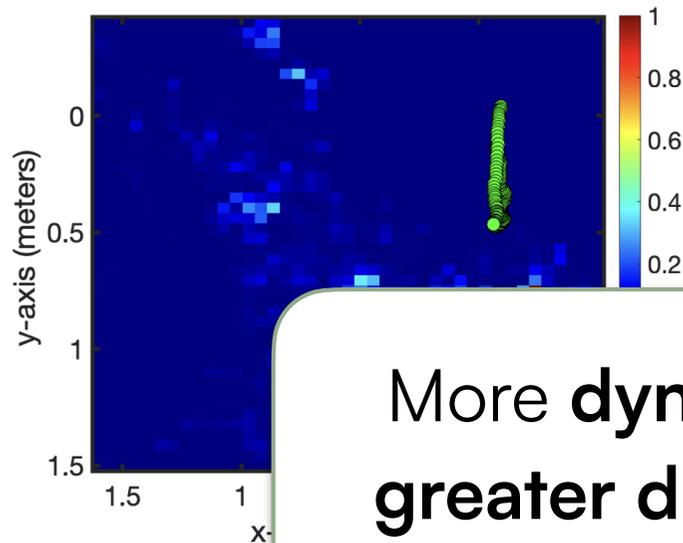


Viewing direction distribution in PC 3

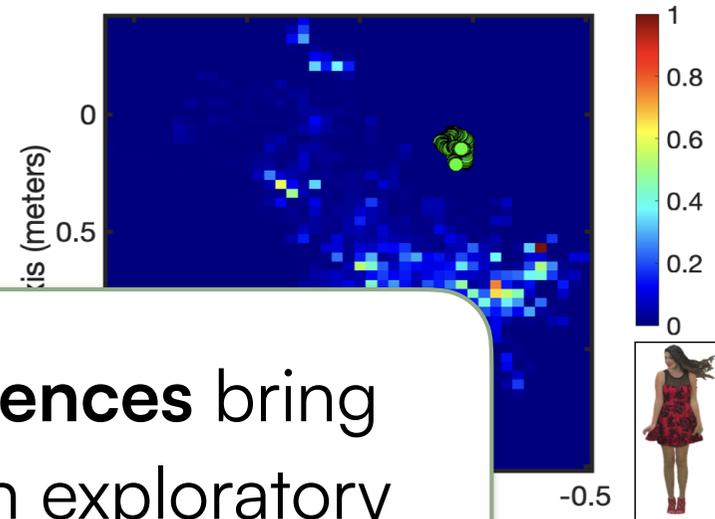


Behavioural Analysis across Content

Floor Heatmap Long dress (PC 1)



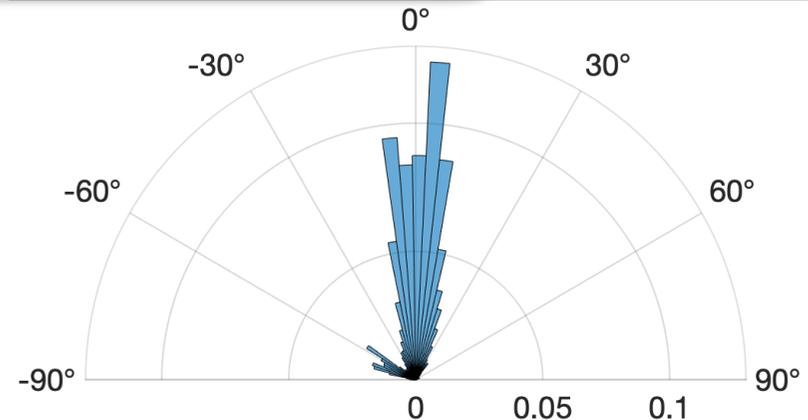
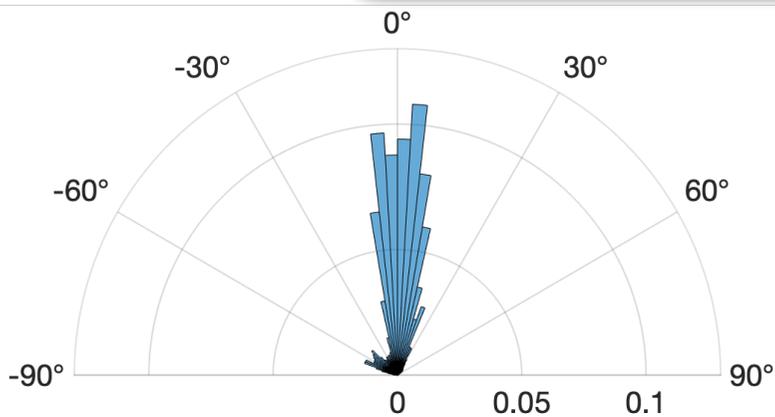
Floor Heatmap Red and Black (PC 3)



