

The Inria logo features the word "Inria" in a red, cursive script font. Below it, the tagline "INVENTEURS DU MONDE NUMÉRIQUE" is written in a smaller, black, sans-serif font.The UMR IRISA logo consists of a blue circular icon with a white stylized shape inside, followed by the text "UMR IRISA" in a grey, sans-serif font.

Virtual Reality and Multi-Sensory Interaction

Master Research in Computer Science (SIF)

Ferran Argelaguet

ferran.argelaguet@inria.fr

Immersion, Presence and Embodiment

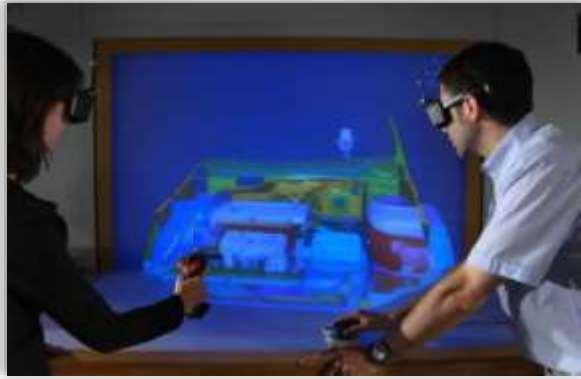
Immersive VR



Immersion

- Immersion was introduced as an objective characteristic of a VR system.
- The immersion of a VR system is given by the set of all valid actions supported by that VR system.
 - Action that will change the state of the virtual environment (an effective valid action)
 - Action that will change the perception of the virtual environment (a sensorimotor valid action).
- VR system that is less immersive (or has lower immersion) than another, more immersive (higher immersion) system can be simulated by the second system, but not vice versa.

More Immersive?



Feeling Present?

Presence

- Numerous definitions of presence exist...
 - is a psychological state or subjective perception in which even though part or all of an individual's current experience is generated by and/or filtered through human-made technology, part or all of the individual's perception fails to accurately acknowledge the role of the technology in the experience. Except in the most extreme cases, the individual can indicate correctly that s/he is using the technology, but at **some level** and to **some degree**, her/his perceptions overlook that knowledge and objects, events, entities, and environments are perceived as if the technology was not involved in the experience. Experience is defined as a person's observation of and/or interaction with objects, entities, and/or events in her/his environment; perception, the result of perceiving, is defined as a meaningful interpretation of experience.
 - ...
 - “The feeling of being there”

Presence

- Numerous definitions of presence exist...
 - “The feeling of being there”

- Place Illusion (PI)
 - The illusion of being in a place in spite of the sure knowledge that you are not there.

- Plausibility Illusion (Psi)
 - The illusion that what is apparently happening is really happening, in spite of the sure knowledge that it is not.

Measuring Presence

➤ Self-reports

- **Slater-Usoh-Steed (SUS) questionnaire**
- Witmer-Singer Presence Questionnaire (PQ)
- Igroup Presence Questionnaire (IPQ)
- ITC-Sense of Presence Inventory (ITC-SOPI)
- Lombard and Ditton questionnaire

Rosakranse, C. and Oh, S. Y. (2014). Measuring presence: The use trends of five canonical presence questionnaires from 1998-2012. In Proceedings of the International Society for Presence Research 2014. International Society for Presence Research.

Measuring Presence – SUS Questionnaire (1/2)

- Please rate your sense of being in the virtual environment, on a scale of 1 to 7, where 7 represents your normal experience of being in a place.
- To what extent were there times during the experience when the virtual environment was the reality for you?
- When you think back to the experience, do you think of the virtual environment more as images that you saw or more as somewhere that you visited?

Usoh, M., Catena, E., Arman, S., and Slater, M. (2000). Using presence questionnaires in reality. *Presence: Teleoperators and Virtual Environments*, 9:497-503.

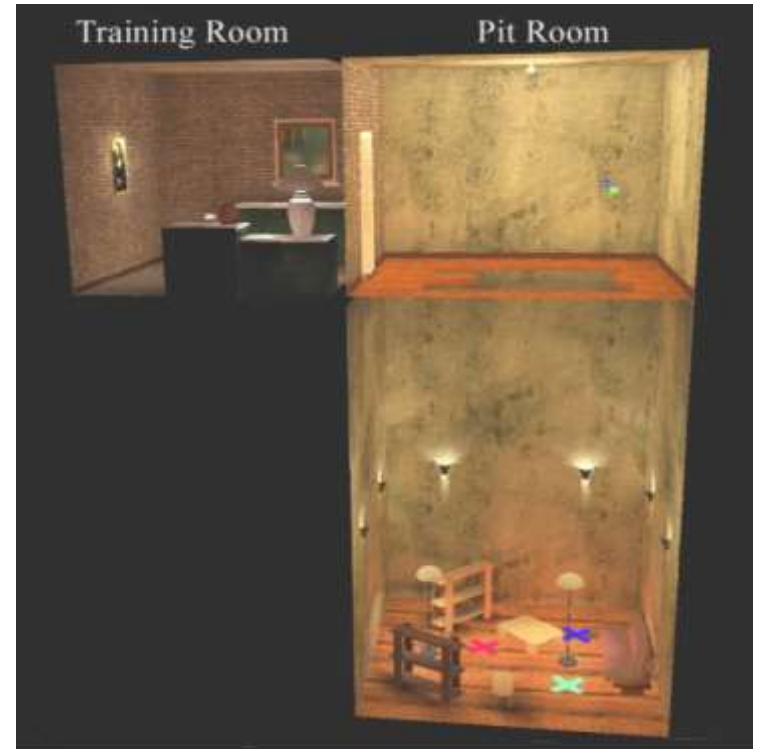
Measuring Presence – SUS Questionnaire (2/2)

- During the time of the experience, which was the strongest on the whole, your sense of being in the virtual environment or of being elsewhere?
- Consider your memory of being in the virtual environment. How similar in terms of the structure of the memory is this to the structure of the memory of other places you have been today? By ‘structure of the memory’ consider things like the extent to which you have a visual memory of the virtual environment, whether that memory is in colour, the extent to which the memory seems vivid or realistic, its size, location in your imagination, the extent to which it is panoramic in your imagination, and other such structural elements.
- During the time of your experience, did you often think to yourself that you were actually in the virtual environment?

Usoh, M., Catena, E., Arman, S., and Slater, M. (2000). Using presence questionnaires in reality. *Presence: Teleoperators and Virtual Environments*, 9:497-503.

