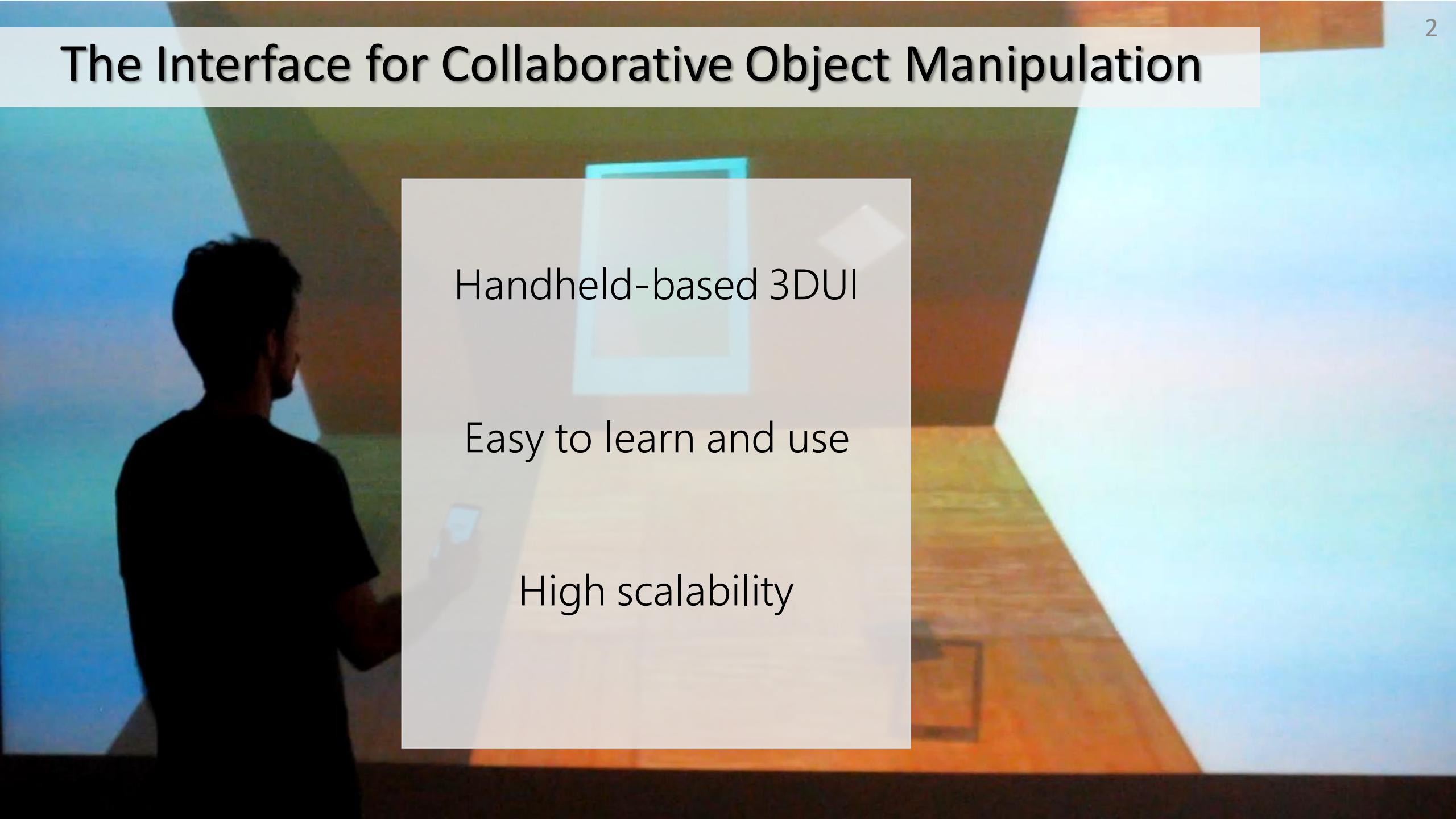


Design and Evaluation of a Handheld-based 3D User Interface for Collaborative Object Manipulation

Jerônimo G. Grandi, Henrique G. Debarba, Luciana Nedel, Anderson Maciel

Federal University of Rio Grande do Sul – Brazil
Graphics, Visualization and Interaction LAB

The Interface for Collaborative Object Manipulation

A photograph showing a man from behind, wearing a black t-shirt, standing in a room with blue walls and a wooden floor. He is holding a small handheld device, likely a smartphone or tablet, and appears to be interacting with a projected 3D user interface (3DUI) on the wall. The 3DUI consists of several translucent colored cubes (red, green, blue) arranged in a 3D space. A large white rectangular overlay box is positioned in the center of the projection.

Handheld-based 3DUI

Easy to learn and use

High scalability

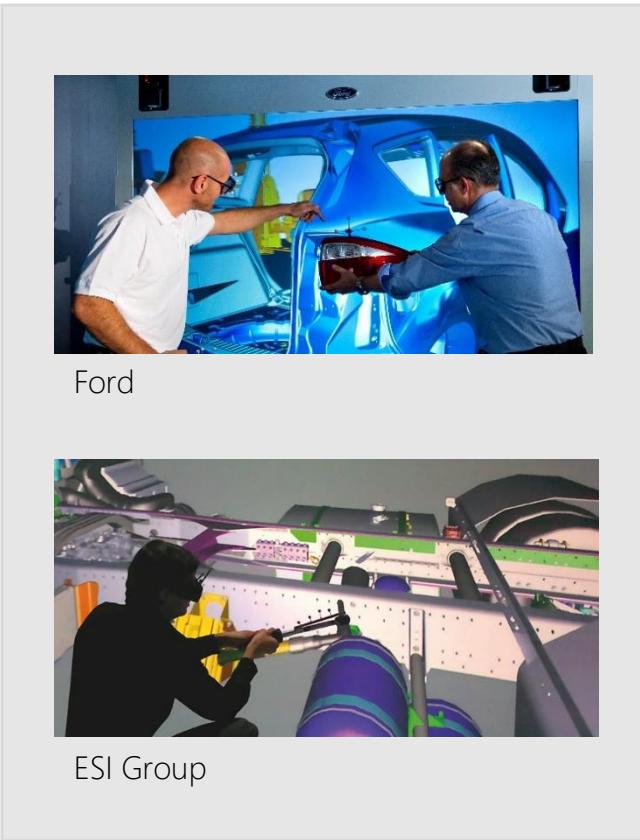
Research Questions

Is our technique suitable for collaborative tasks in VEs?

Does the performance increases accordingly to the number of members in the group?

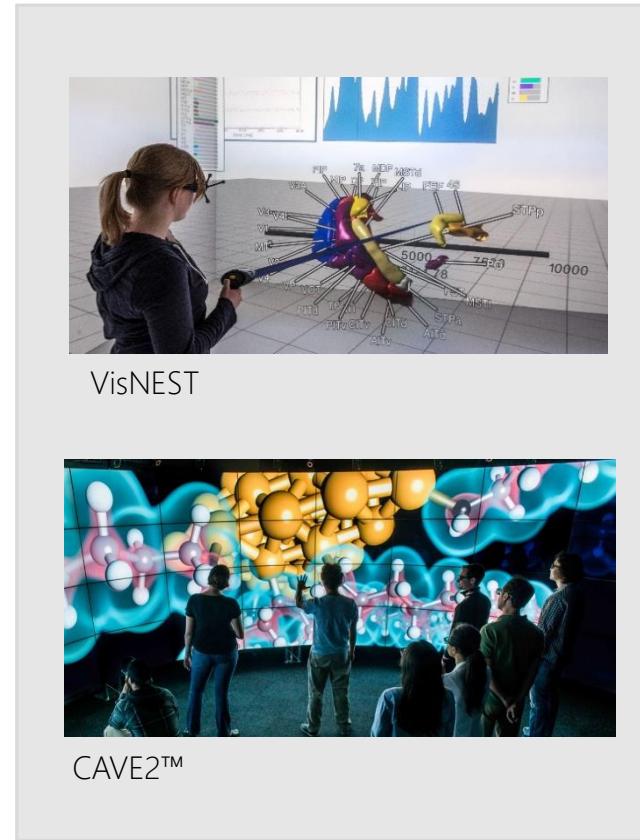
Applications

Assembly tasks



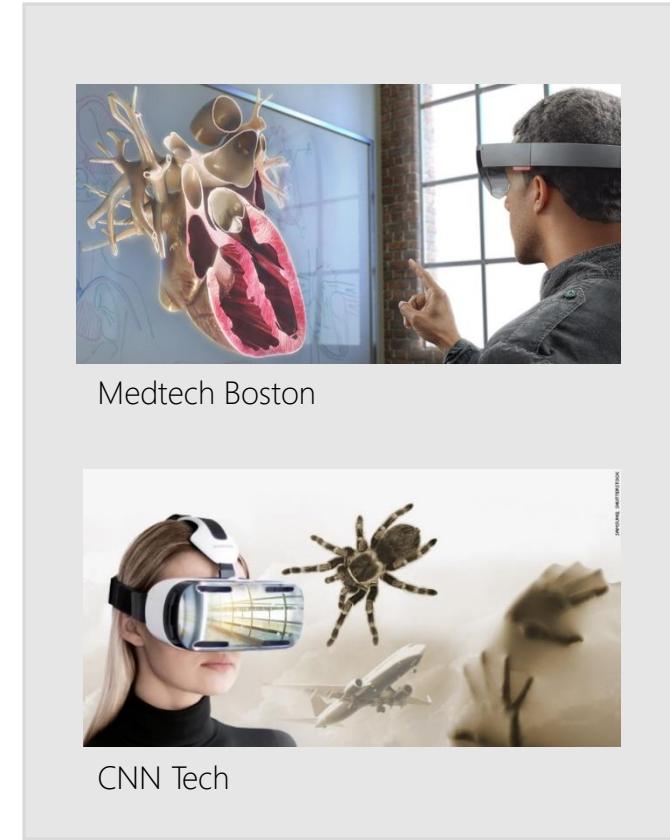
Ford

Data Exploration



VisNEST

Serious Games



Medtech Boston

Collaboration for 3D Spatial Manipulations

Divide and Conquer



Join and Solve

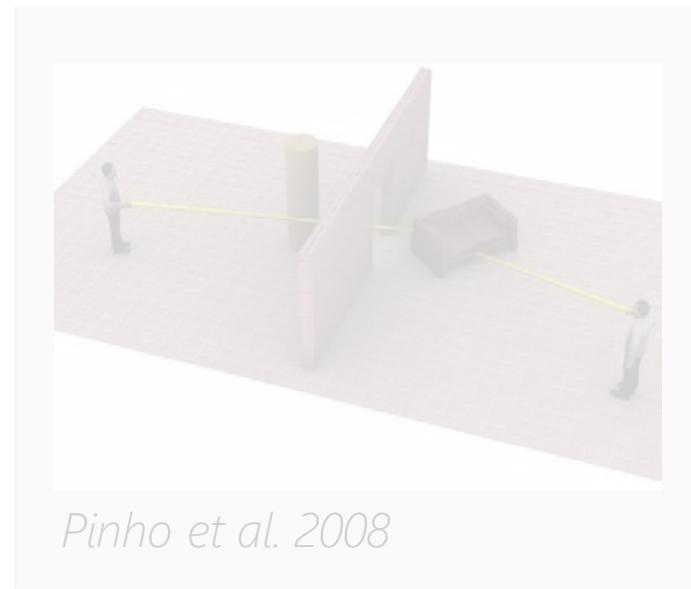


Simultaneous Manipulations of 3D Objects

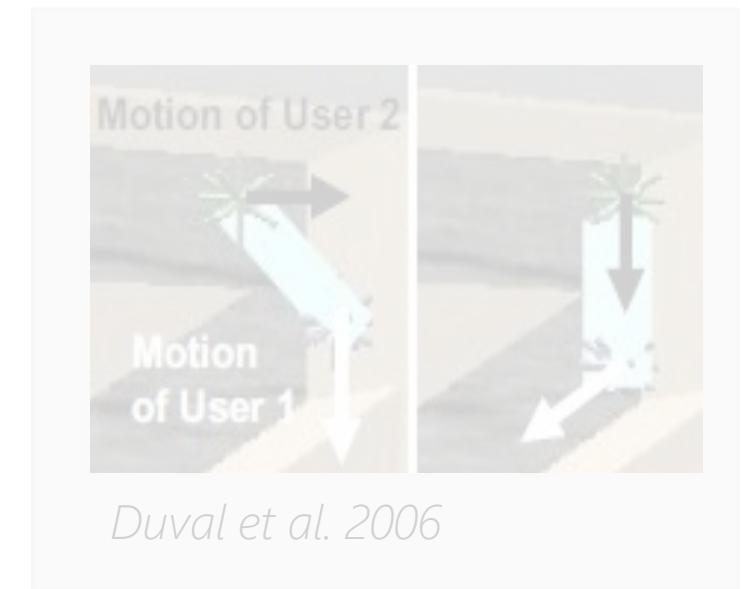
TUI



DOF Separation



Mean Average



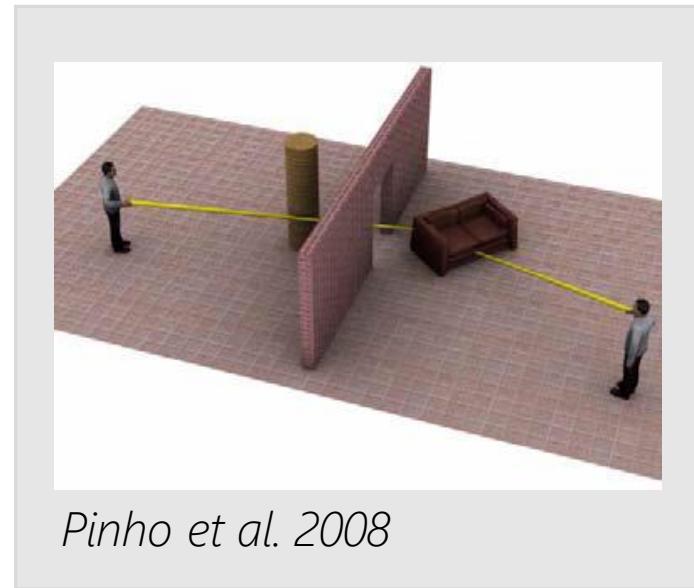
Simultaneous Manipulations of 3D Objects