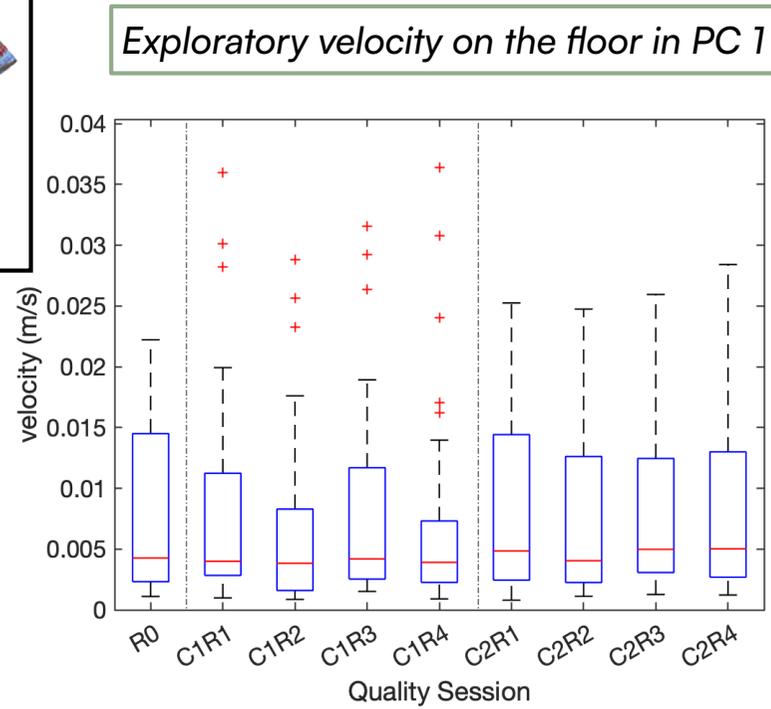
More **dynamic sequences** bring **greater dispersion** in exploratory movements

Viewing direction

Dispersion in PC 3



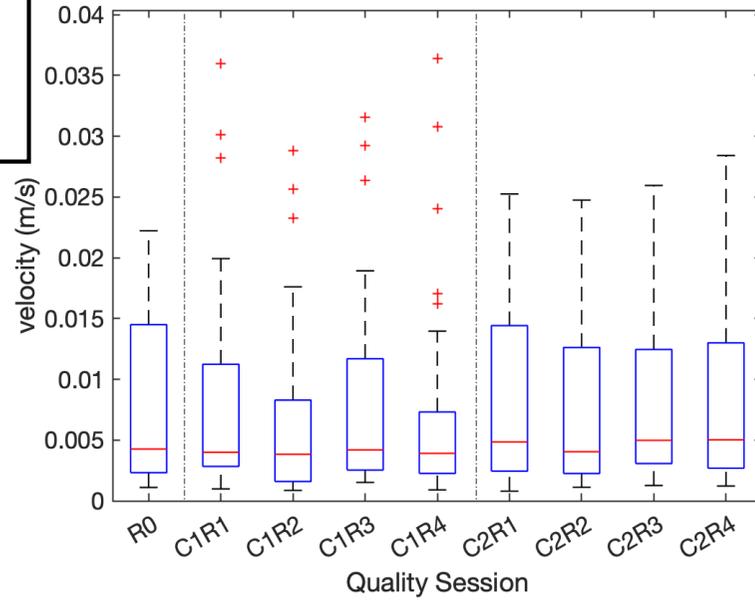
Behavioural Analysis across Content Quality