Measuring Presence

- Physiological metrics
 - Skin conductance response (SCR)
 - Electrocardiogram (EKG)
- Behavioral metrics
 - User reactions



The pit experiment

Meehan, M., Insko, B., Whitton, M., and Brooks, Jr., F. P. (2002). Physiological measures of presence in stressful virtual environments. In Proceedings of the 29th annual conference on Computer graphics and interactive techniques, SIGGRAPH '02, pages 645-652,

Virtual Embodiment

Immersive VR



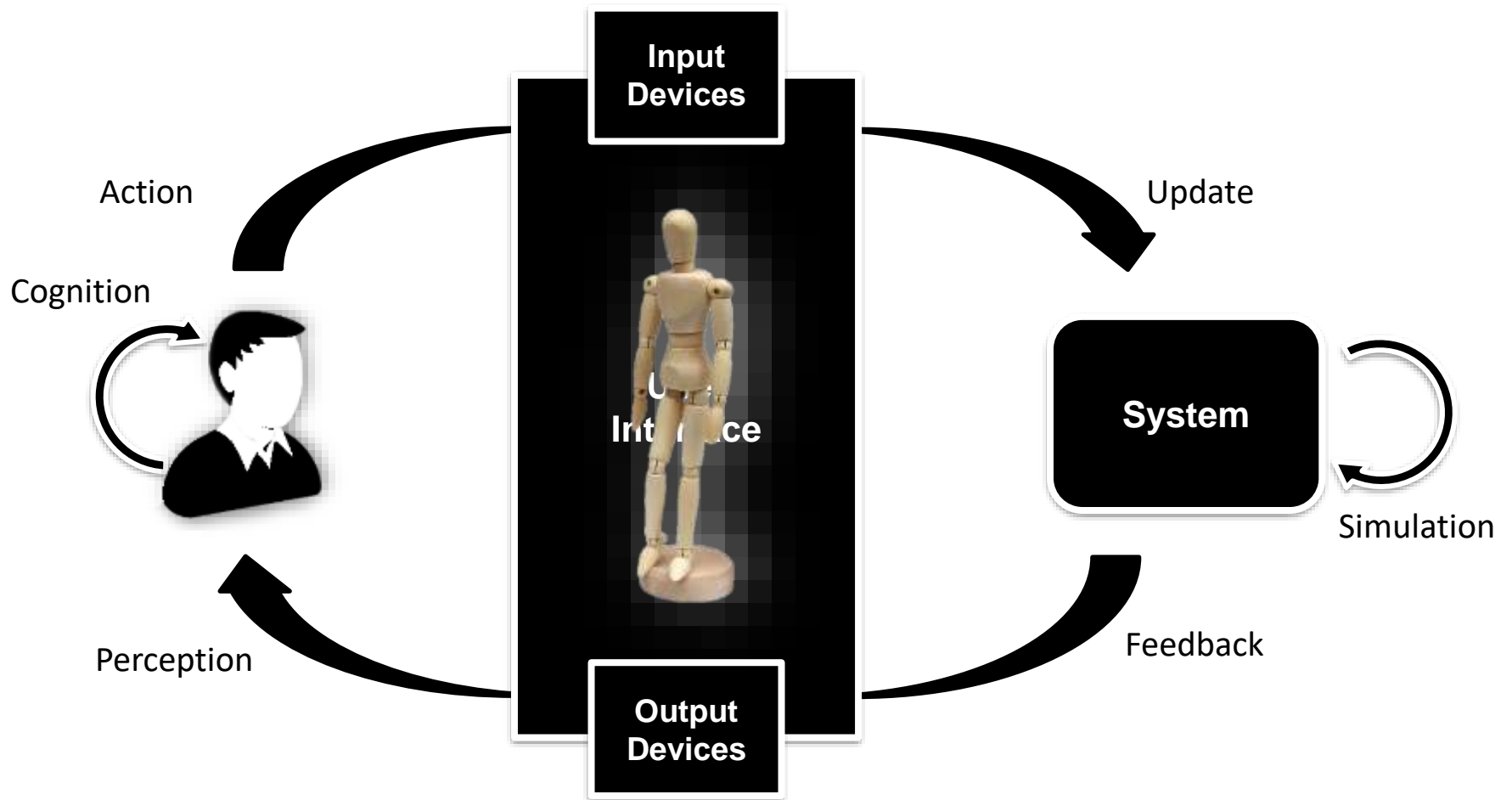


The User's Avatar

- Virtual representation of the user
- Interaction tool with the virtual environment
- Strong relevance for immersive applications
 - E.g. sports, videogames, training, medical.

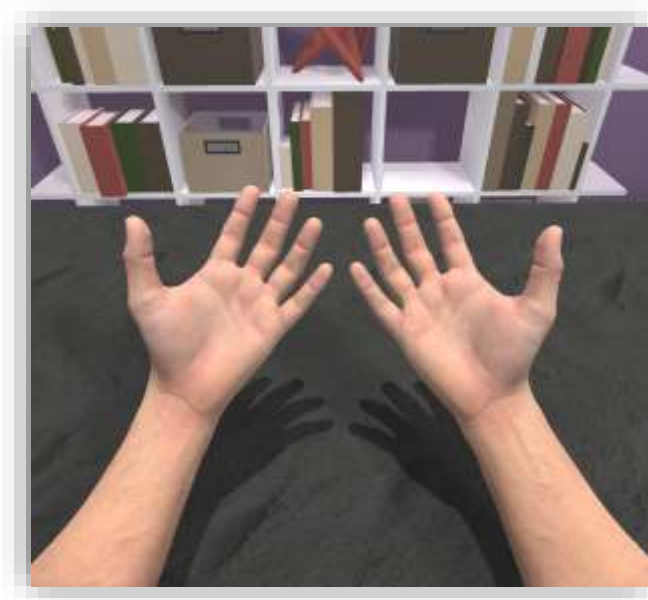
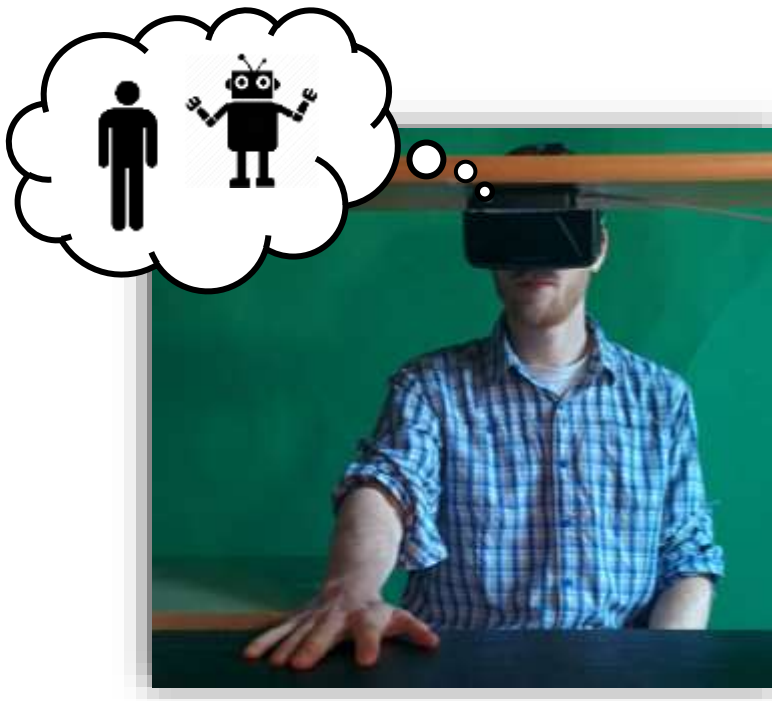