TUI



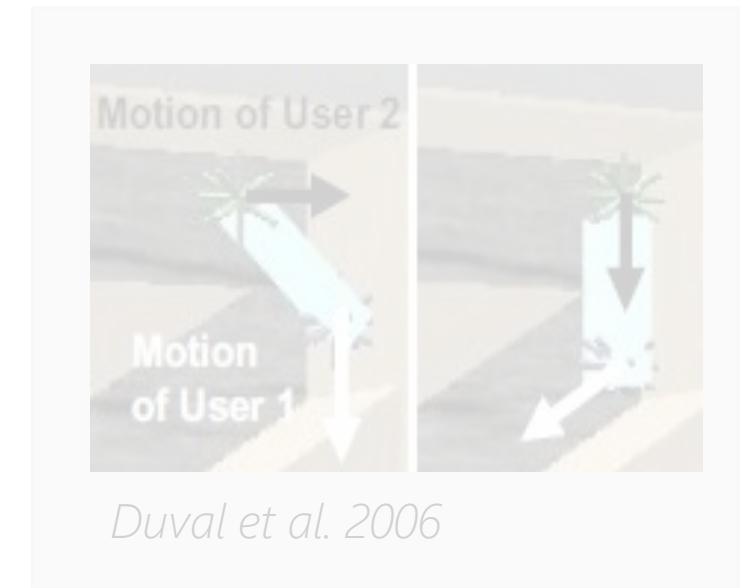
Aguerreche et al. 2010

DOF Separation



Pinho et al. 2008

Mean Average



Duval et al. 2006

Simultaneous Manipulations of 3D Objects

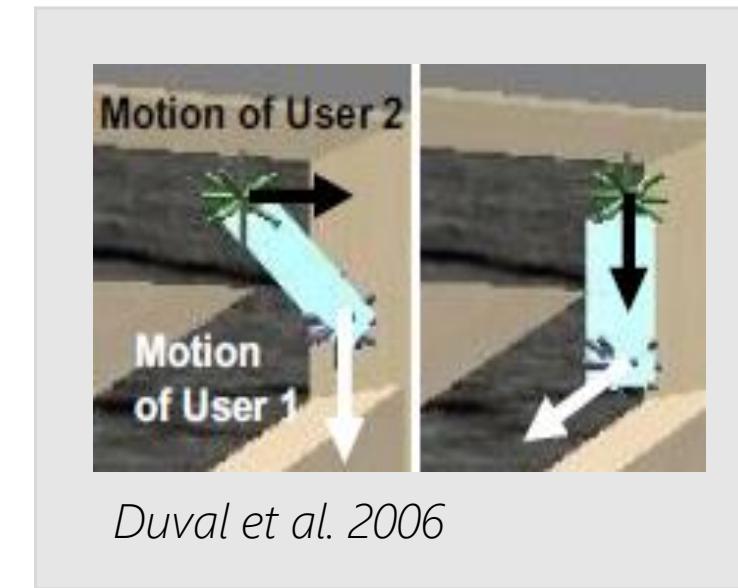
TUI



DOF Separation

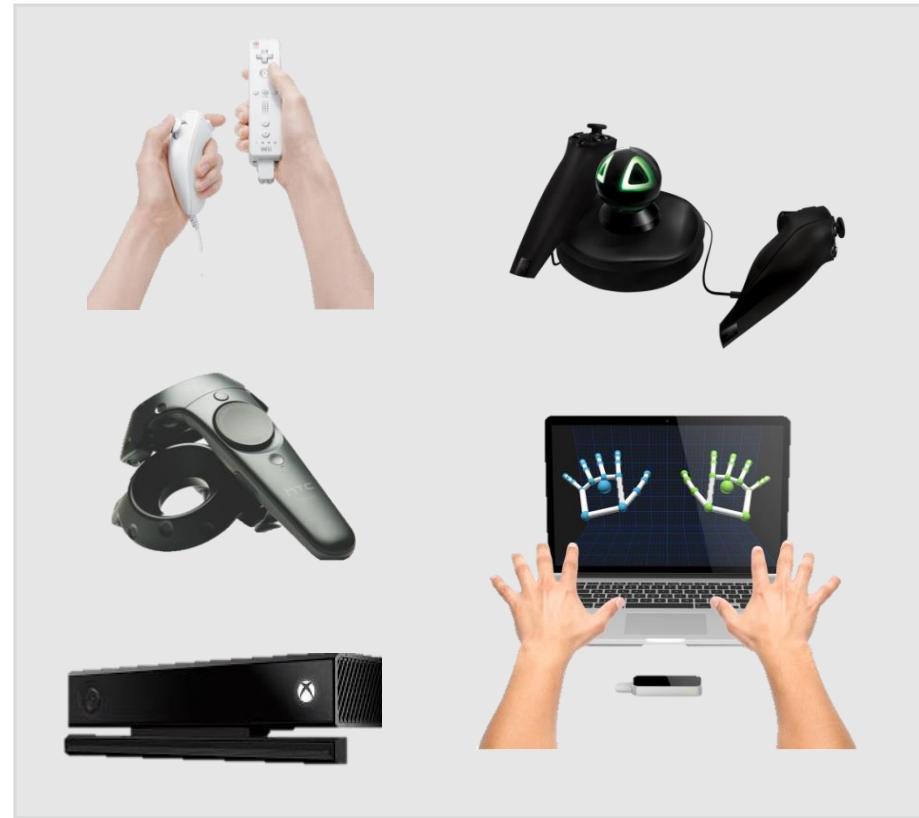


Mean Average



Mobile phones as 3D user interface

3DUIs



Mobile phones as 3D user interface

3DUIs



Mobile Device



Mobile phones as 3D user interface

3DUIs

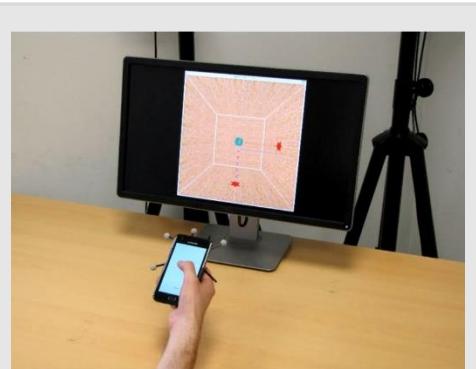


Mobile Device

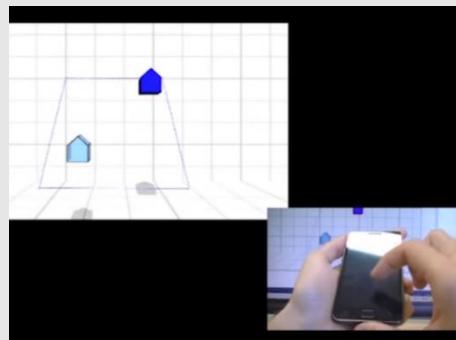


Mobile Phones as 3D User Interface

Manipulation

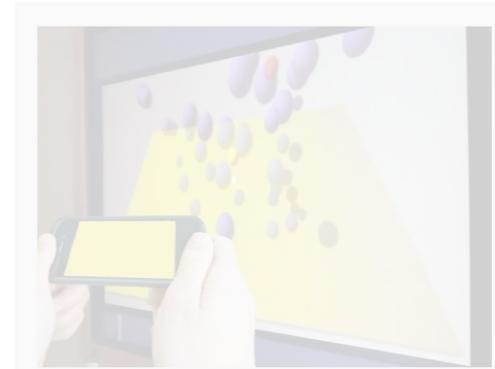


Bergé et al., 2015



Katzakis et al., 2015

Selection

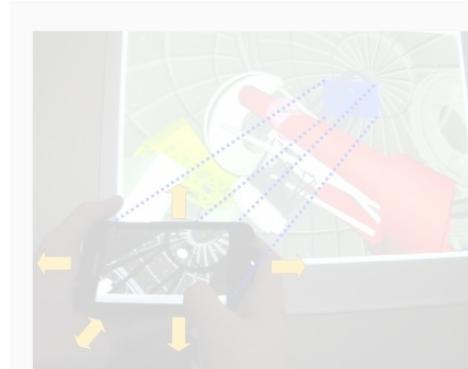


Pietroszek et al., 2015

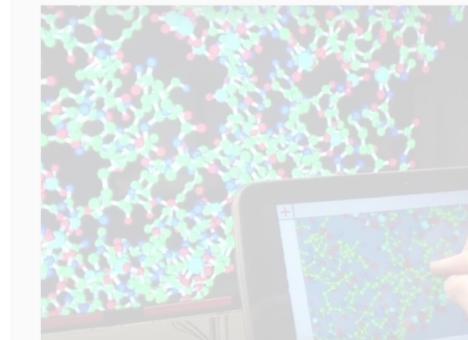


Debarba et al., 2012

Overview + Detail

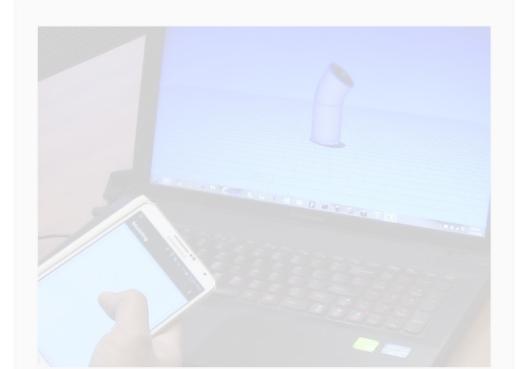


Bergé et al. 2014



López et al., 2016

Object Creation



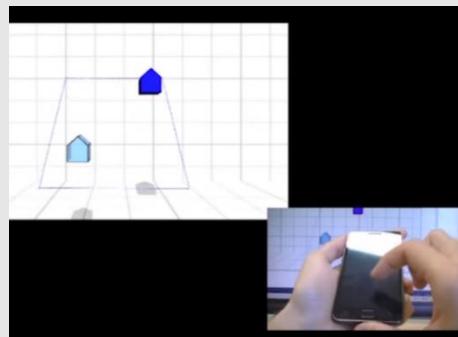
Vinayak et al. 2016

Mobile Phones as 3D User Interface

Manipulation

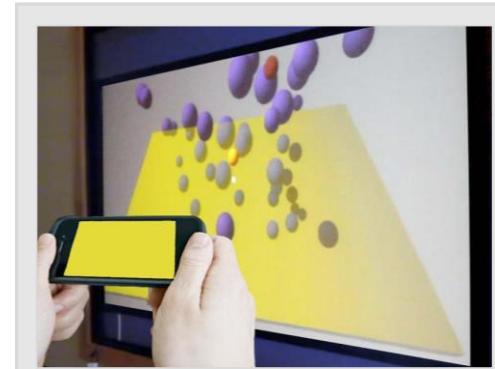


Bergé et al., 2015

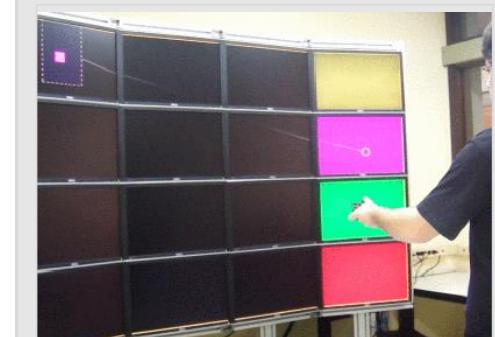


Katzakis et al., 2015

Selection



Pietroszek et al., 2015

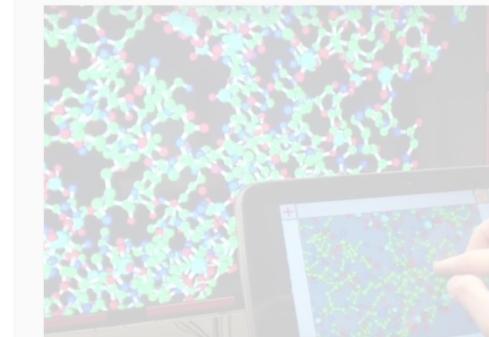


Debarba et al., 2012

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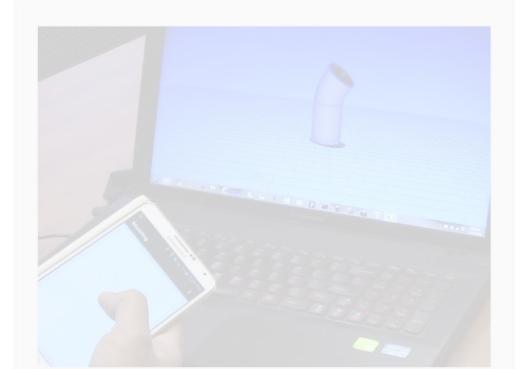