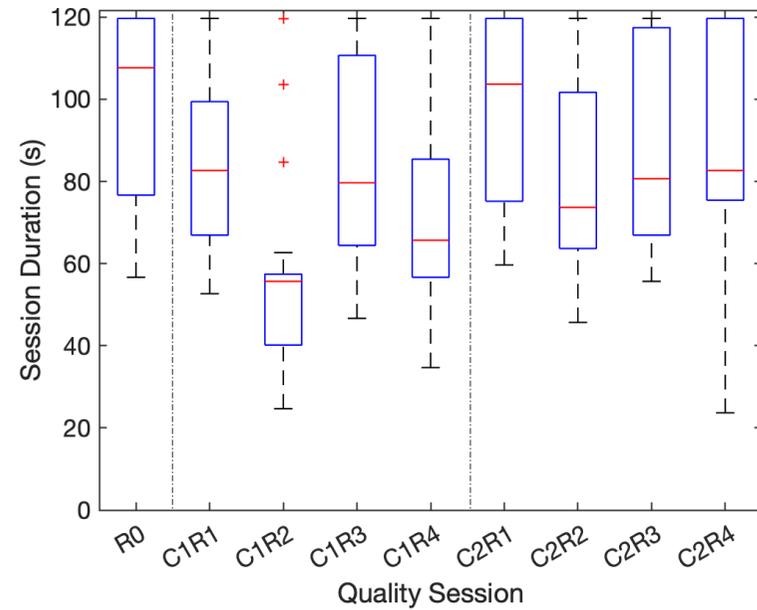
Behavioural Analysis across Content Quality



Exploratory velocity on the floor in PC 1



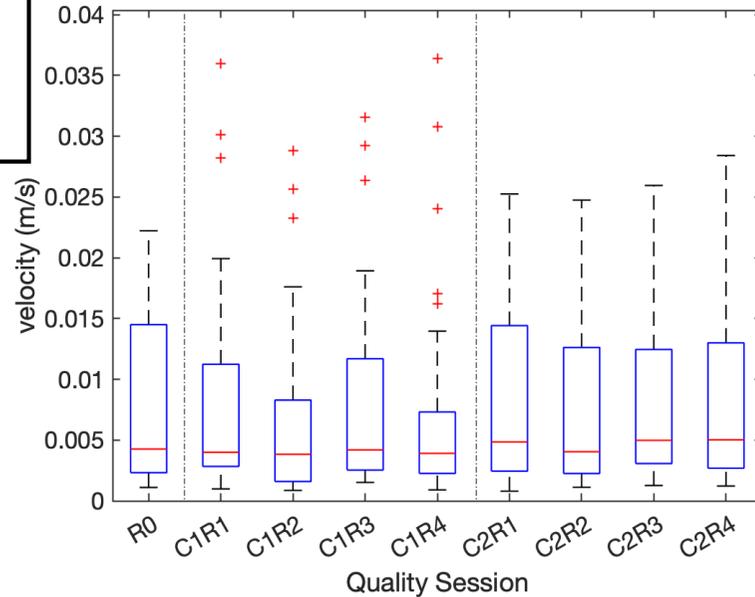
Interactive time spent in PC 1



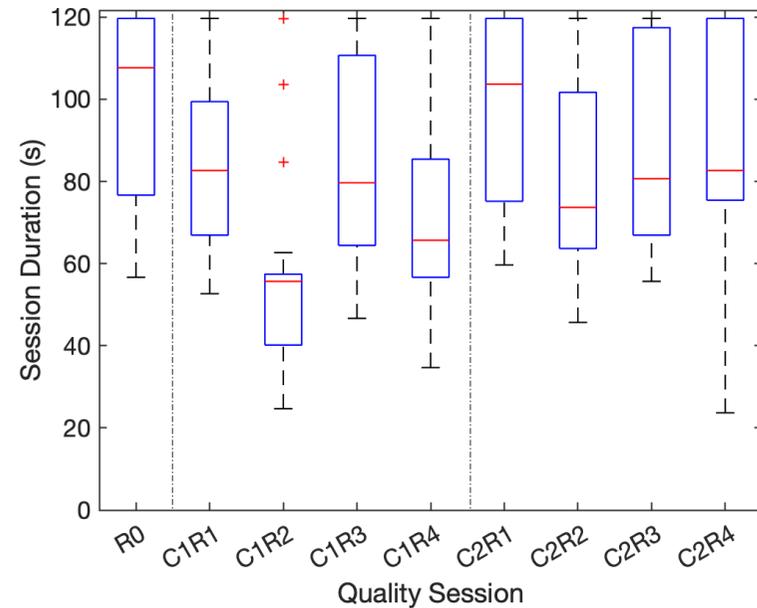
Behavioural Analysis across Content Quality