The Interaction Loop



The Sense of Embodiment

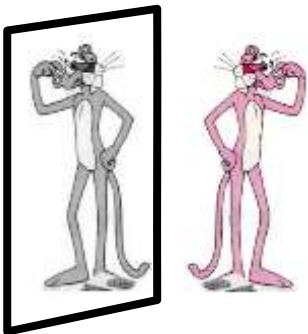
- The sense of embodiment towards an avatar is the sense that emerges when the avatar is perceived as if it was the one's own biological body.



K. Kilteni, et al.. The Sense of Embodiment in Virtual Reality. Presence: Teleoperators and Virtual Environments, 21:373–387, 2012.

The Sense of Embodiment

- The sense of embodiment towards an avatar is the sense that emerges when the avatar is perceived as if it was the one's own biological body.
- Three main components [Kilteni2012]
 - **Ownership**: The sense that one's own body is the source of sensations
 - **Self-location**: The space in which we perceive the self to be located
 - **Agency**: Elicited when oneself is the agent of one's own actions.



- Alternative naming convention [DeVignemont2011]
 - Spatial, Motor, Affective

M. R. Longo, et al. What is embodiment? A psychometric approach. *Cognition*, 107(3):978–98, 2008.

K. Kilteni, et al. The Sense of Embodiment in Virtual Reality. *Presence: Teleoperators and Virtual Environments*, 21:373–387, 2012.

F. De Vignemont. Embodiment, ownership and disownership. *Consciousness and Cognition*, 20(1):82–93, 2011..

Body Ownership - The Rubber Hand Illusion



M. Botvinick and J. Cohen. Rubber hands 'feel' touch that eyes see. Nature, 391(6669):756, 1998.

The Sense of Agency

- The **feeling of agency** is preceded by the action outcome (i.e., the perception of the feedback)
 - Triggered at the very early stages of the action.
 - Pre-reflective, implicit, low-level and non-conceptual.
- The **judgment of agency** results from the comparison between the predicted and actual outcomes of the action
 - Triggered during and after the action.
 - Reflective, explicit, high-order, belief-like and conceptual.

S. Gallagher. Multiple aspects in the sense of agency. *New Ideas in Psychology*, 30(1):15–31, 2012.

D. M. Wegner and T. Wheatley. Apparent mental causation: Sources of the experience of will. *American psychologist*, 54(7):480, 1999.

The Judgment of Agency

- Relies on three principles, which would be the general conditions for attribution of causality:
- The **priority** principle: the conscious intention to perform an act must immediately precede the action, which in turn should immediately precede the outcome.
- The **consistency** principle: the sensory outcome must fit the predicted outcome.
- The **exclusivity** principle: one's thoughts must be the only apparent cause of the outcome (i.e. one must not believe there to be an outside influence).

S. Gallagher. Multiple aspects in the sense of agency. *New Ideas in Psychology*, 30(1):15–31, 2012.

D. M. Wegner and T. Wheatley. Apparent mental causation: Sources of the experience of will. *American psychologist*, 54(7):480, 1999.

The Sense of Embodiment

- How the user appropriates/identifies with the avatar?



Age
[Youn Oha et al. 2016]



Hand appearance
[Yuan 2010]



Body Mass Index
[Piryankova et al. 2014]

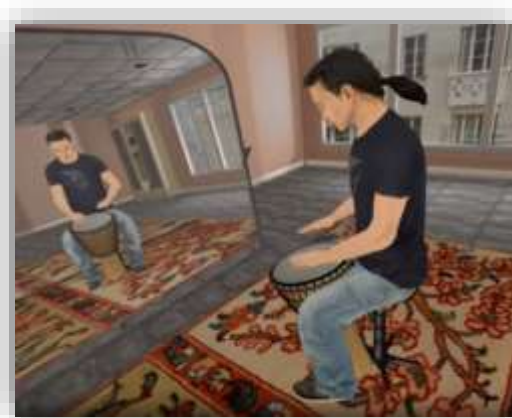
Piryankova, I., et al. (2014). 592 Owning an overweight or underweight body: Distinguishing the physical, experienced and virtual body.593 PLoS ONE 9

Avatar Appearance

- How the appearance of the avatar influences the user behavior?



Skin Appearance
[Peck et al. 2013]



Avatar appearance
[Kilteni et al. 2013]



Avatar anthropomorphism
[Lugrin et al. 2015]

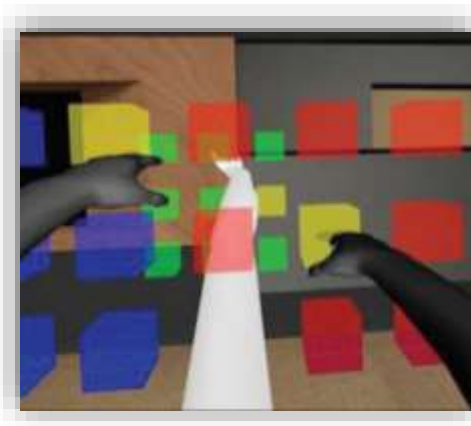
Peck, T. C., et al. (2013). Putting yourself in the skin of a black avatar reduces implicit racial bias. *Consciousness and Cognition* 22, 779–787
K. Kilteni, et al.. Drumming in immersive virtual reality: the body shapes the way we play. *IEEE TVCG*, 19(4):597–605, 2013.
J.-L. Lugrin, J. Latt, and M. E. Latoschik. Avatar Anthropomorphism and Illusion of Body Ownership in VR. In *IEEE VR (Posters)*, 2015.