Bergé et al. 2014



López et al., 2016

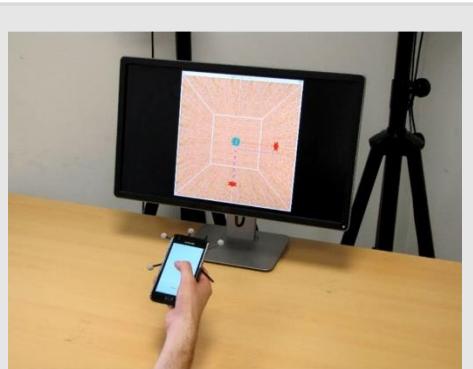
Object Creation



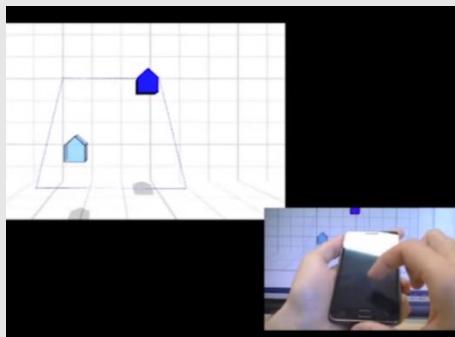
Vinayak et al. 2016

Mobile Phones as 3D User Interface

Manipulation

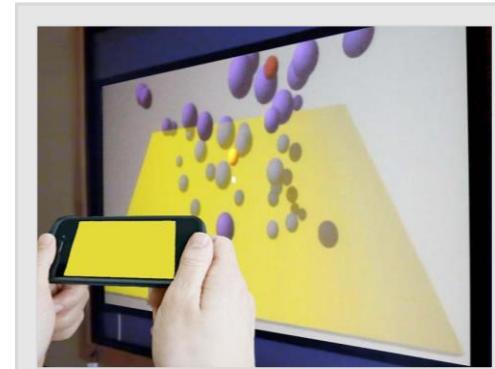


Bergé et al., 2015

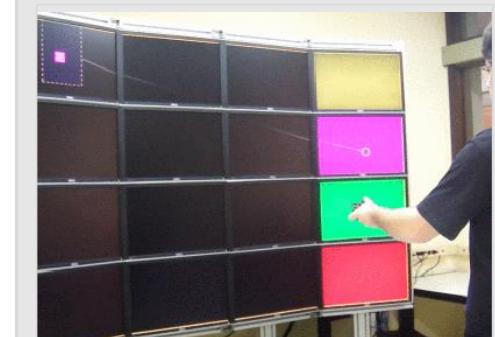


Katzakis et al., 2015

Selection

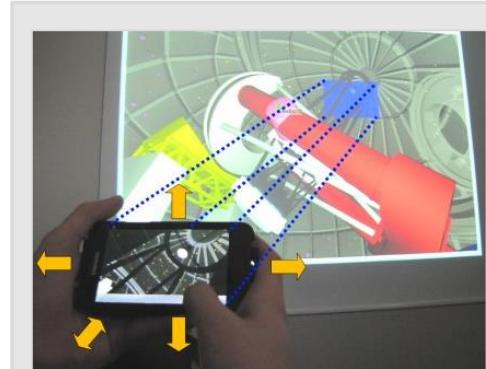


Pietroszek et al., 2015

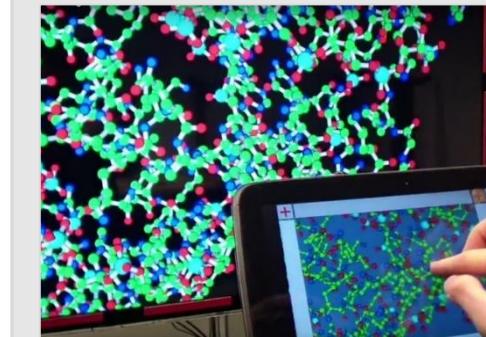


Debarba et al., 2012

Overview + Detail

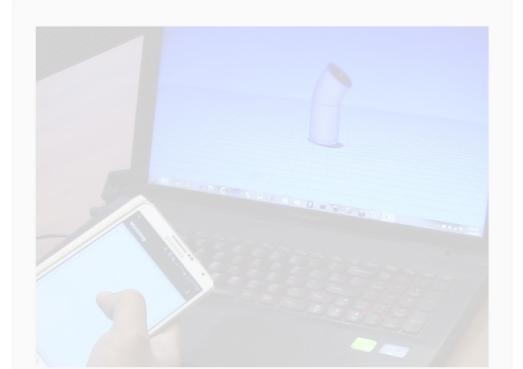


Bergé et al. 2014



López et al., 2016

Object Creation



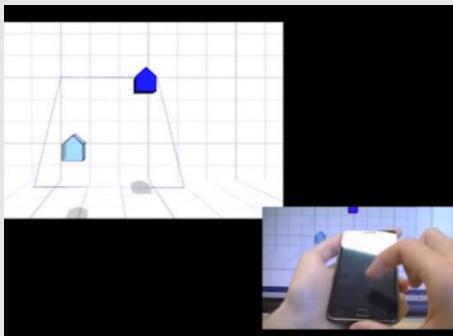
Vinayak et al. 2016

Mobile Phones as 3D User Interface

Manipulation

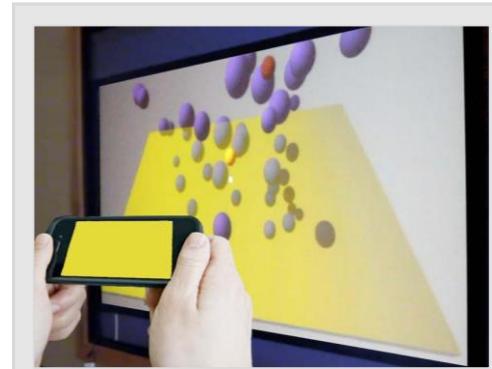


Bergé et al., 2015

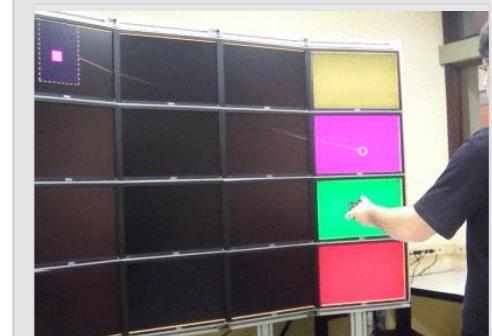


Katzakis et al., 2015

Selection

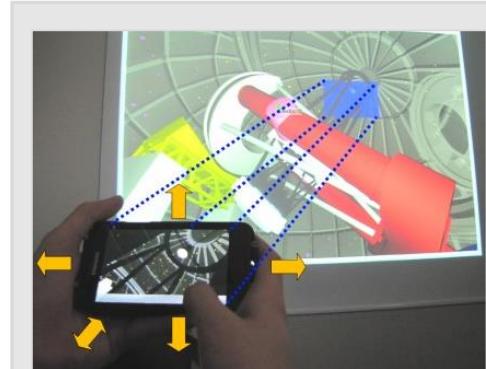


Pietroszek et al., 2015

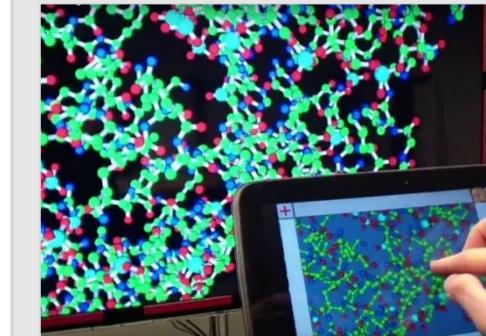


Debarba et al., 2012

Overview + Detail



Bergé et al. 2014



López et al., 2016

Object Creation

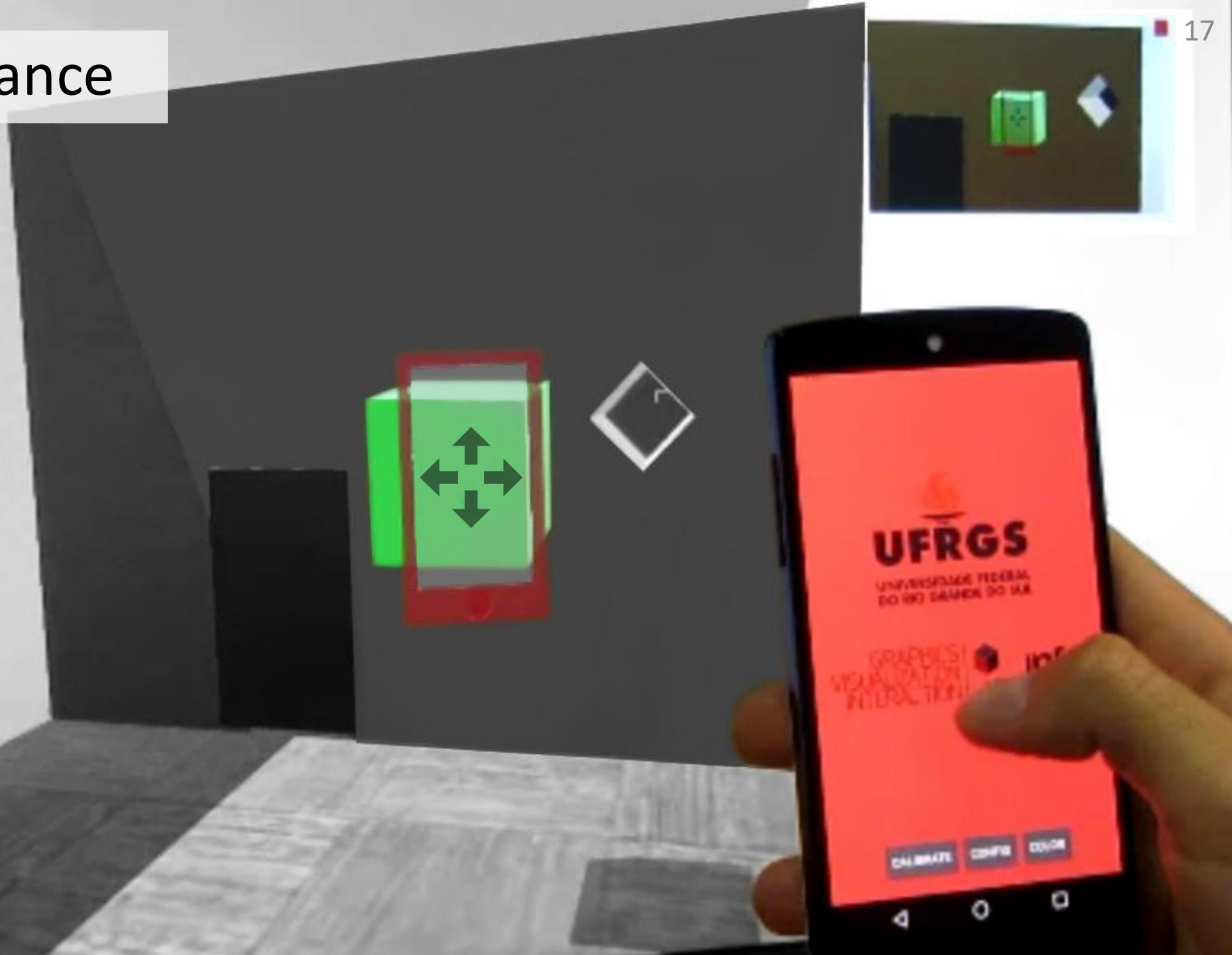


Vinayak et al. 2016

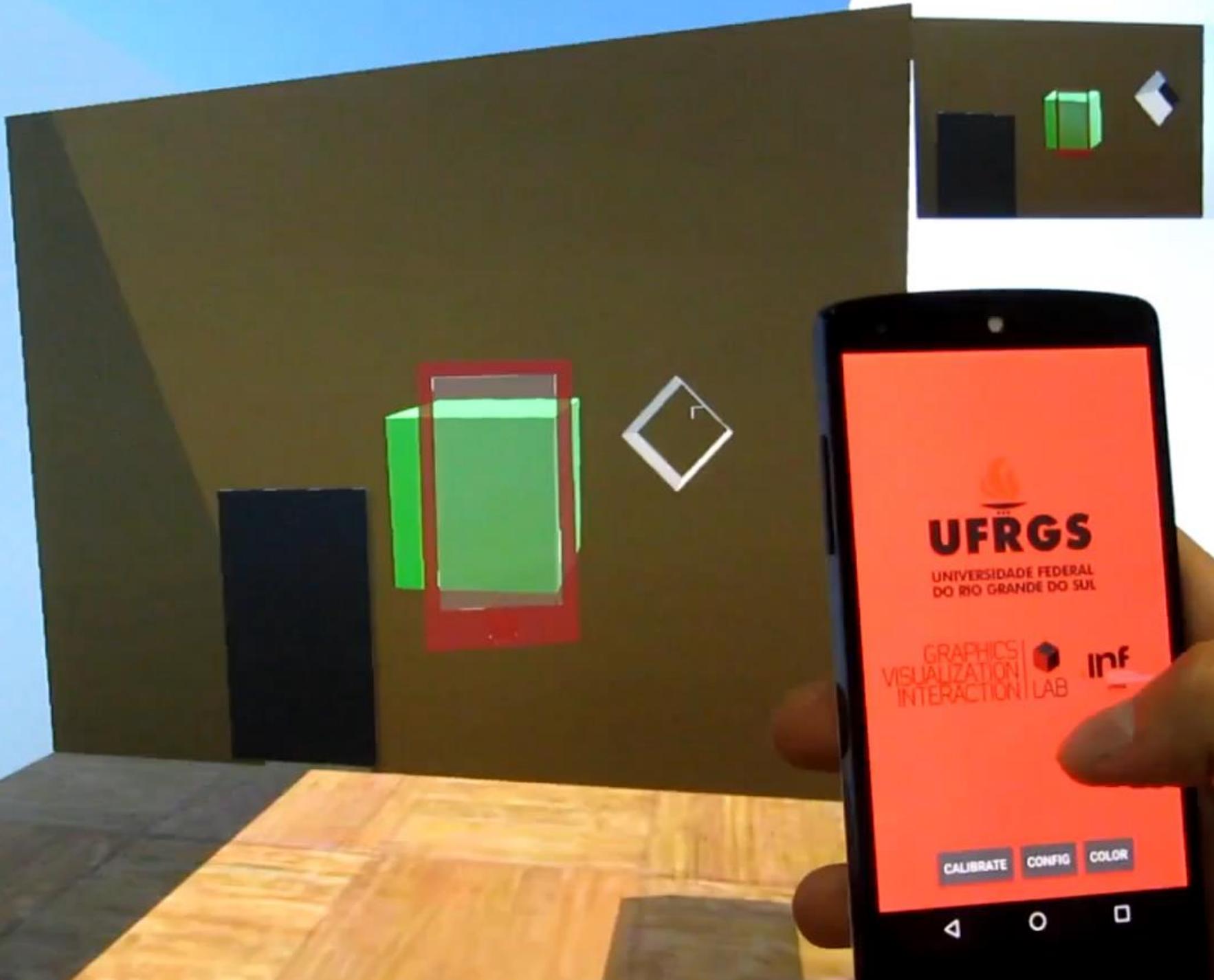
3D Manipulation Using Mobile Phones



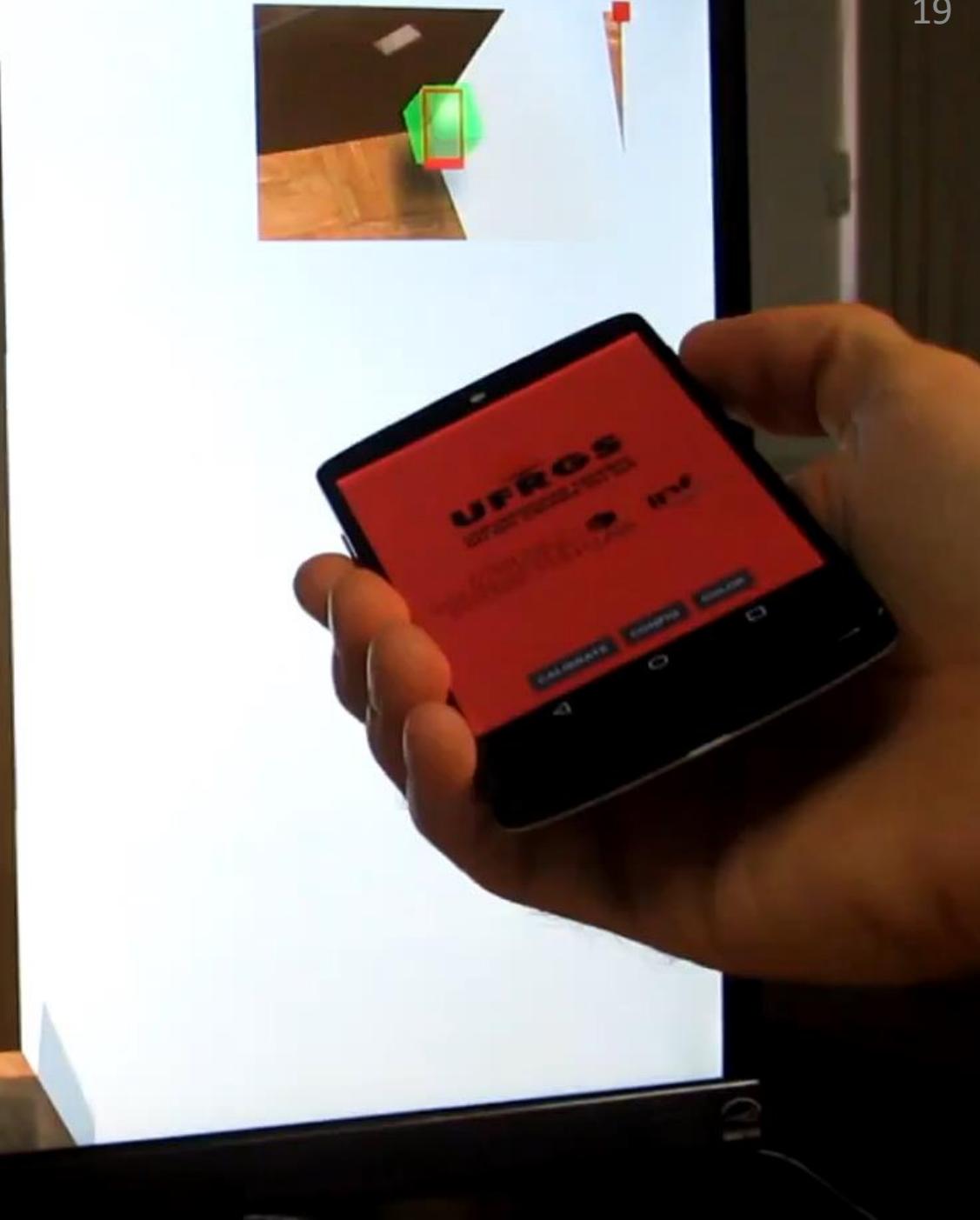
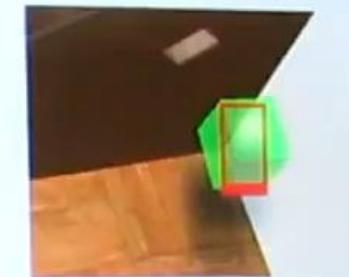
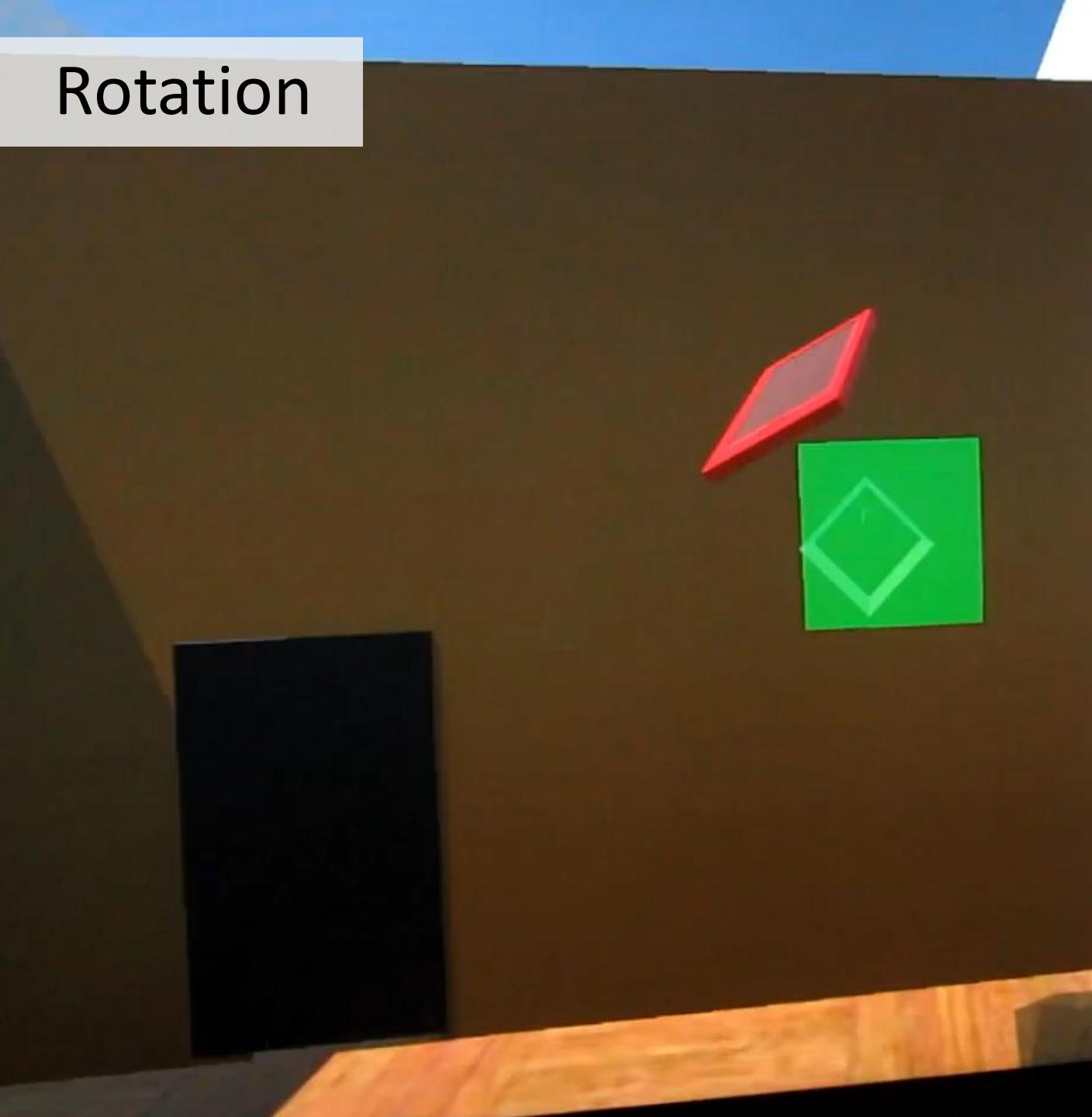
Interface Affordance