Exploratory velocity on the floor in PC 1



Interactive time spent in PC 1



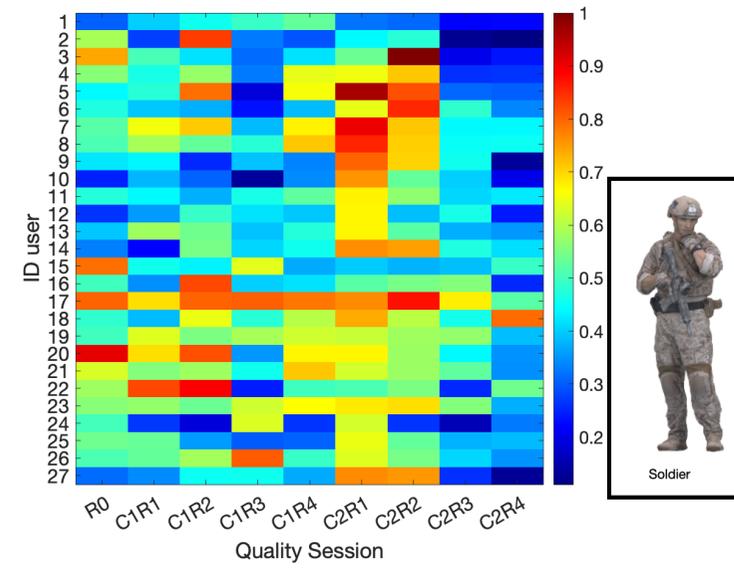
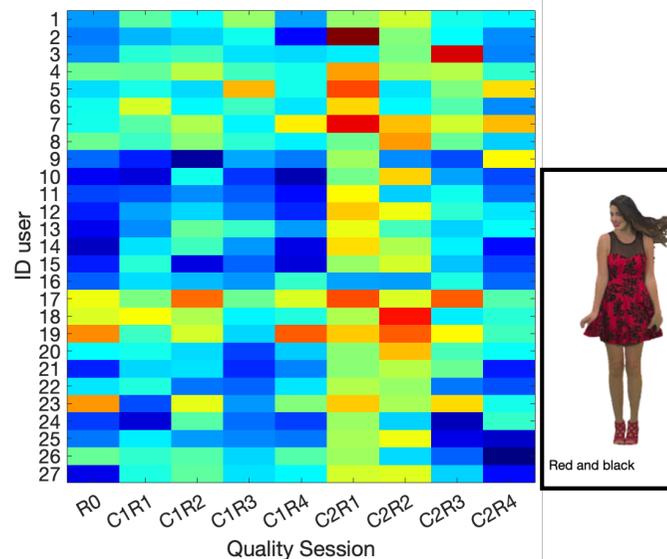
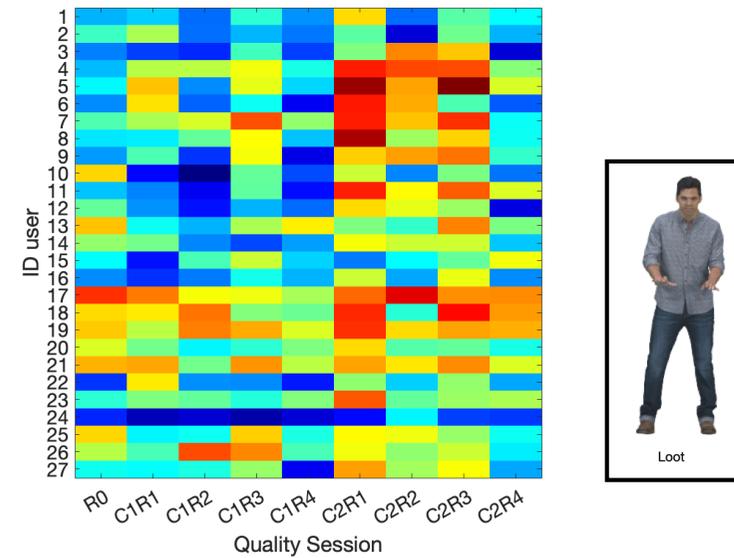
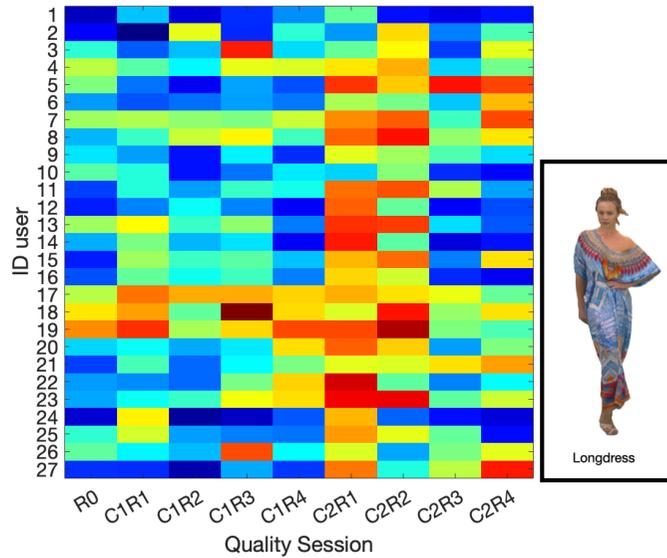
The **visual quality** barely affects the way of navigating but **compromises** the **interaction time** which increases with the quality.