Morphological Structure

- How the user embodies an avatar with a different morphology?
 - Can we own a virtual body which differs from ours?
 - How we can control it?



Human Tail
[Steptoe et al. 2013]



Homuncular Flexibility
[Won. 2015]



Non-Human Avatars
[Seol et al. 2015]

Steptoe, W., et al. (2013). Human tails: ownership and control of extended humanoid avatars. IEEE TVCG 19, 583–90
Won, A. S., et al. (2015). Homuncular flexibility in virtual reality. Journal 619 of Computer-Mediated Communication 20, 241–259

Measuring Embodiment

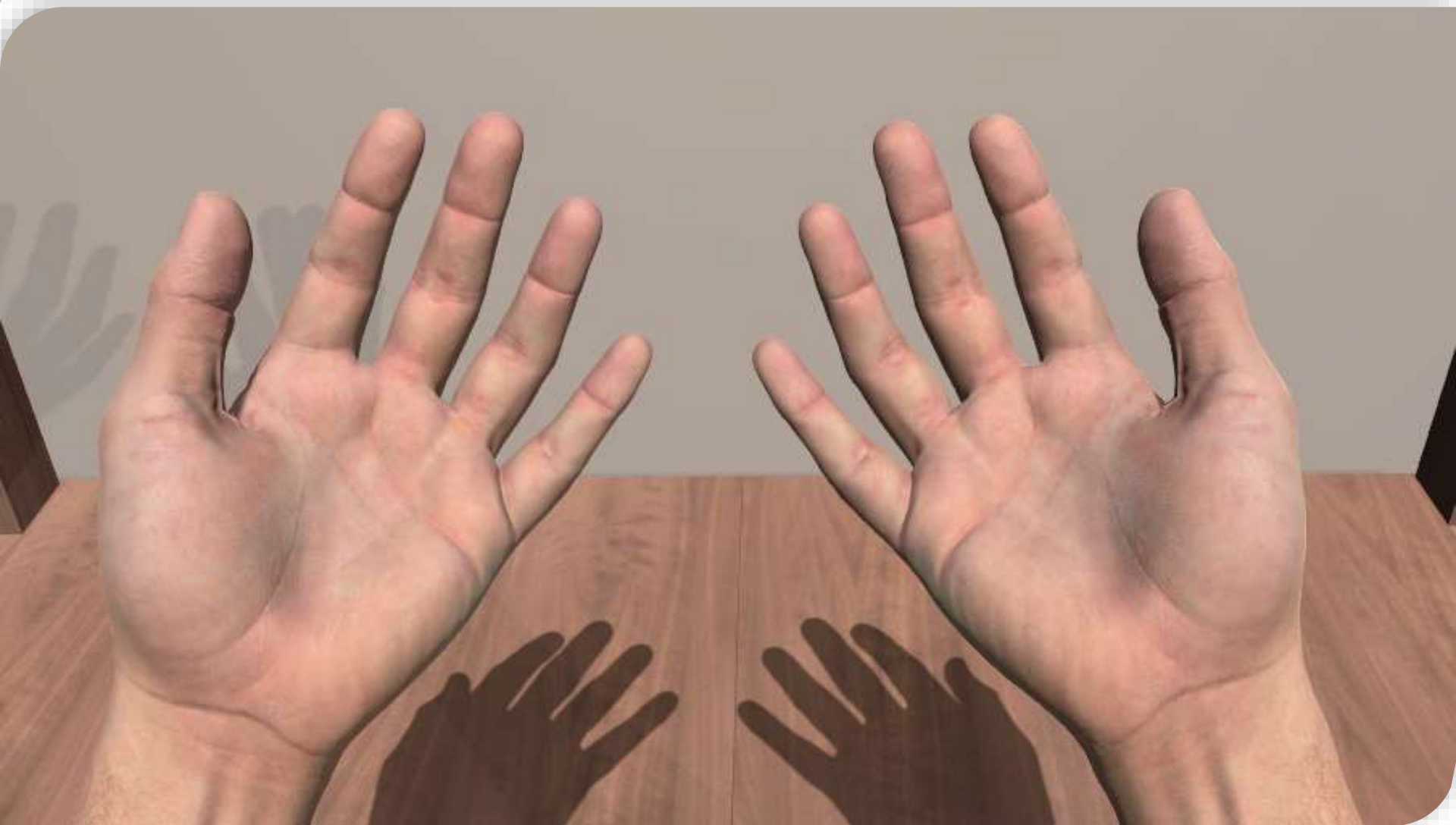
- Questionnaires
 - There is no standardized questionnaire
 - Structured in the different dimensions of embodiment

- Behavioral responses (examples)
 - Racial bias
 - Voice tone
 - Collision avoidance

Gonzalez-Franco, M., & Peck, T. C. (2018). Avatar embodiment. towards a standardized questionnaire. *Frontiers in Robotics and AI*, 5, 74.
Roth, D., & Latoschik, M. E. (2019). Construction of a Validated Virtual Embodiment Questionnaire. arXiv preprint arXiv:1911.10176.