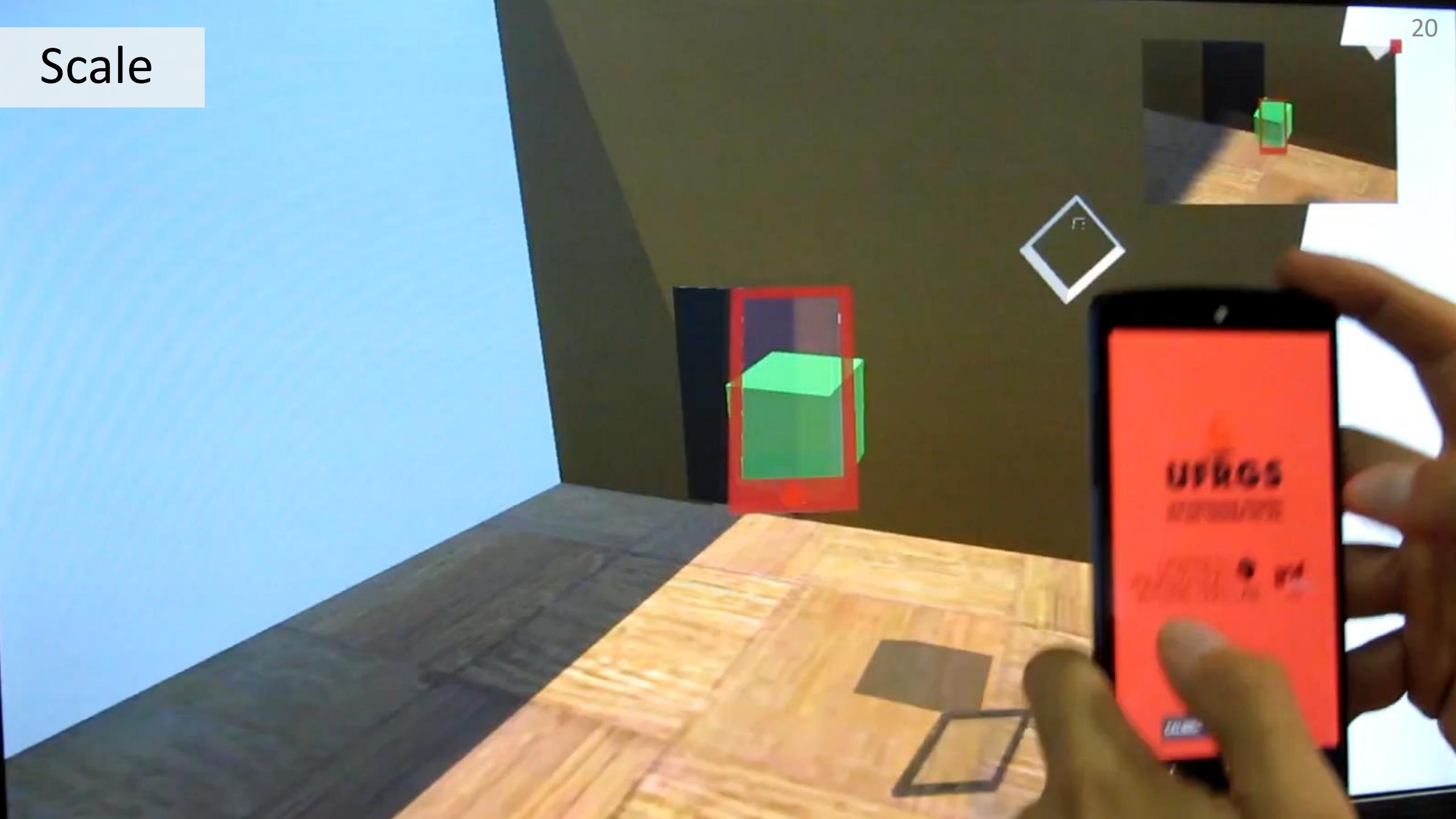
Translation



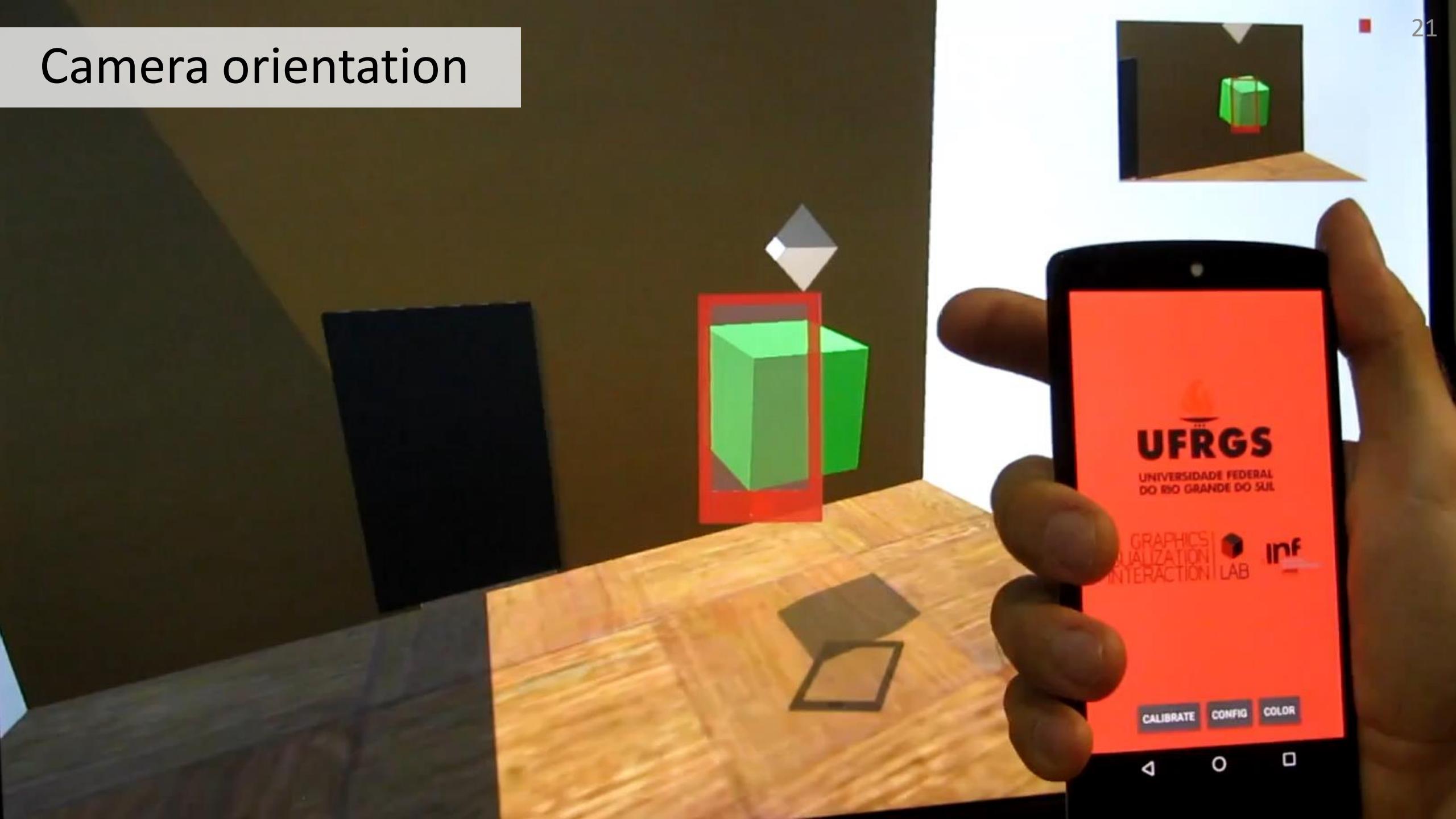
Rotation



Scale

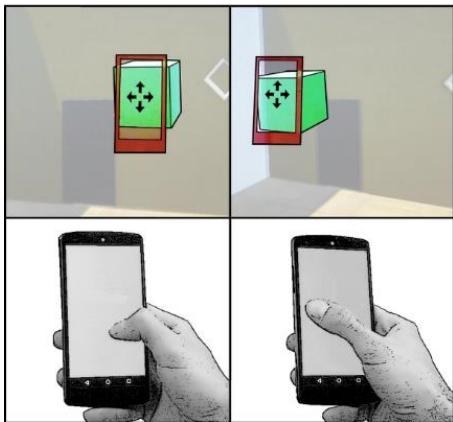


Camera orientation



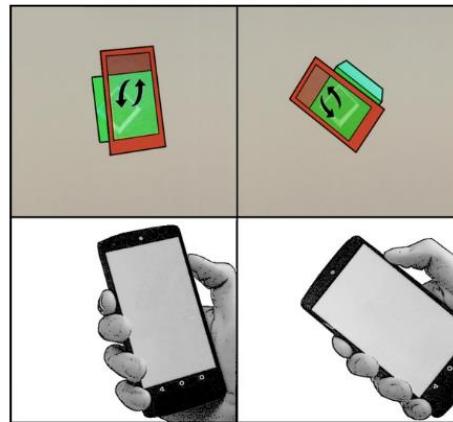
Transformations

Translation



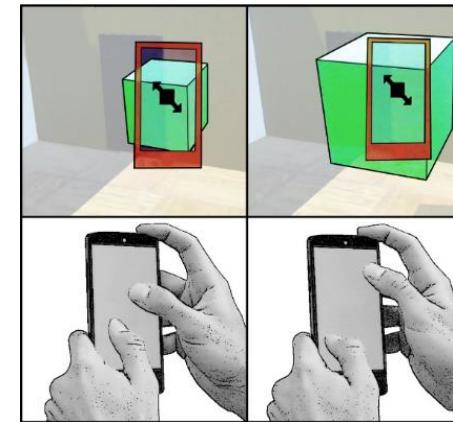
validated in *Katzakis et al., 2015*

Rotation



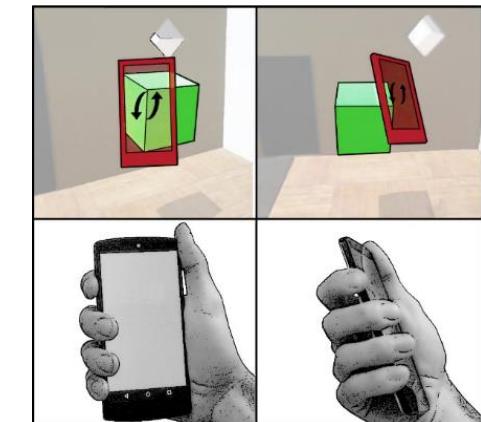
validated in *Bergé et al., 2015*

Scale



well known gesture

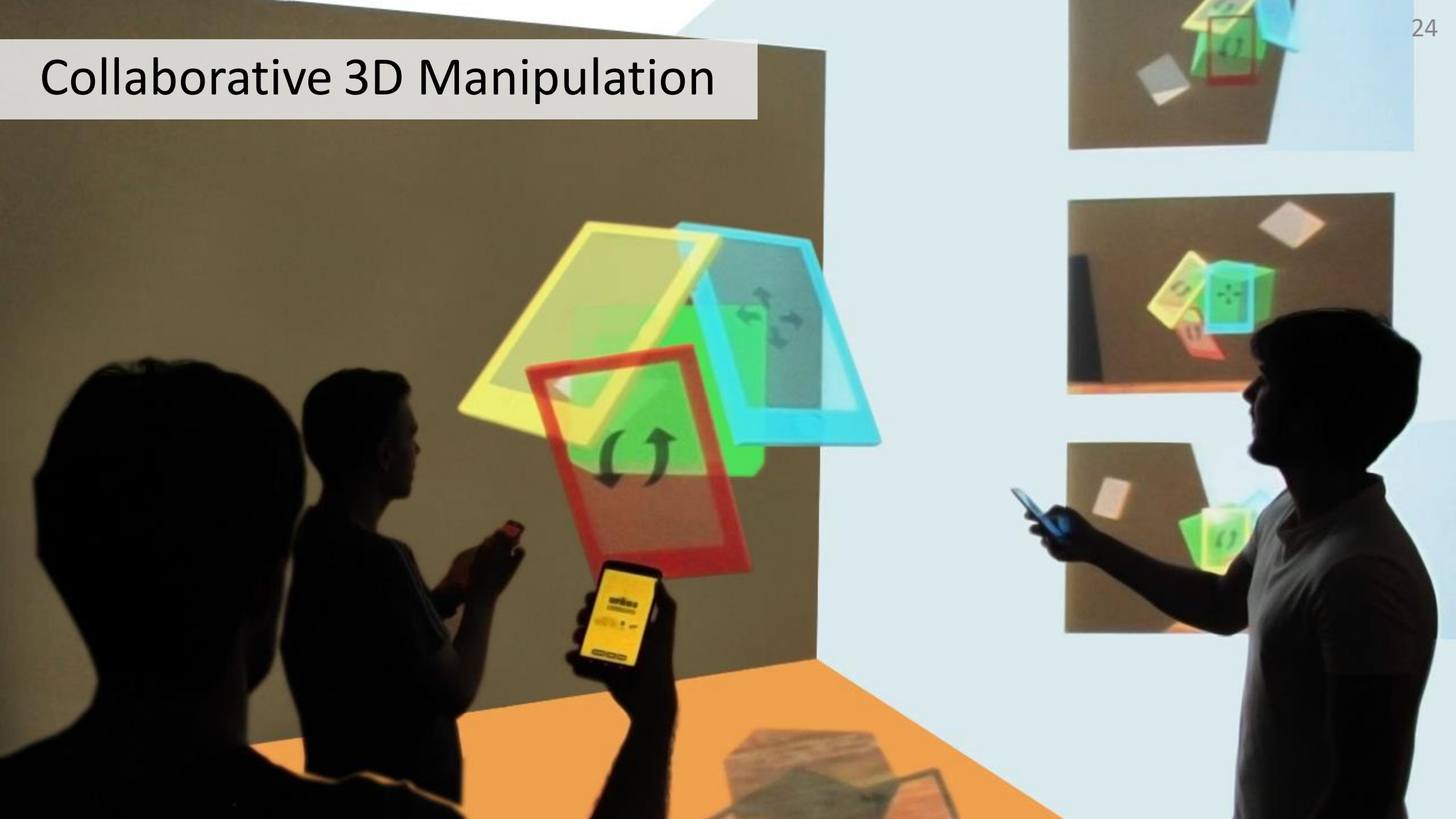
Camera Rotation



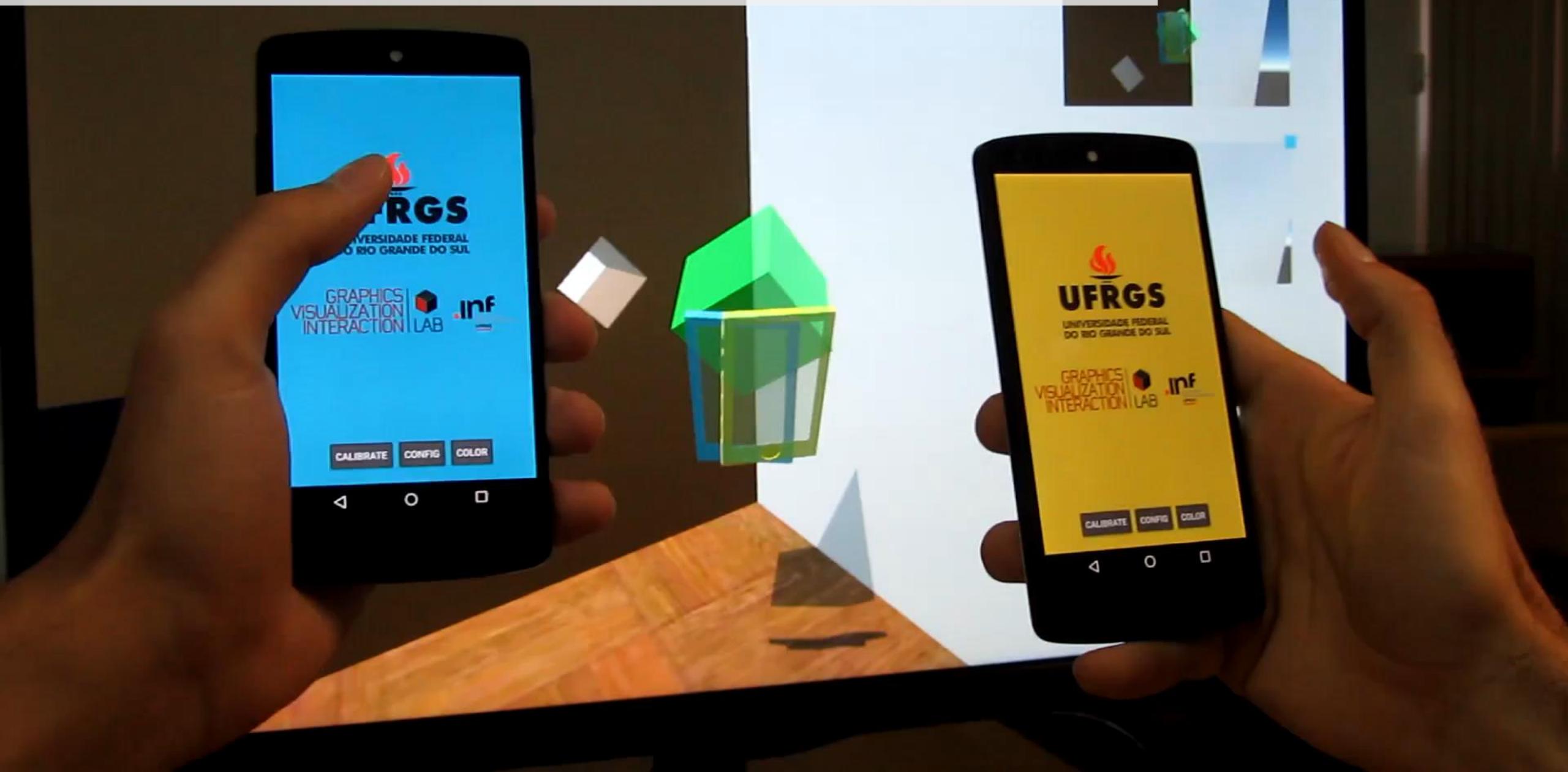
Collaborative 3D Manipulation



Collaborative 3D Manipulation



Collaborative actions negotiation



Collaborative actions negotiation



Is our technique suitable for collaborative tasks in VEs?

Collaborative 3D Manipulation Assessment

Public Demonstration



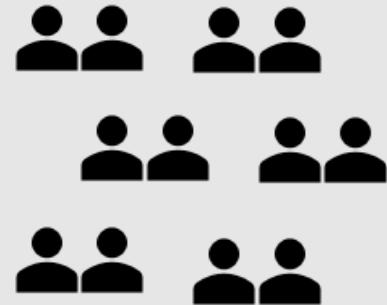
4 Demos

Over 100 people

Pair Work

Collaborative 3D Manipulation Assessment

Public Demonstration

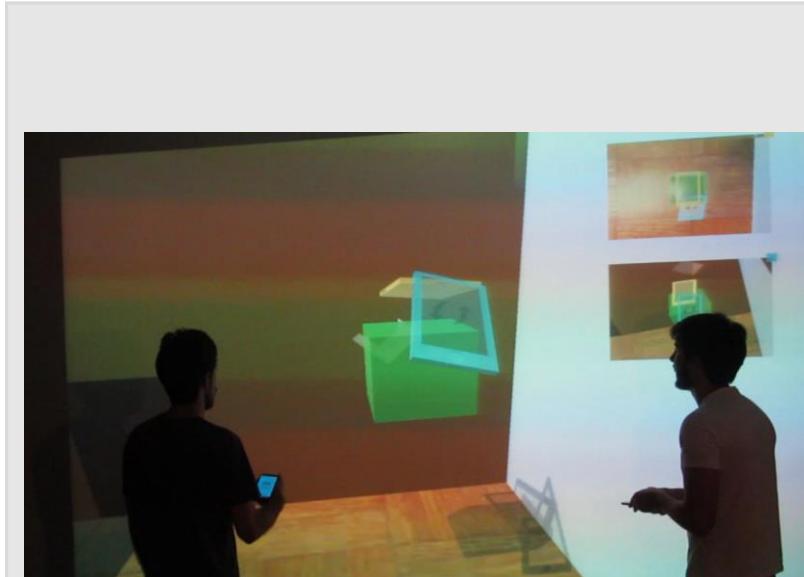


4 Demos

Over 100 people

Pair Work

Tunnel crossing



Docking



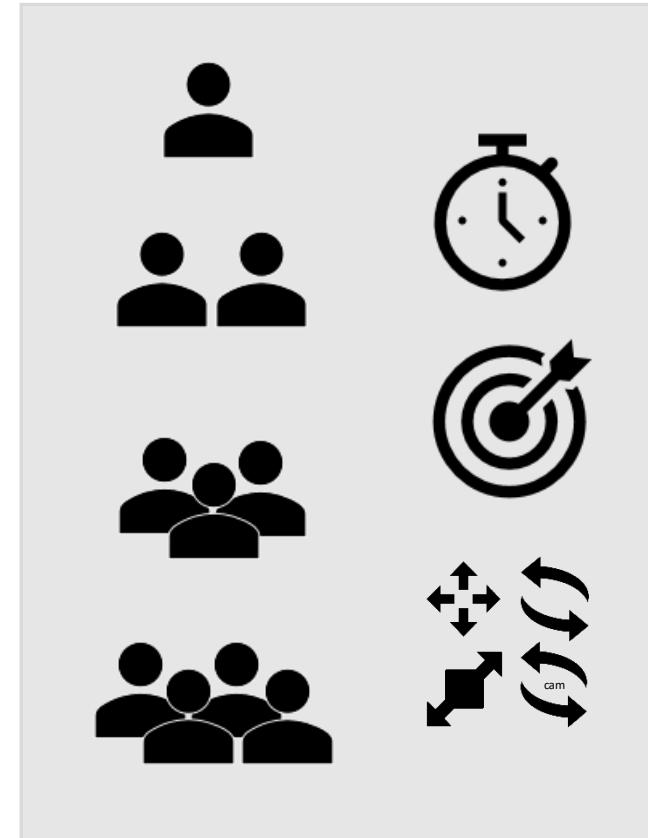
Is our technique suitable for collaborative tasks in VEs?



Does the performance increases accordingly to the number of members in the group?

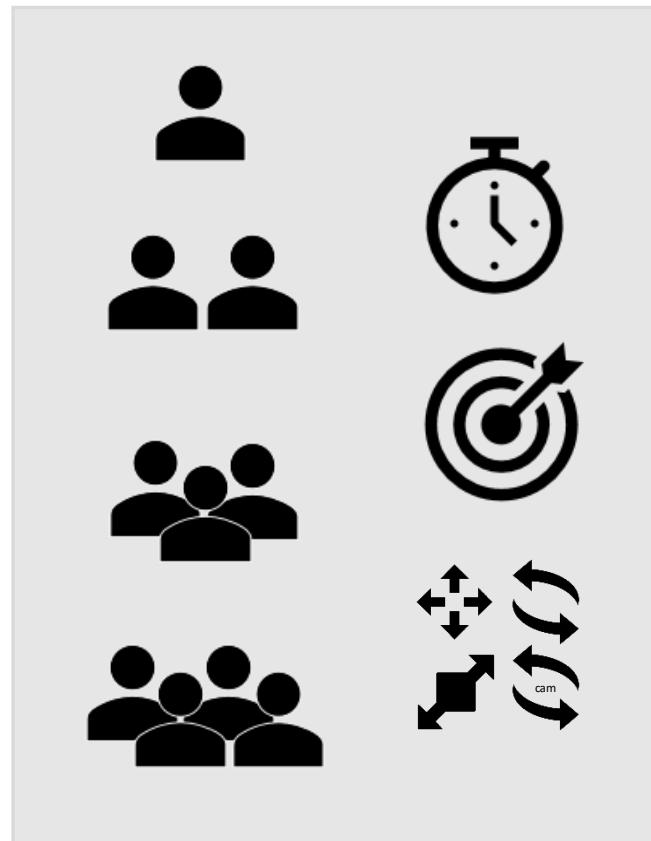
User Study – Design and Procedure

Group Size vs. Time and Accuracy

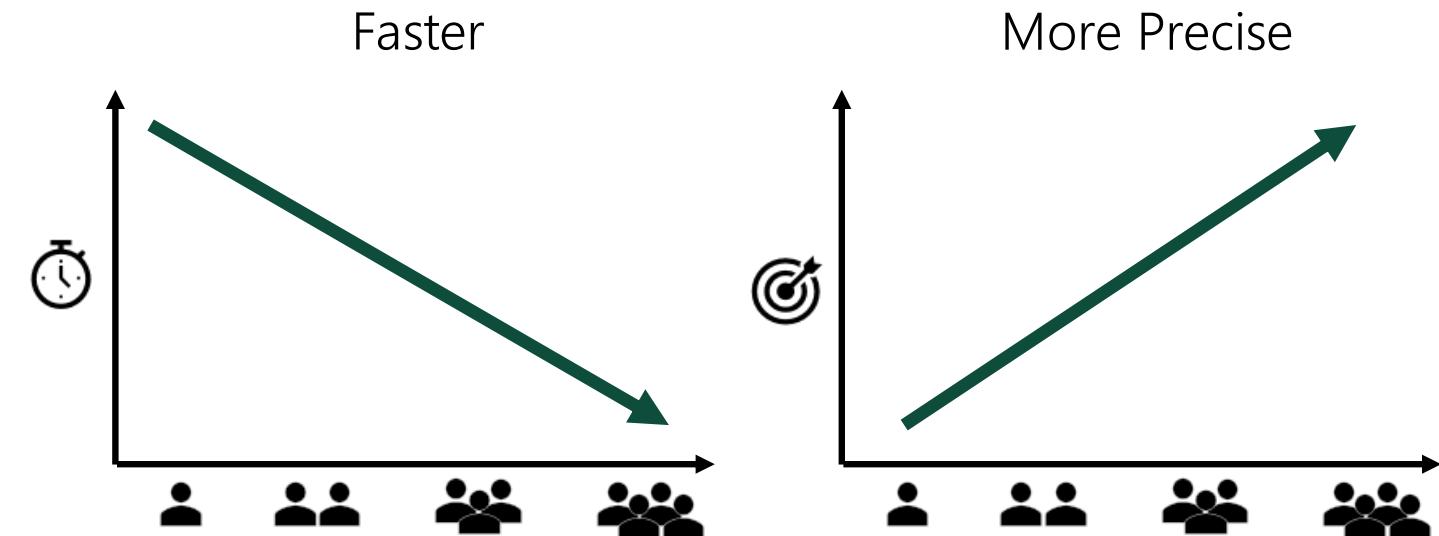


User Study – Main Hypothesis

Group Size vs. Time and Accuracy

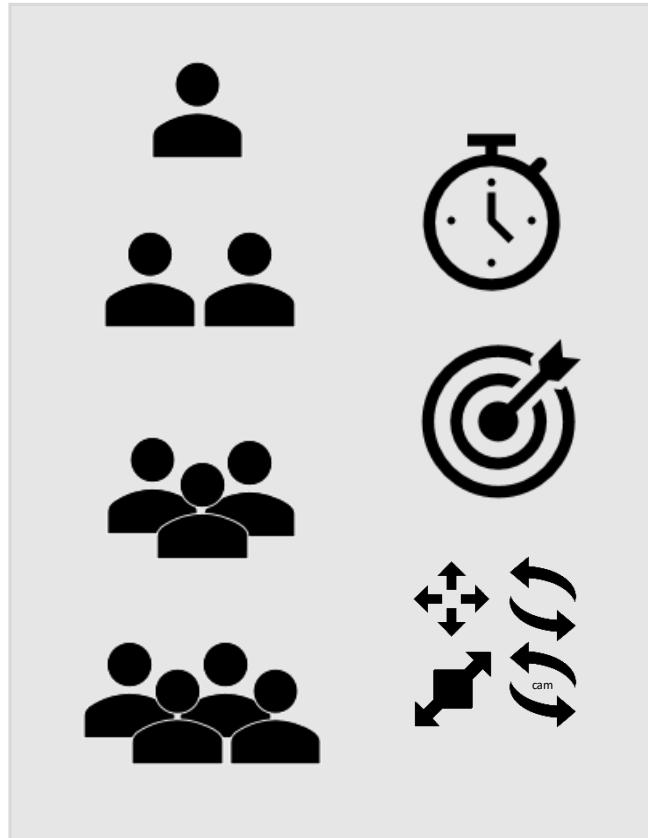


The overall **performance** of a team **increases** accordingly to the **number of members** in the group.