Behavioural Analysis across Users

Probability per user to be detected as a single cluster across quality session

Behavioural Analysis across Users

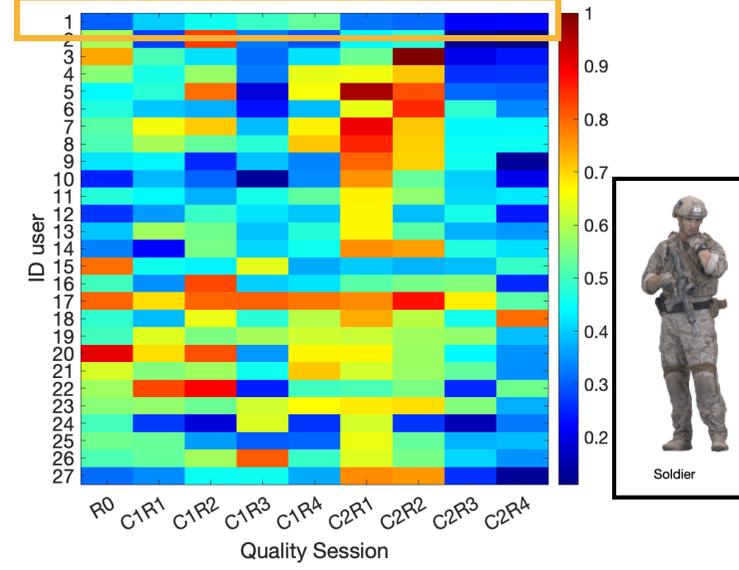