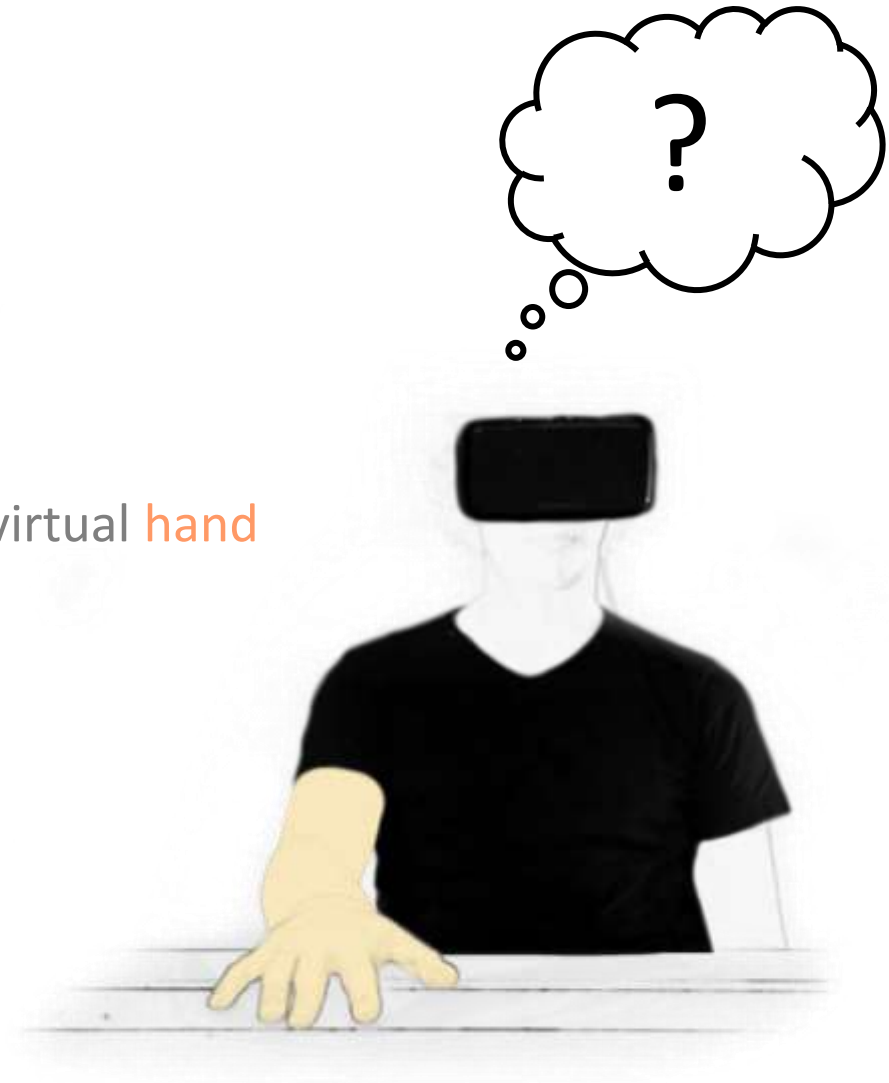
Illustrative Example

Virtual Hand



Research Question

- How do people appropriate their virtual **hand** when interacting in VEs?



F. Argelaguet, L. Hoyet, M. Trico, and A. Lécuyer. The role of interaction in virtual embodiment: Effects of the virtual hand representation. In *Virtual Reality (VR)*, pp. 3–10. IEEE, 2016.

Experimental Questions

- Does the virtual representation of the virtual hand alter the **sense of agency**?
- Does the virtual representation of the virtual hand alter the **sense of ownership**?