User Study – Design and Procedure

Group Size vs. Time and Accuracy

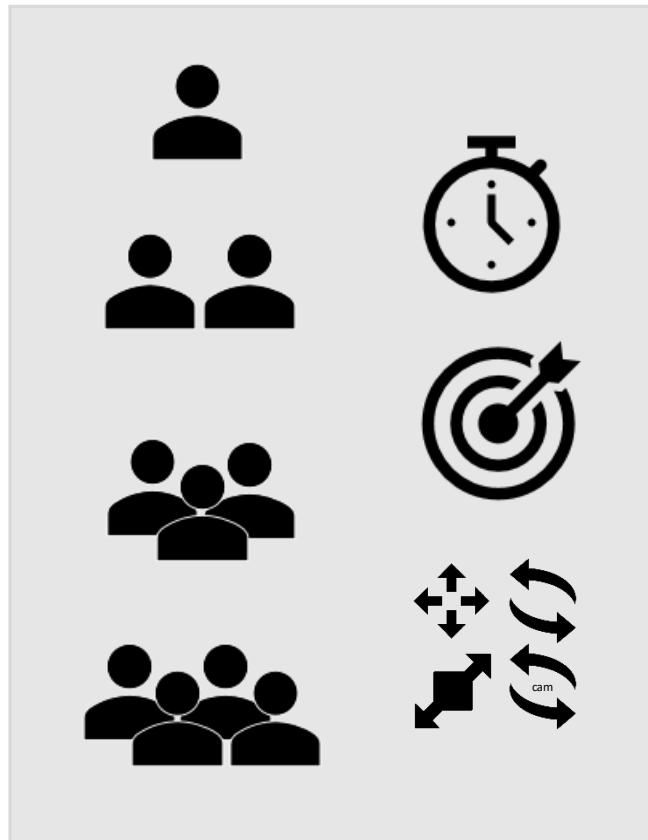


Evaluation Details

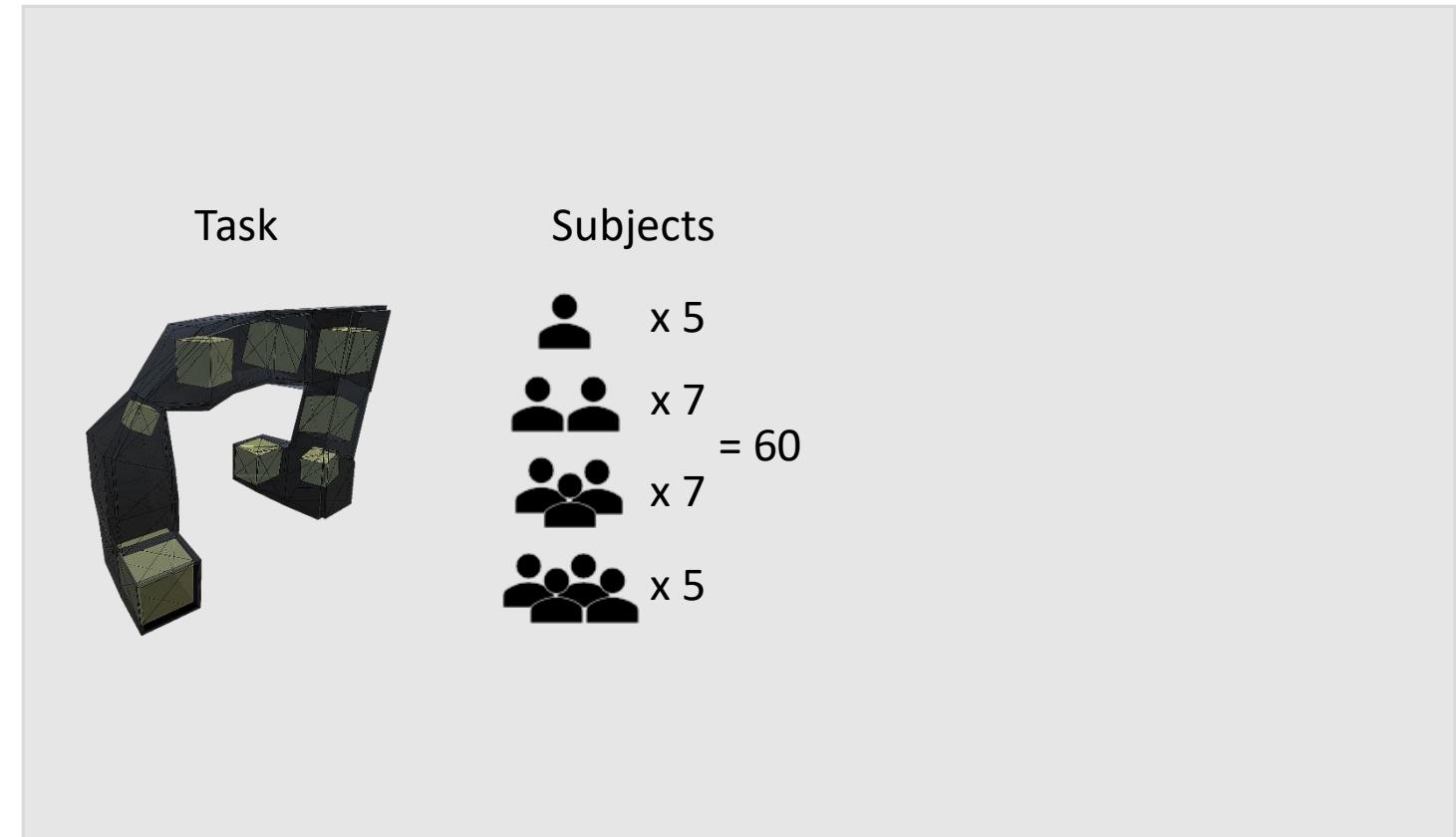


User Study – Design and Procedure

Group Size vs. Time and Accuracy

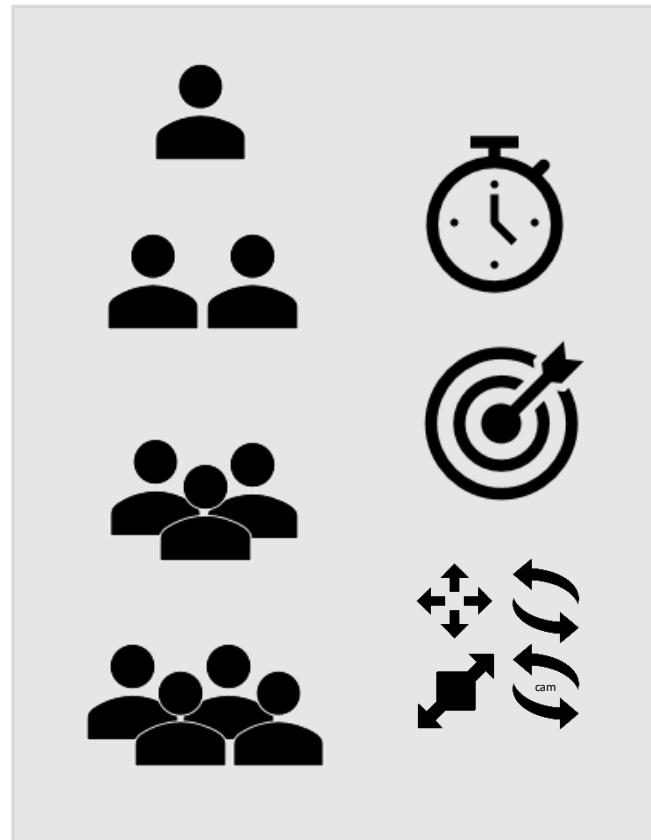


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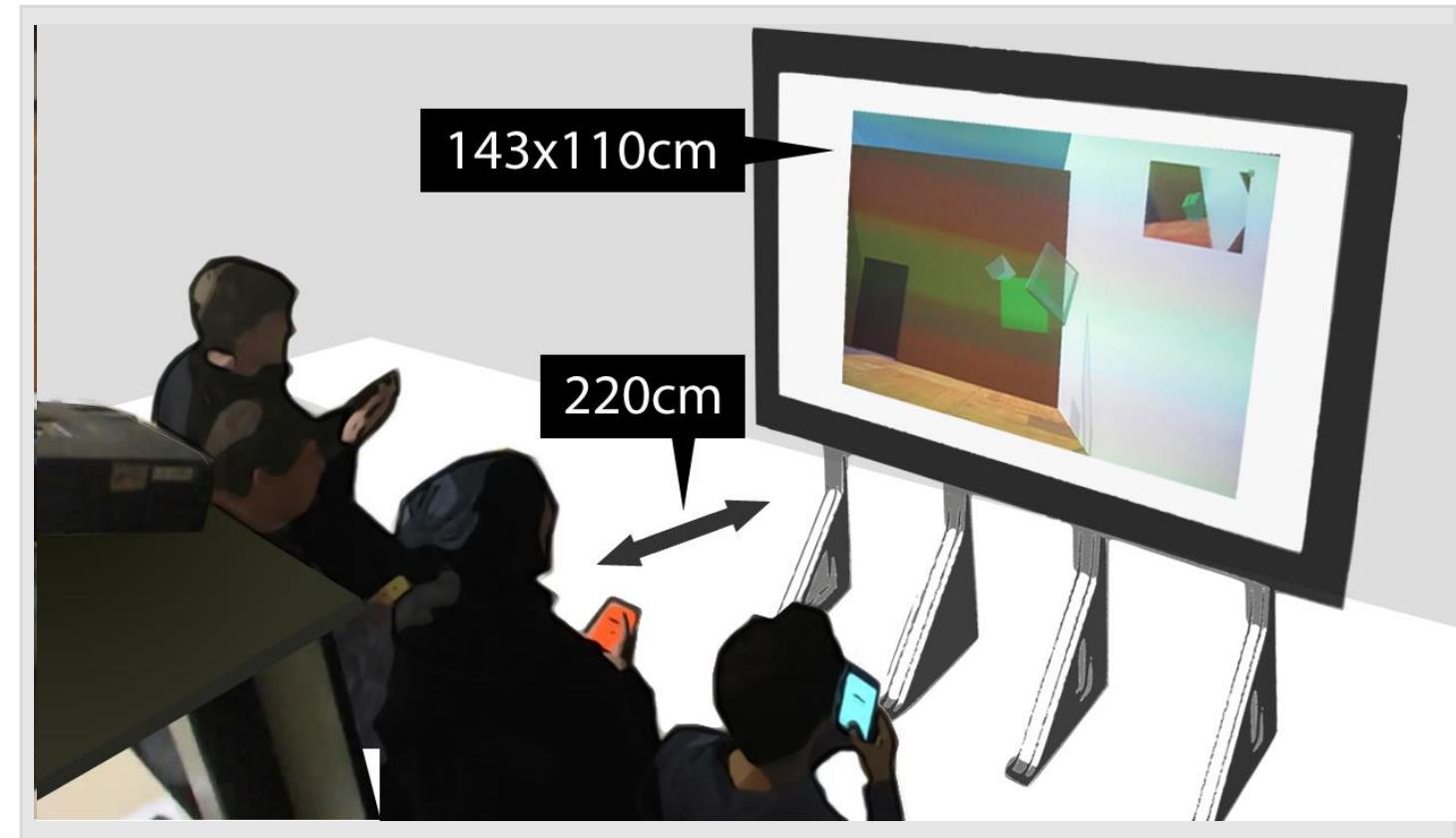


User Study – Design and Procedure

Group Size vs. Time and Accuracy

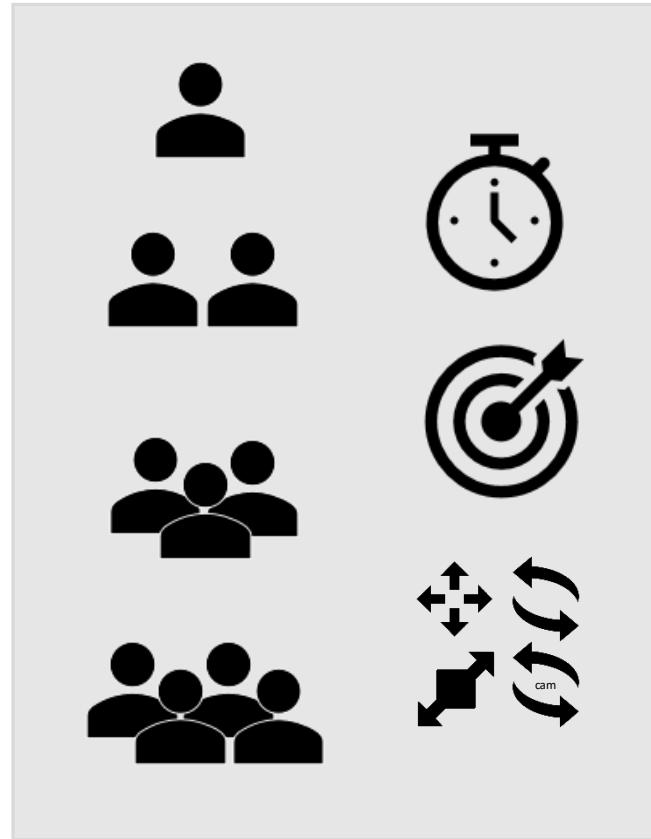


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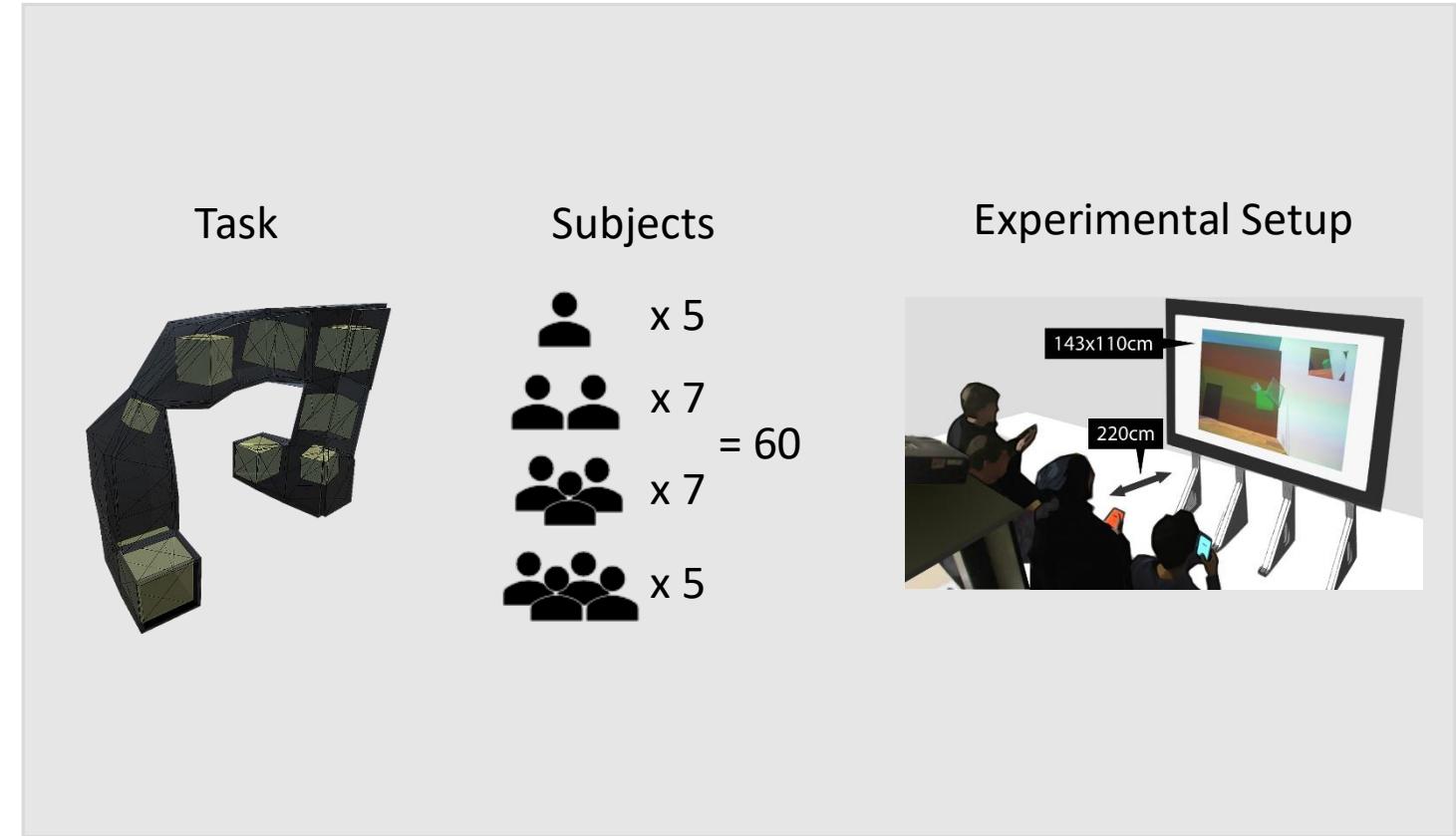