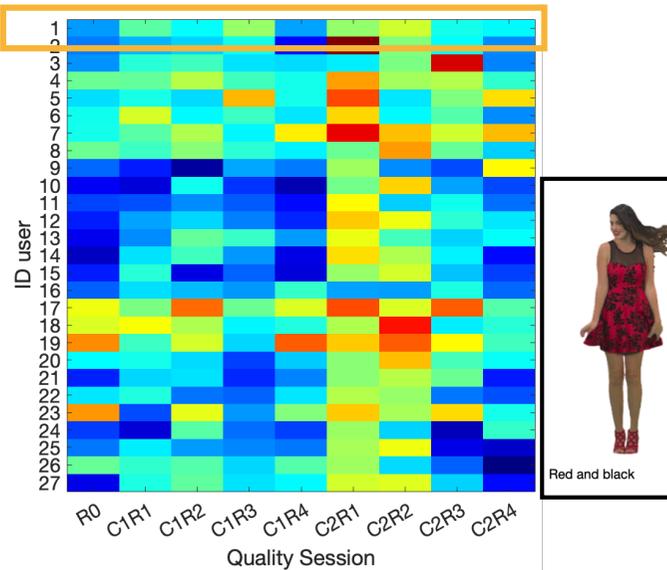
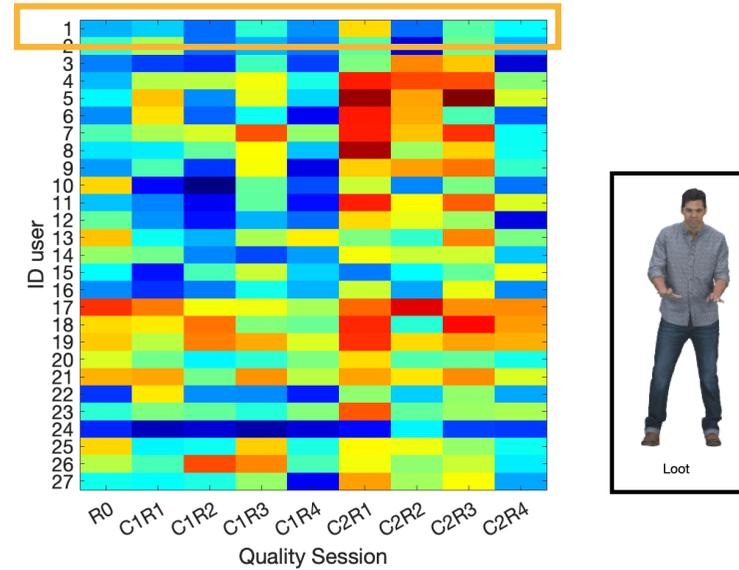
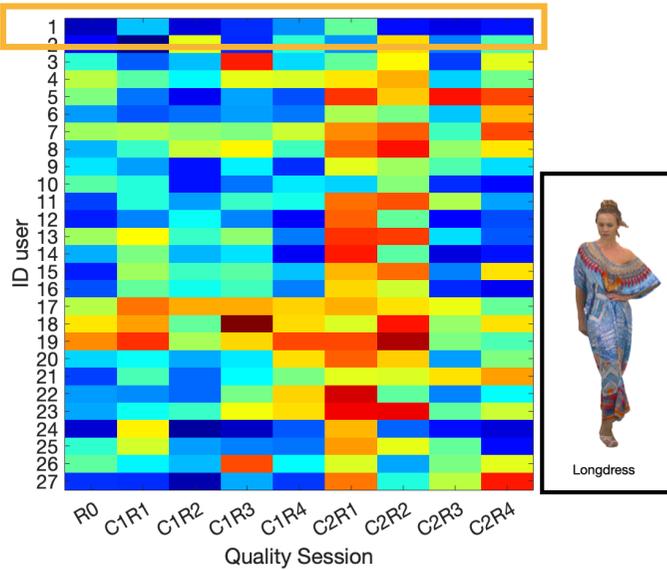
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Behavioural Analysis across Users