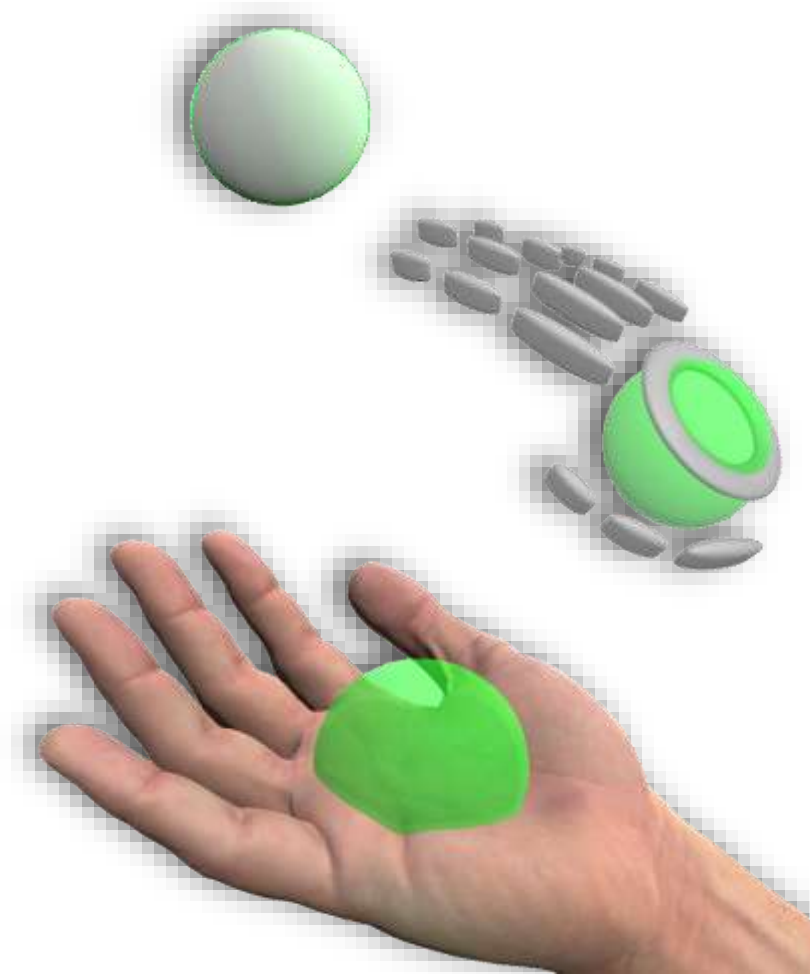
Prototype

Interacting with a virtual hand

➤ **Appearance**

➤ Control

➤ System



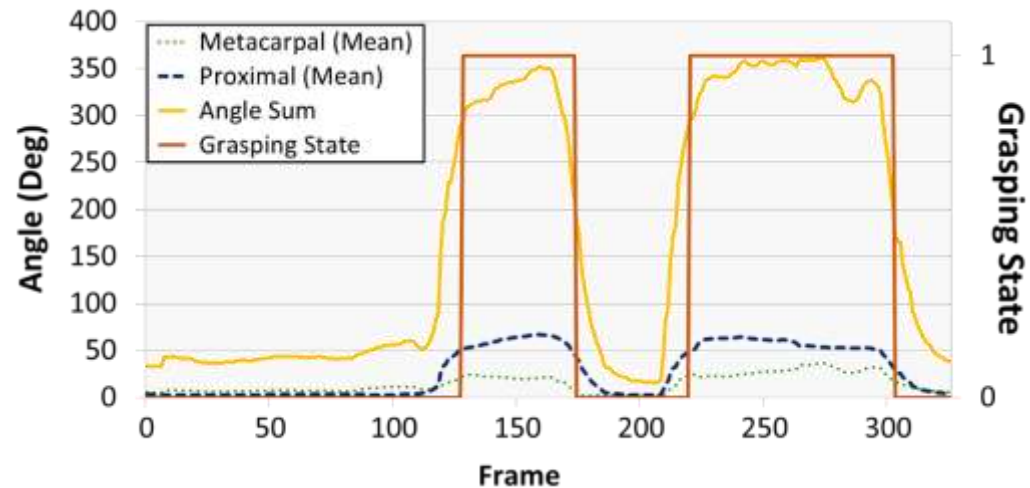
Realism

Low

High

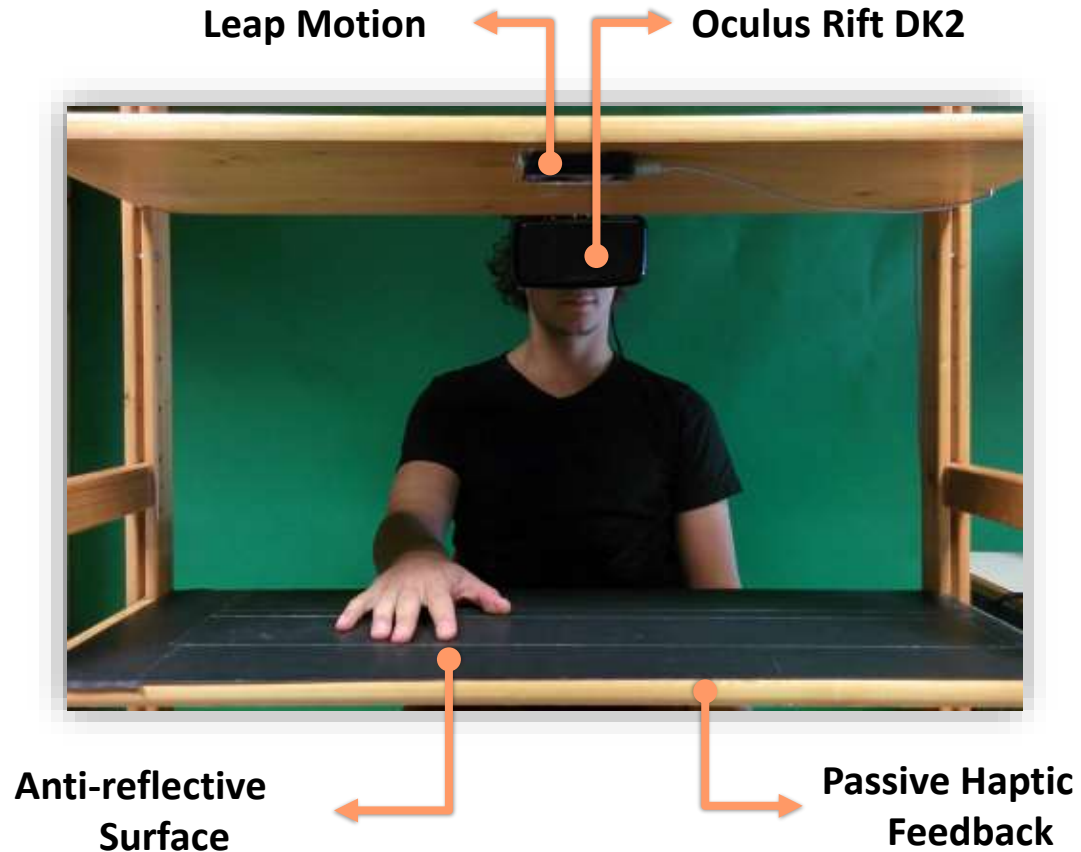
Interacting with a virtual hand

- Appearance
 - Control
 - System
- The **prehension area** was considered to be a half-sphere driven by the palm of the real hand.
 - The **grabbing intent** detection method relies on the angles of both metacarpal and proximal joints