User Study – Design and Procedure

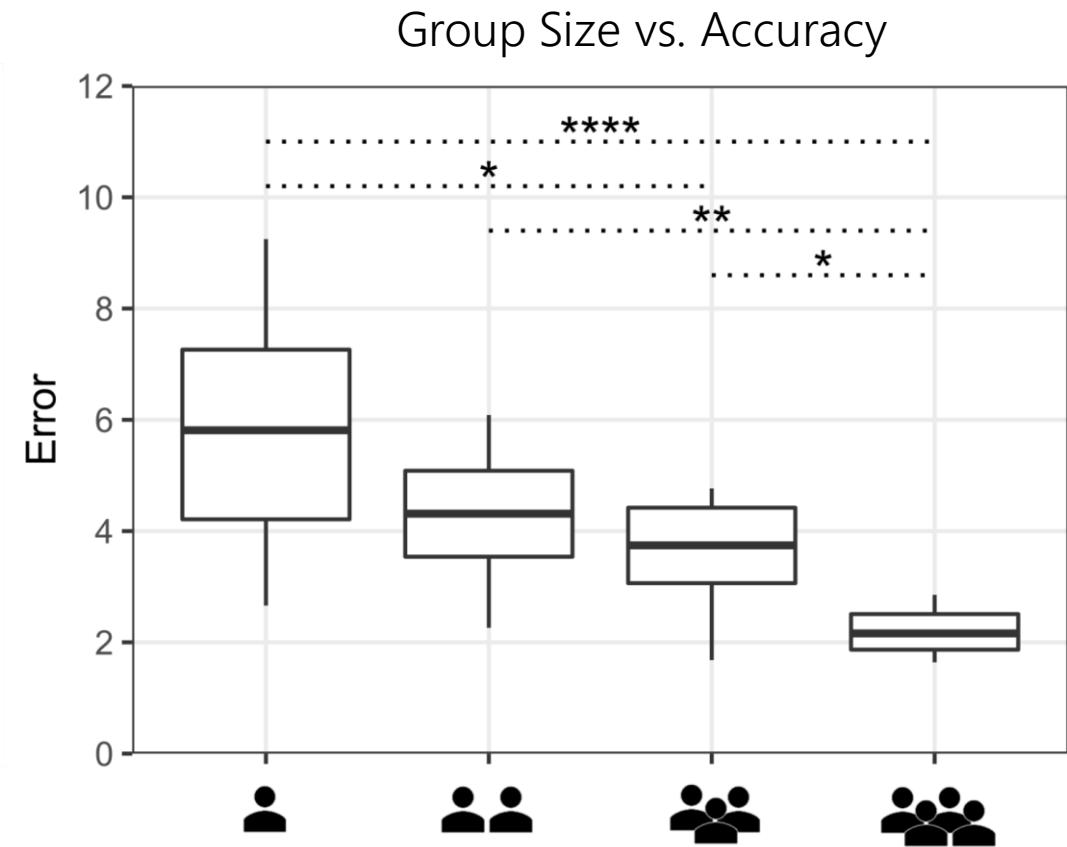
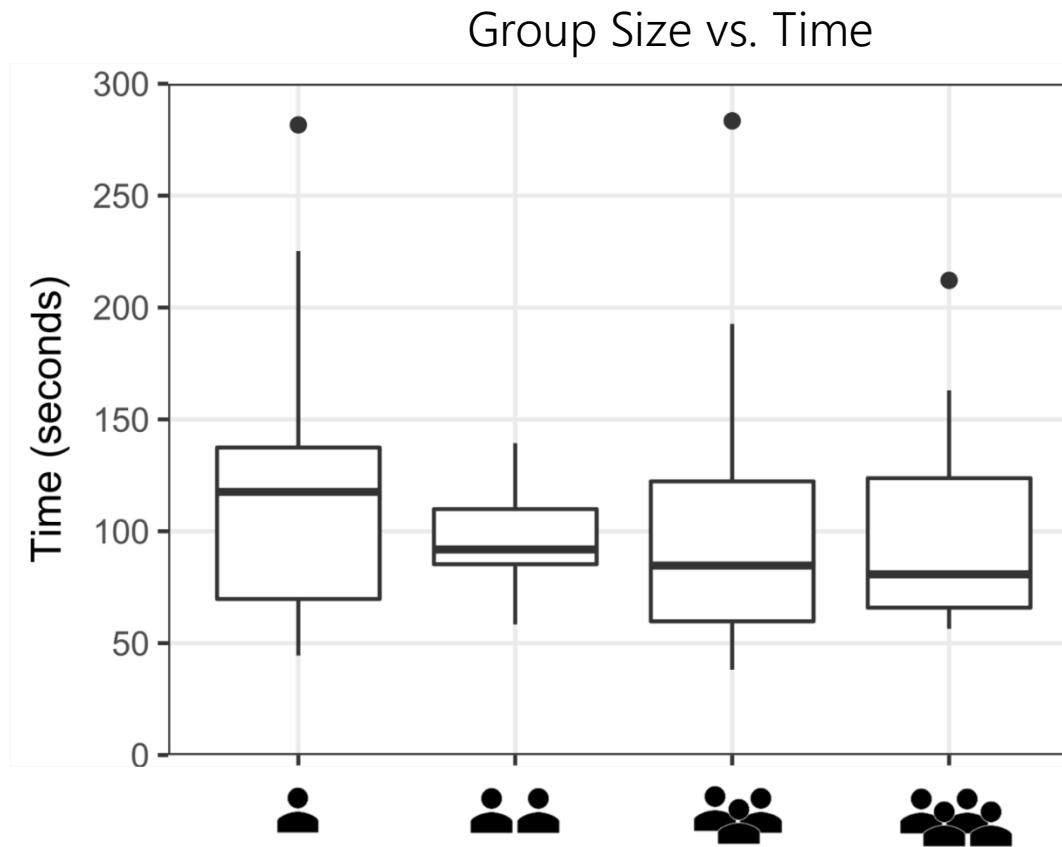
Group Size vs. Time and Accuracy



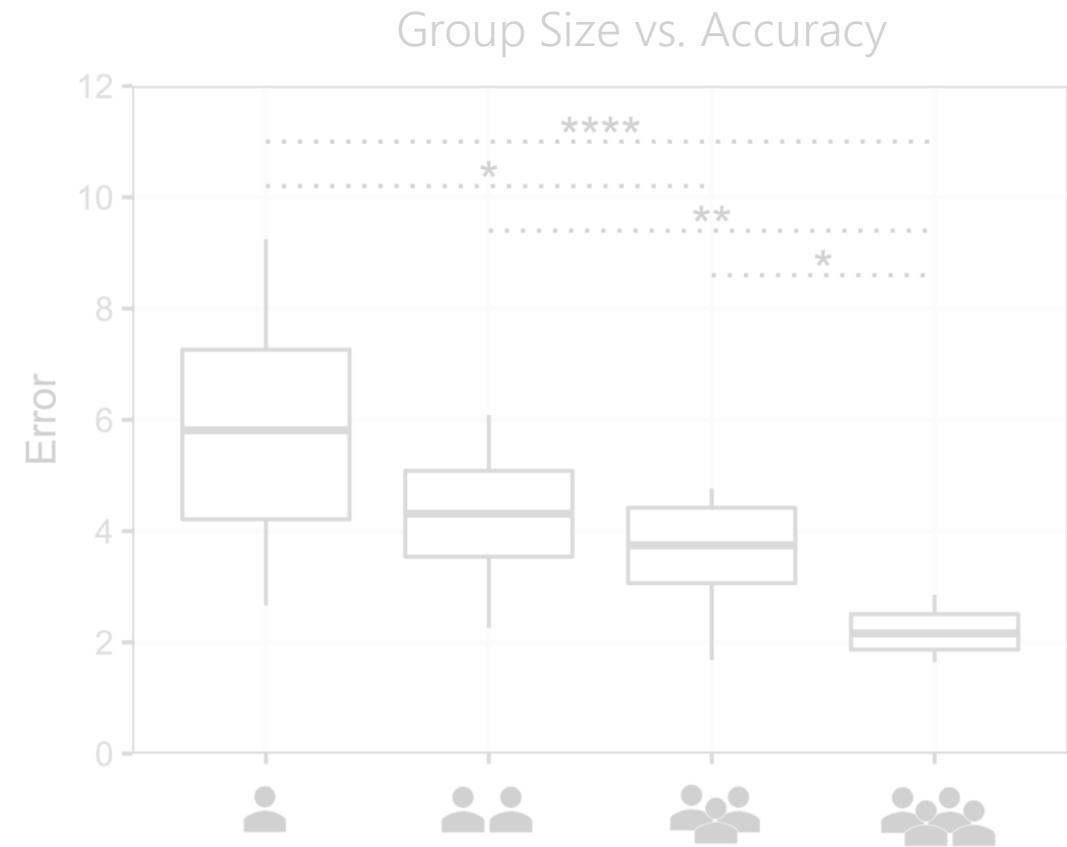
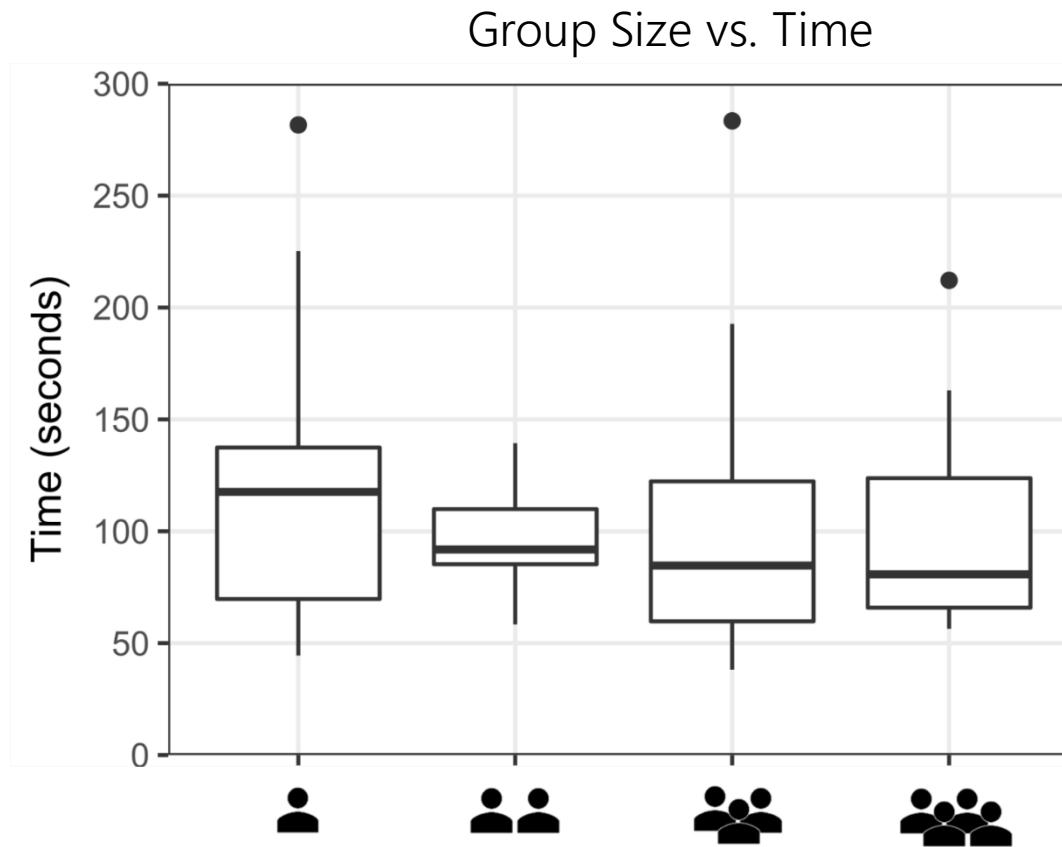
Evaluation Details



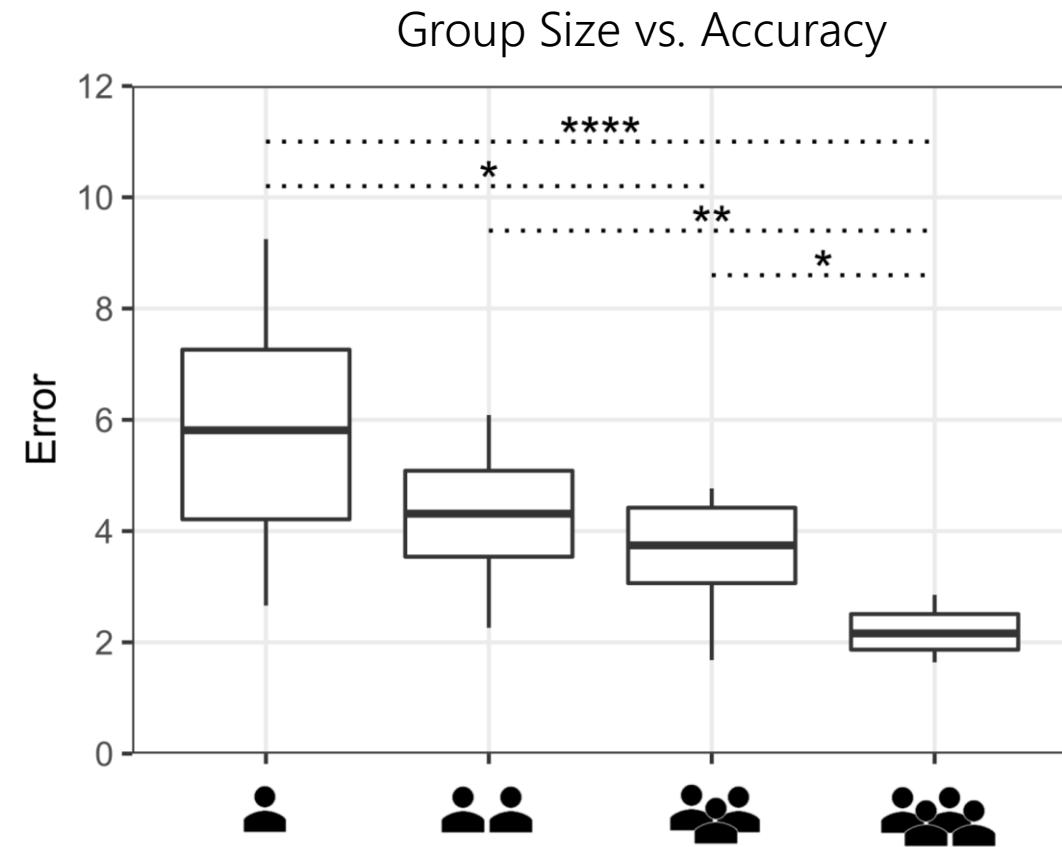
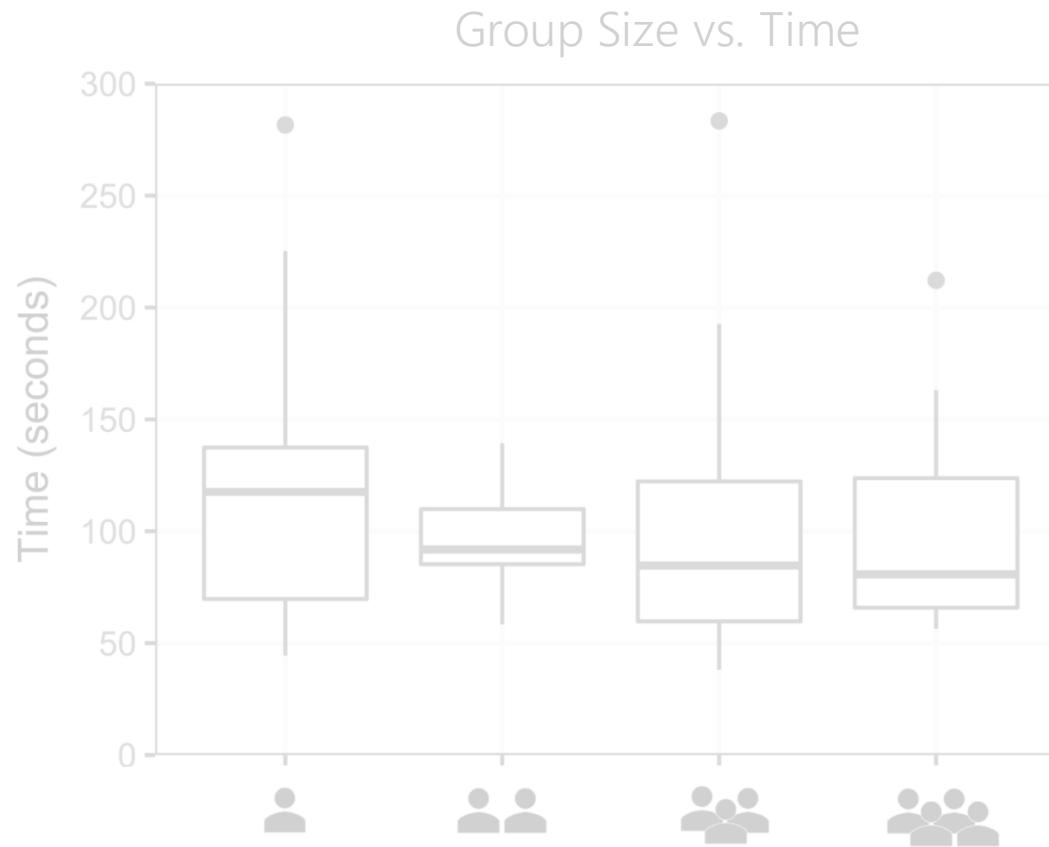
User Study – Group Size vs. Time and Accuracy