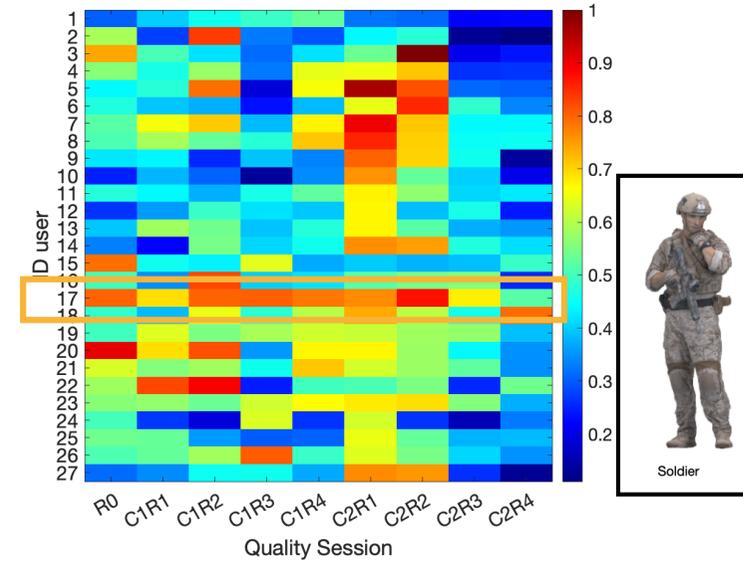
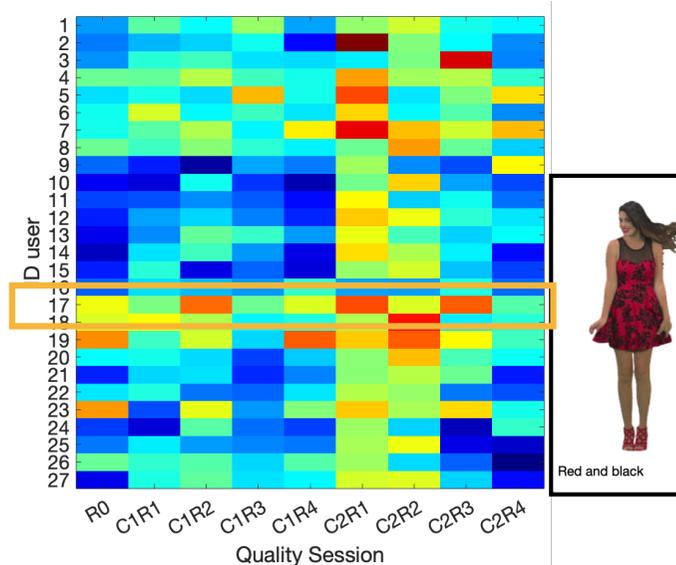
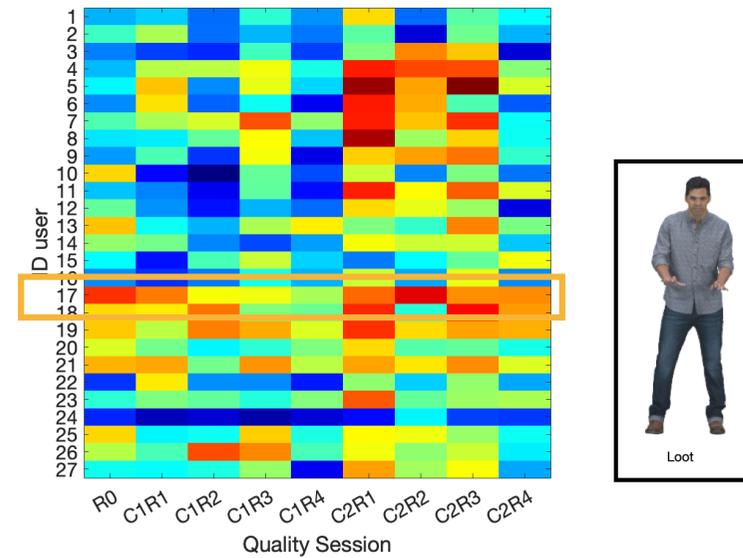
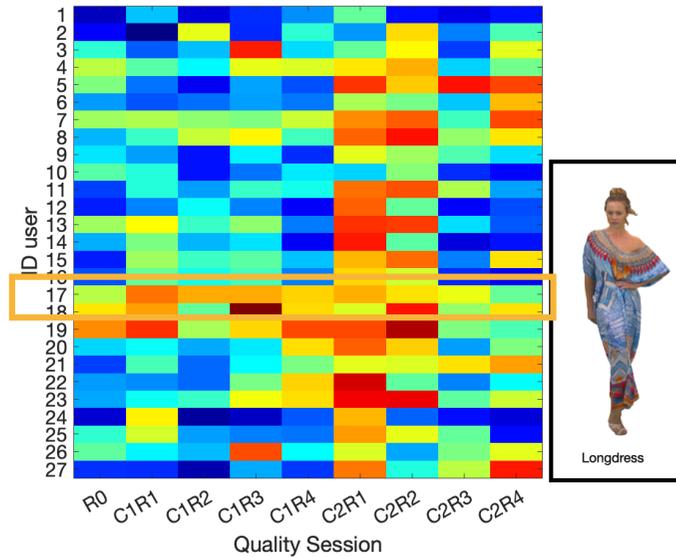
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Behavioural Analysis across Users