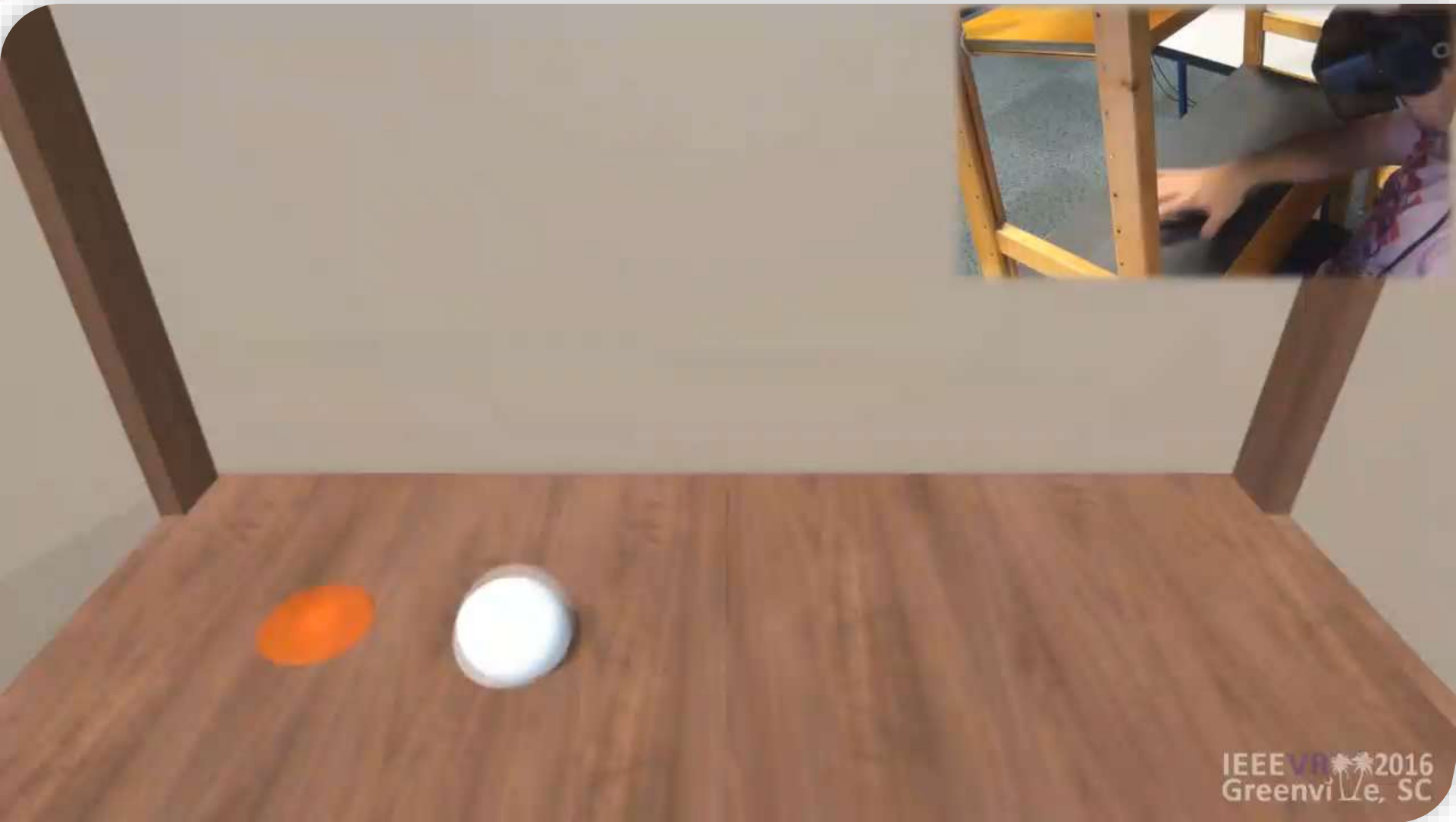


Interacting with a virtual hand

- Appearance
- Control
- System



Interacting with a virtual hand

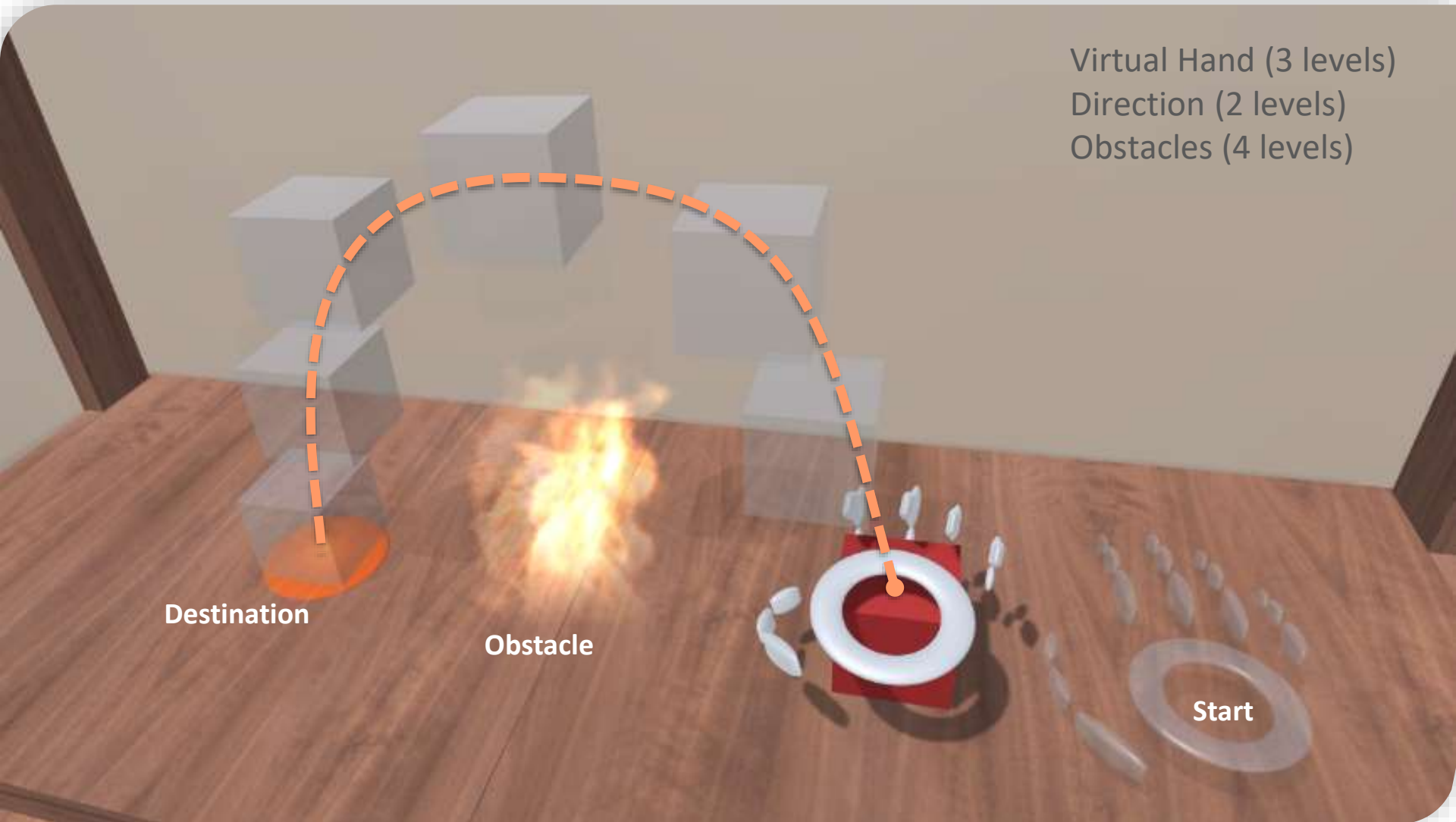


IEEE VR 2016
Greenville, SC

Experiment

Experimental Tasks - Pick-and-place

Virtual Hand (3 levels)
Direction (2 levels)
Obstacles (4 levels)