User Study – Group Size vs. Time

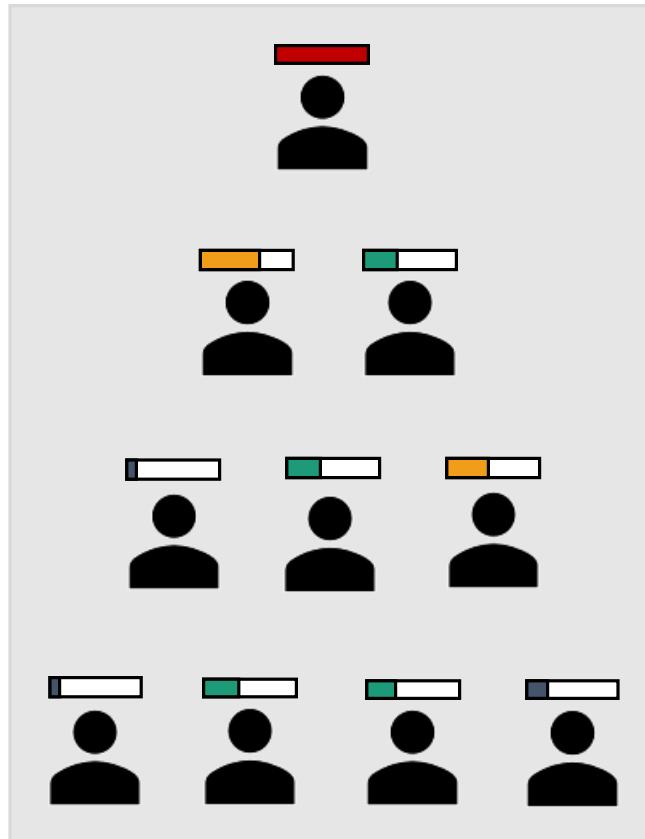


User Study – Group Size vs. Accuracy

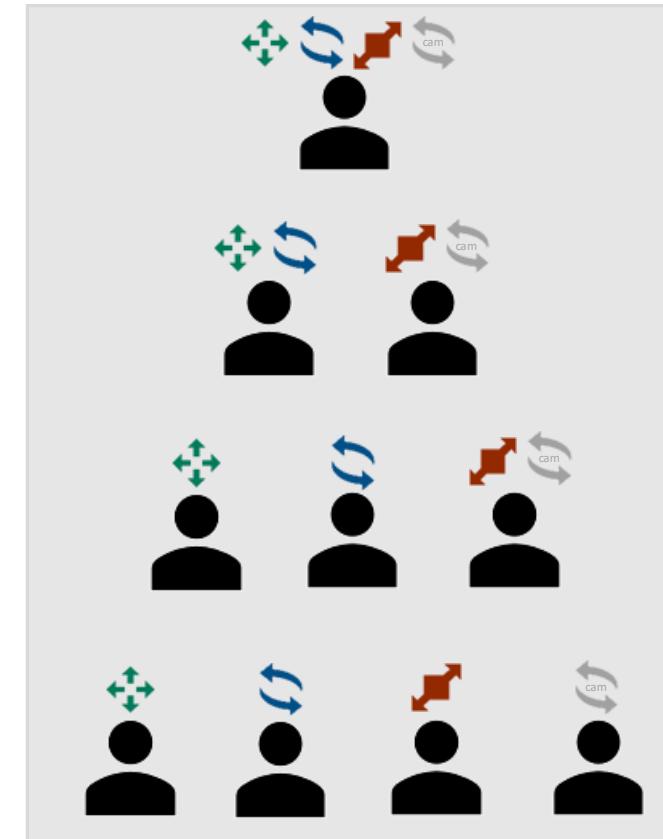


User Study – Accuracy vs. Work Strategies

Work distribution balance

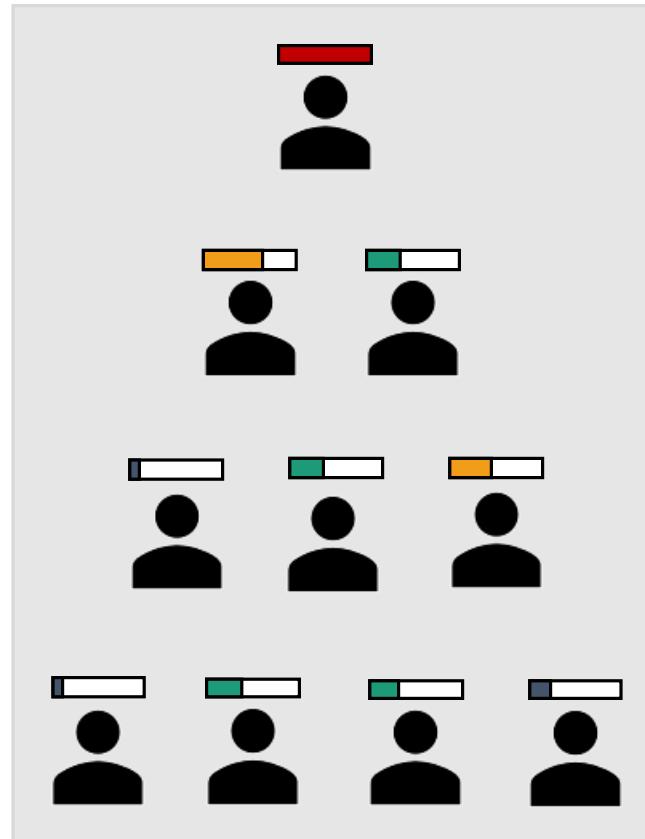


Work division

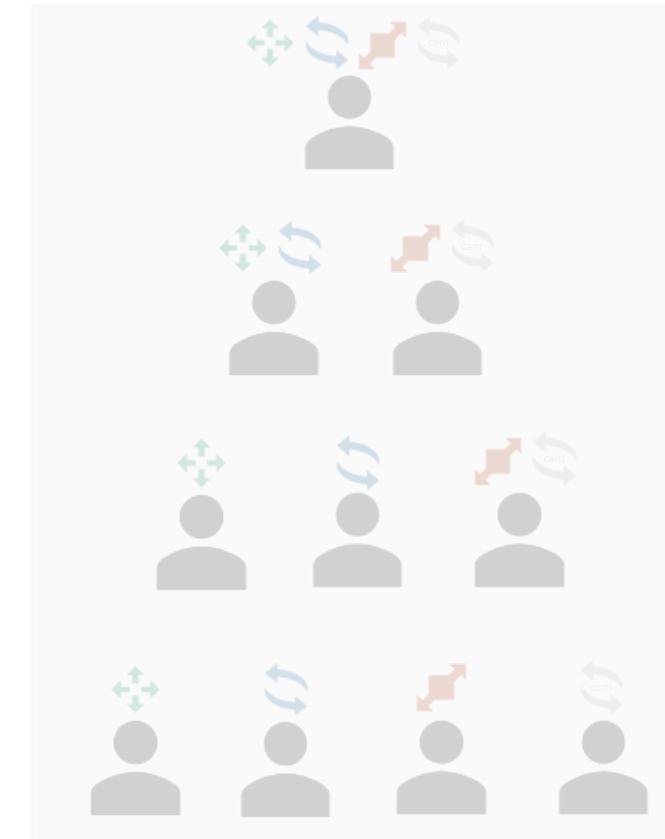


User Study – Accuracy vs. Work Strategies

Work distribution balance

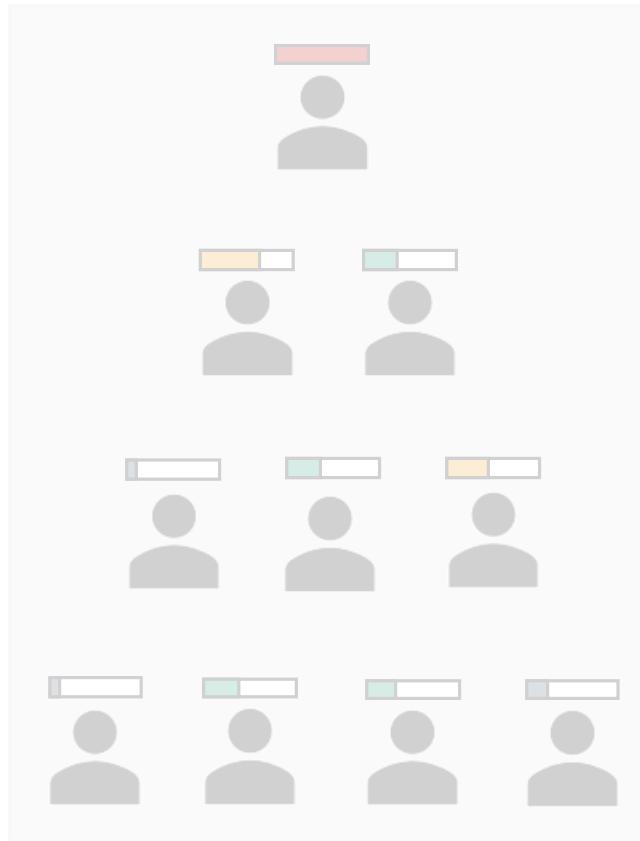


Work division

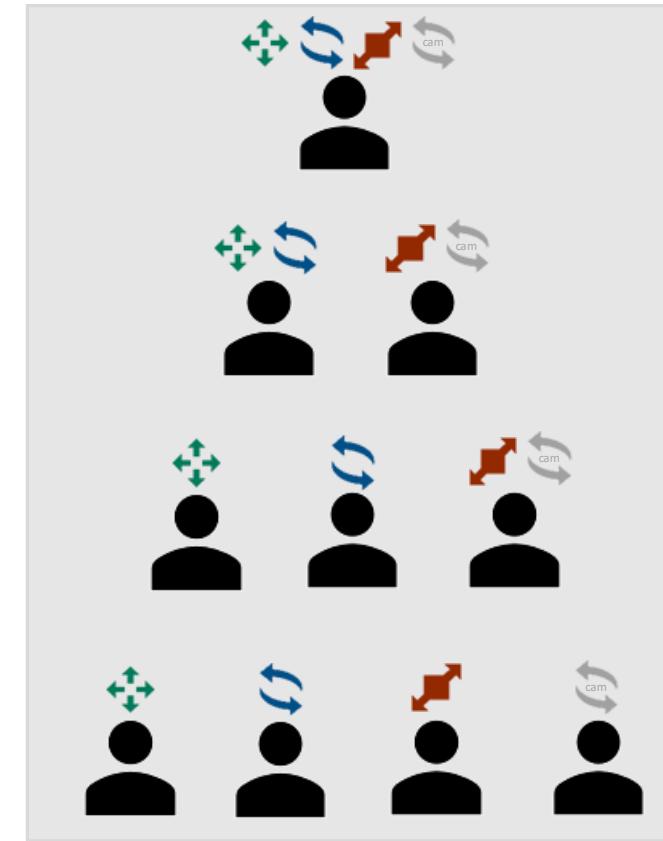


User Study – Accuracy vs. Work Strategies

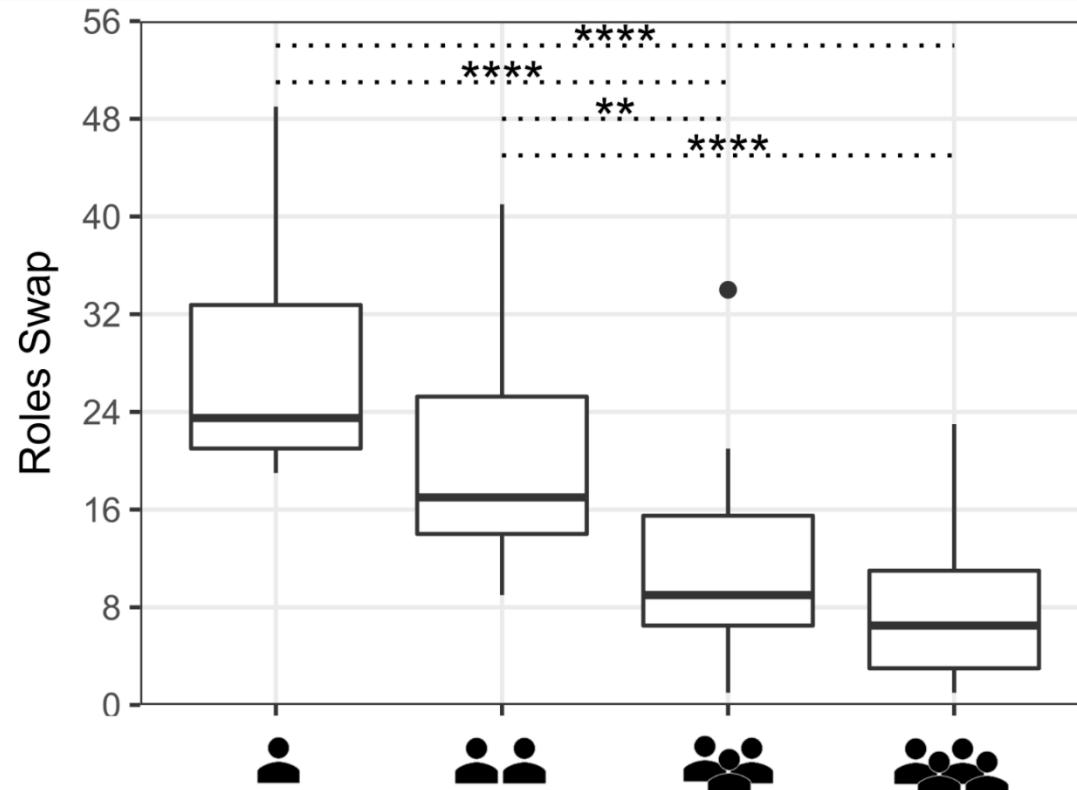
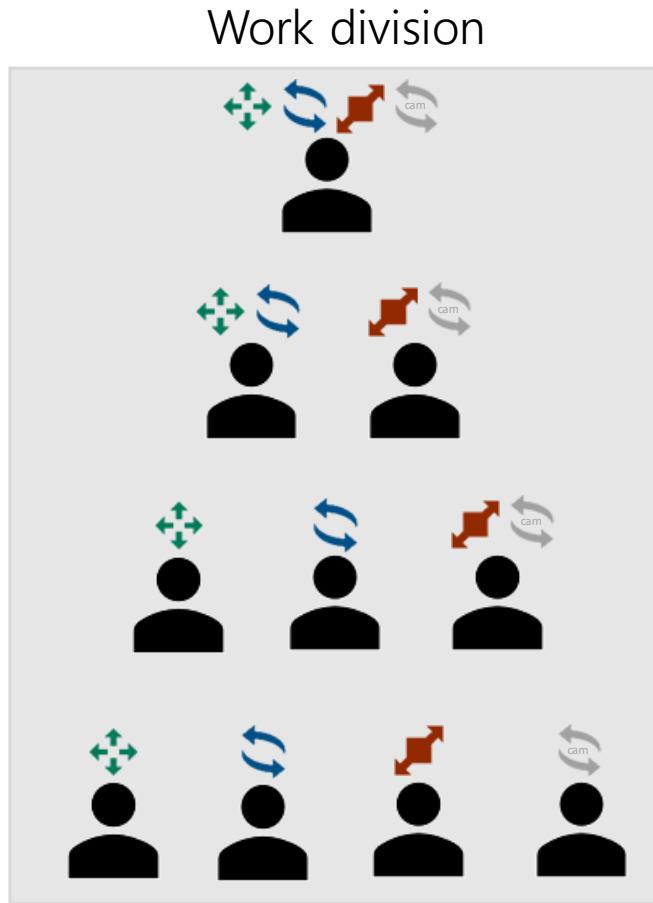
Work distribution balance