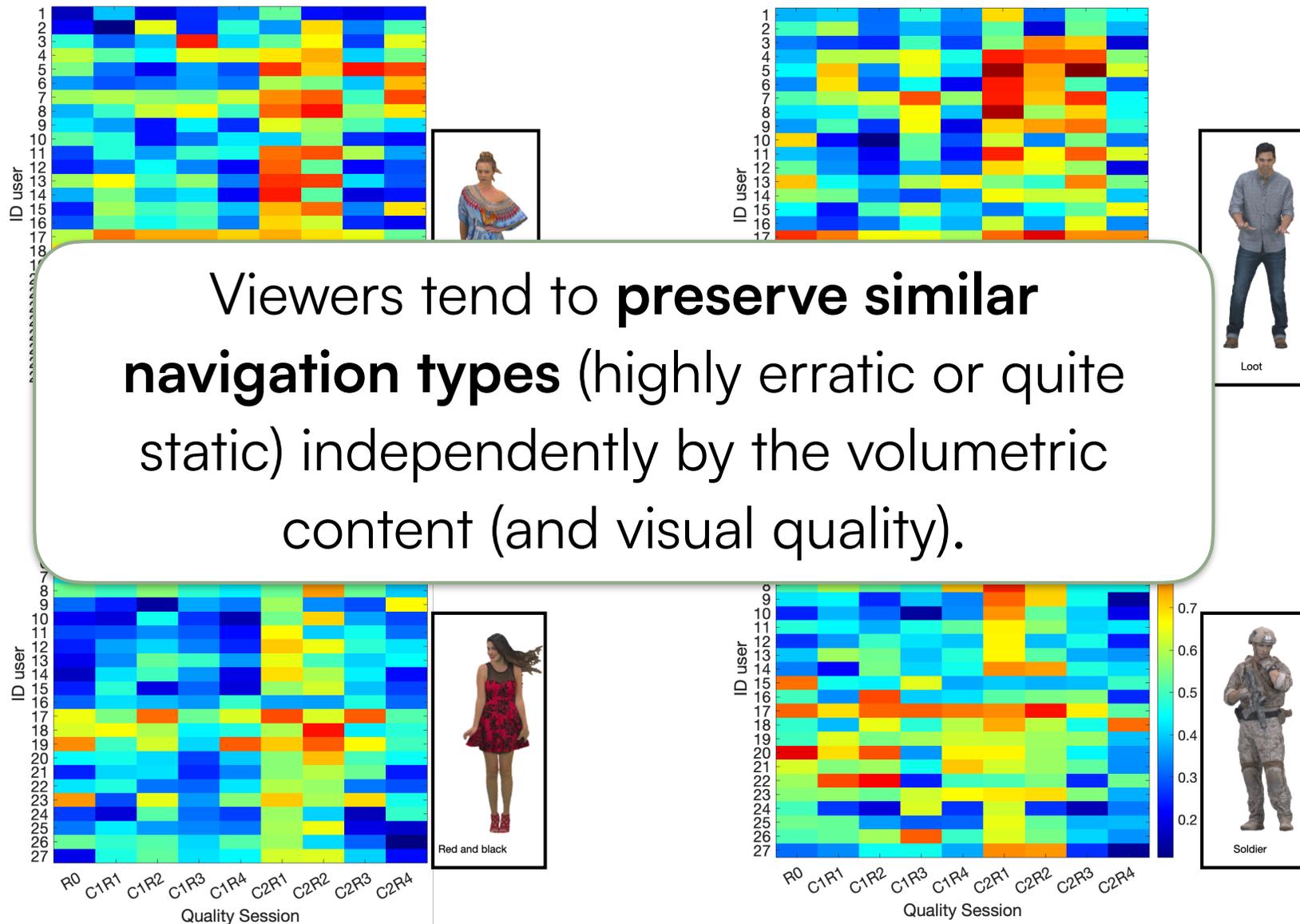
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Behavioural Analysis across Users

Probability per user to be detected as a single cluster across quality session



Summary

We have carried out a first generic behavioural investigation aimed at detecting how user navigation changes in 6-DoF VR environment:

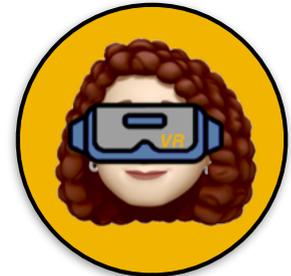
- ➔ The **more dynamic** the sequences are, the **more dispersive** the way users move around the immersive content is
 - ➔ The presence or not of **visual impairment does not affect** the **user movements** during the immersive experience but **compromises** its **attractiveness** in term of time
 - ➔ Viewers tend to **preserve similar navigation types** (highly erratic or quite static) independently by the volumetric content (and visual quality).
-

Any Questions?

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