Work division

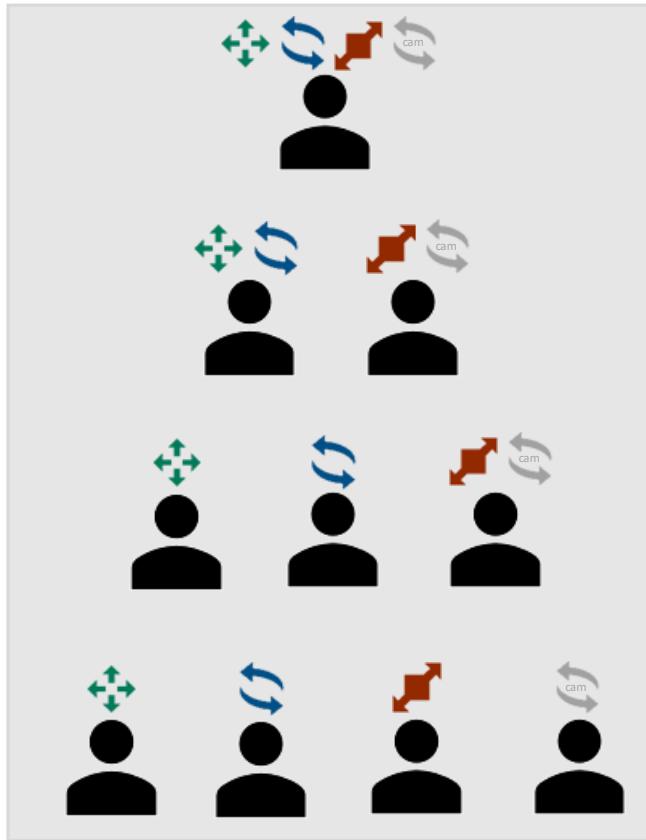


User Study – Work Division

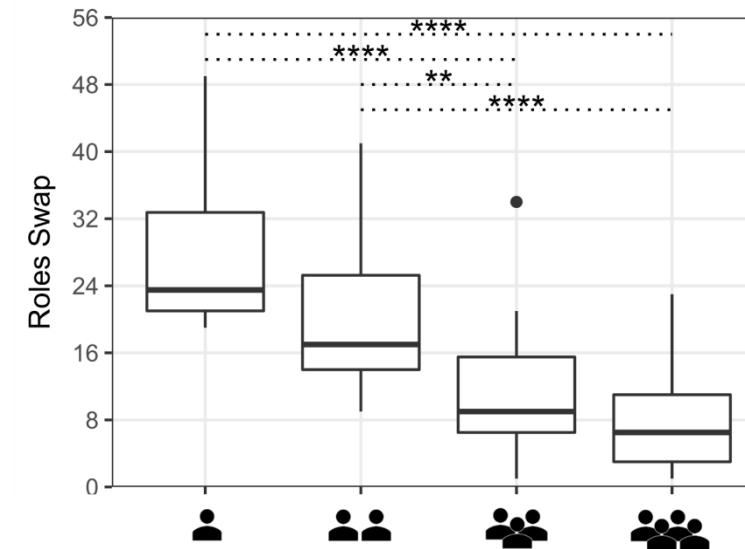


User Study – Work Division

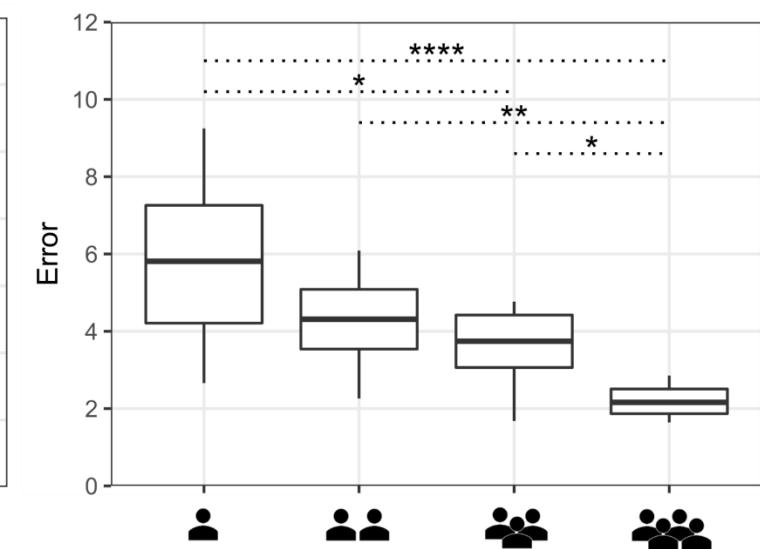
Work division



Work Division

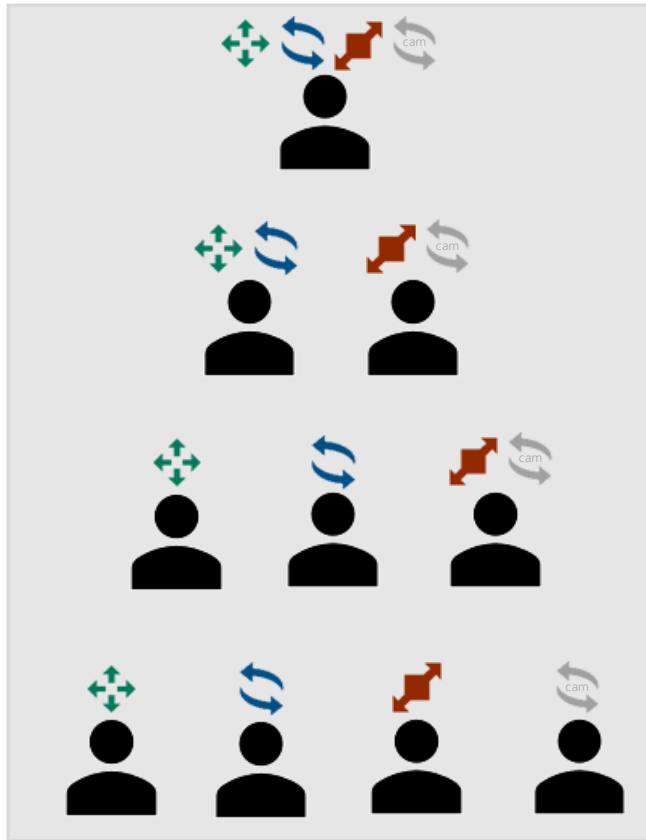


Accuracy

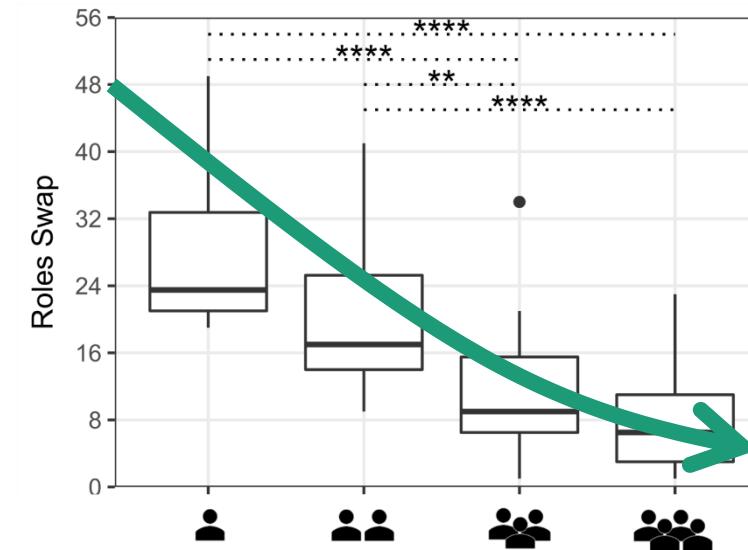


User Study – Work Division

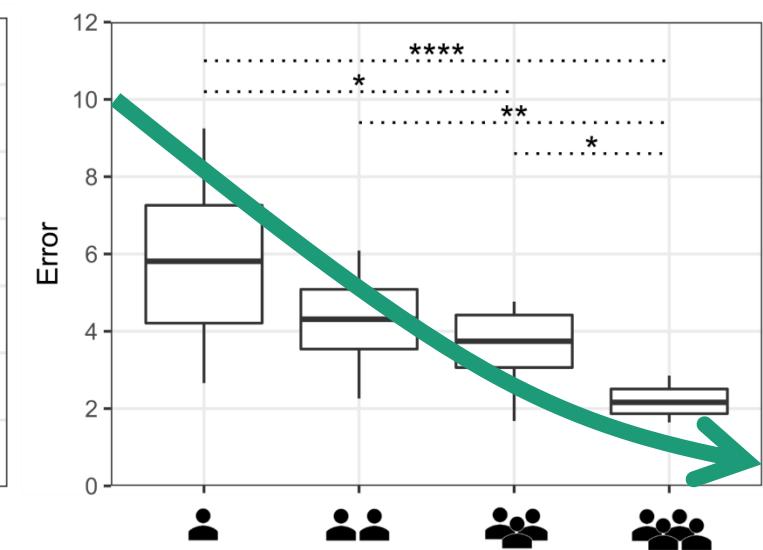
Work division



Work Division



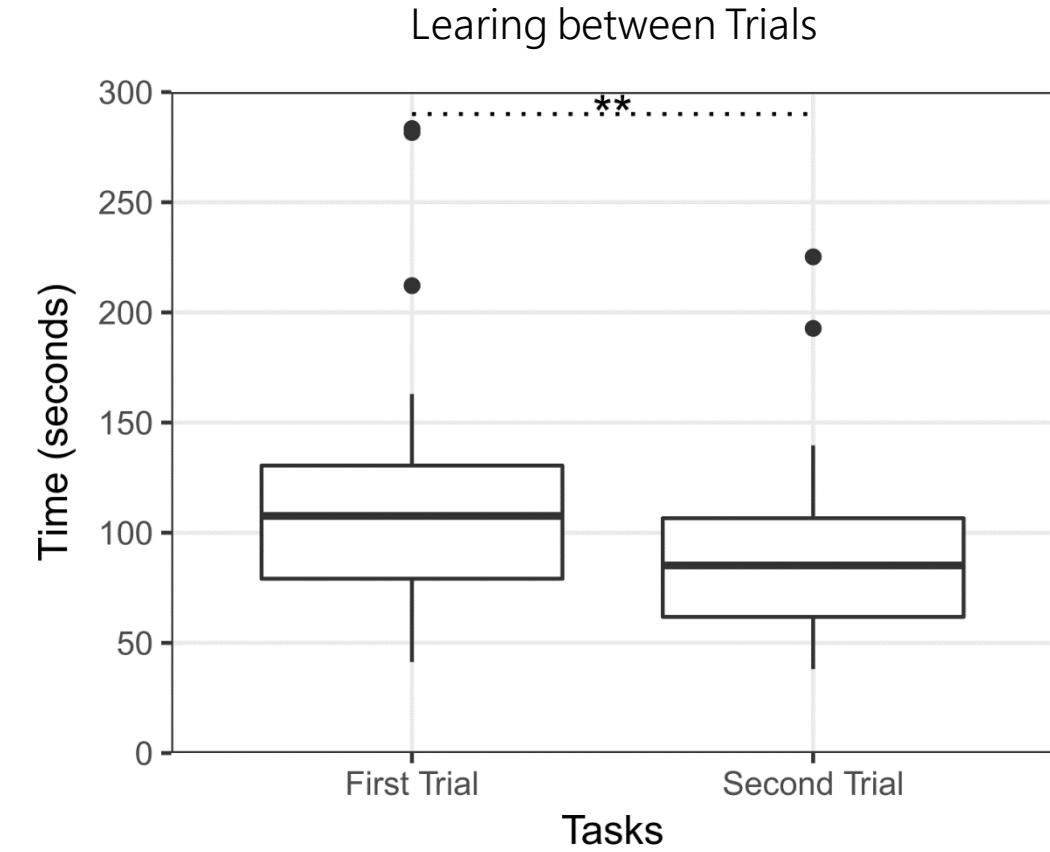
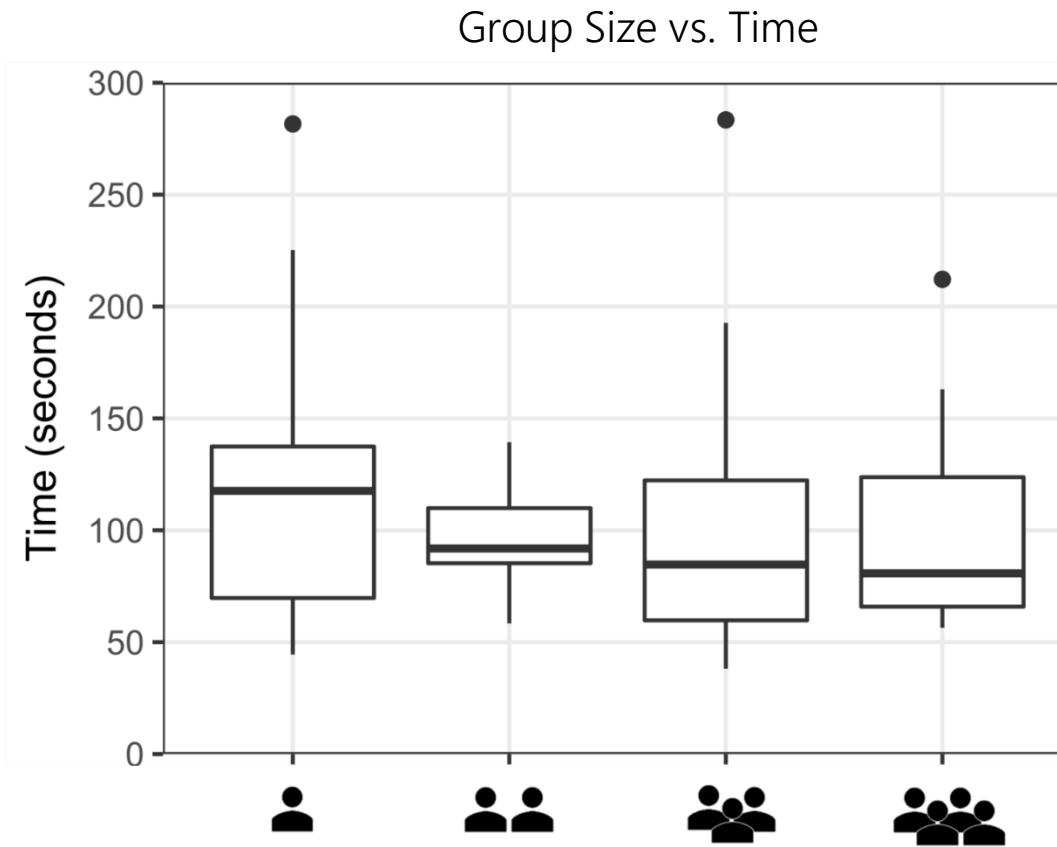
Accuracy



User Study – Work Division Strategies

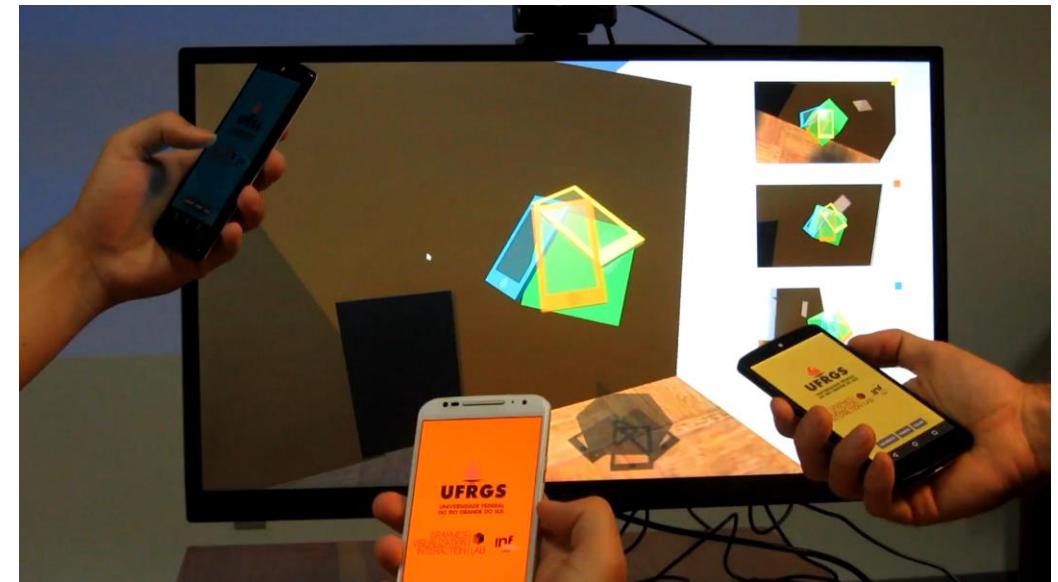


User Study – Learning Effect



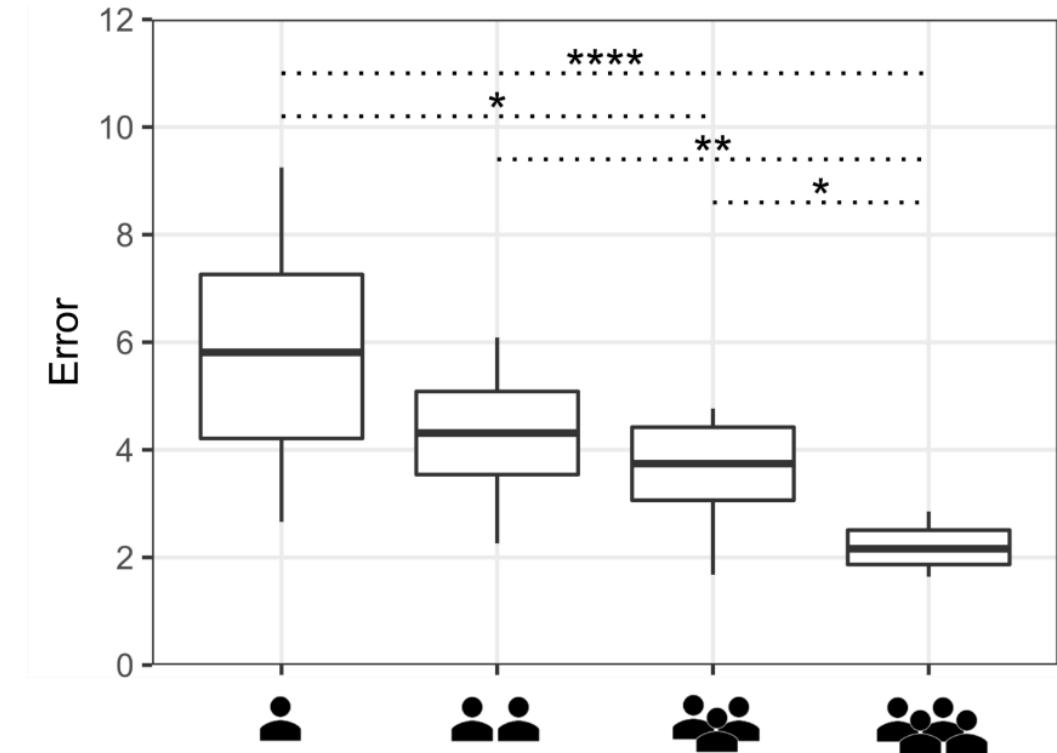
Results Summary

- Handheld devices are powerful tools for 3D collaborative tasks



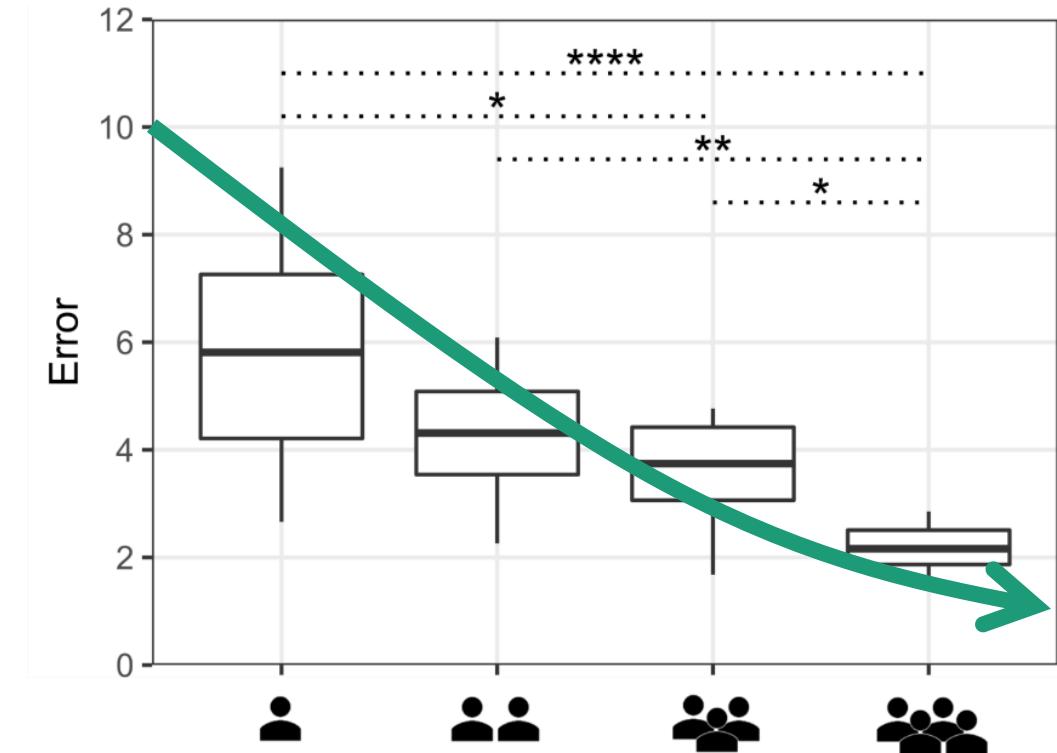
Results Summary

- Handheld devices are powerful tools for 3D collaborative tasks
- Teams are significantly more accurate than individuals



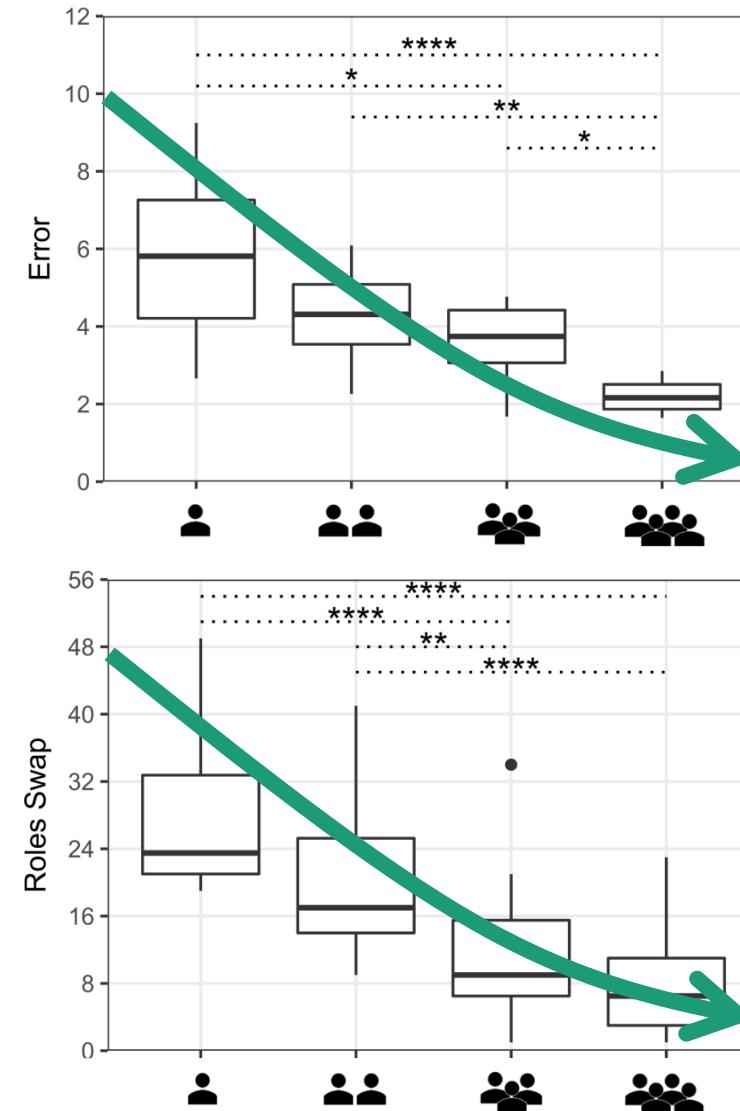
Results Summary

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Results Summary

- Handheld devices are powerful tools for 3D collaborative tasks
- Teams are significantly more accurate than individuals
- Accuracy increases with larger group sizes (up to 4)
- Teams are accurate because they divide the tasks



Future Work

- Controlled labor division

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- Explore other immersion scenarios



Future Work

- Controlled labor division
- Explore other immersion scenarios
- Collaboration in augmented reality



Design and Evaluation of a Handheld-based 3D User Interface for Collaborative Object Manipulation

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Teams are accurate because they divide the tasks