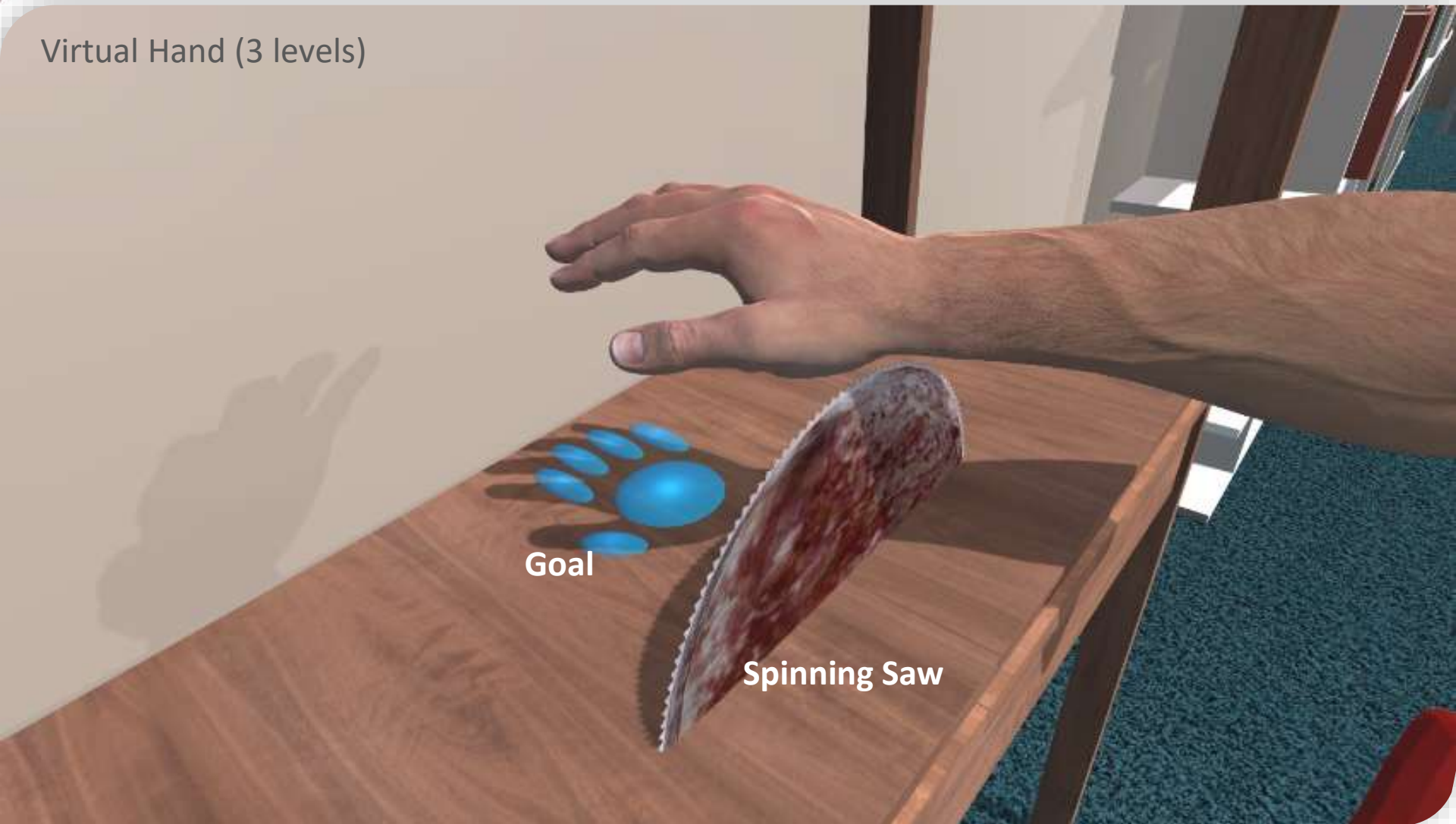
Destination

Obstacle

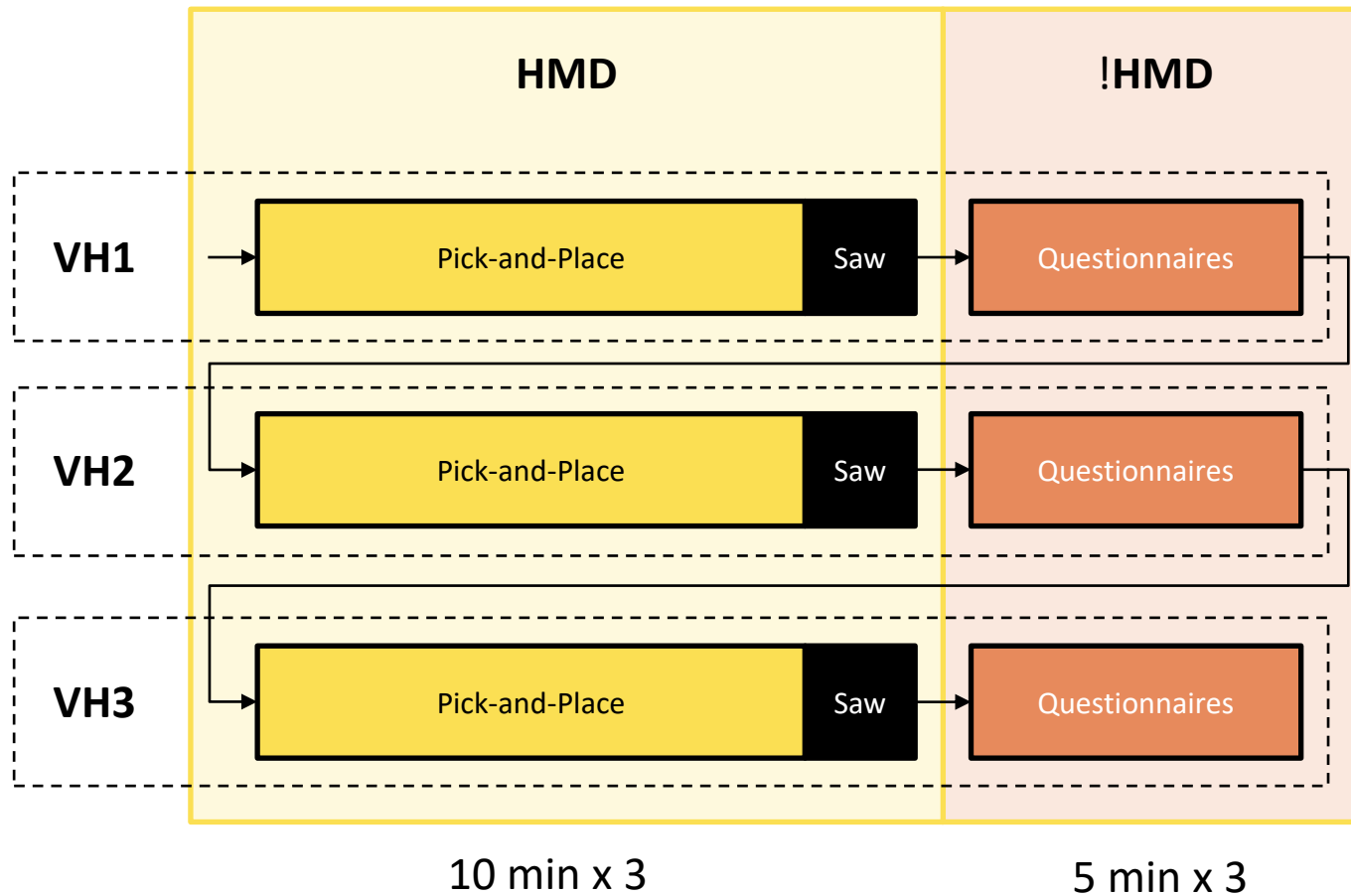
Start

Experimental Tasks - Spinning Saw

Virtual Hand (3 levels)



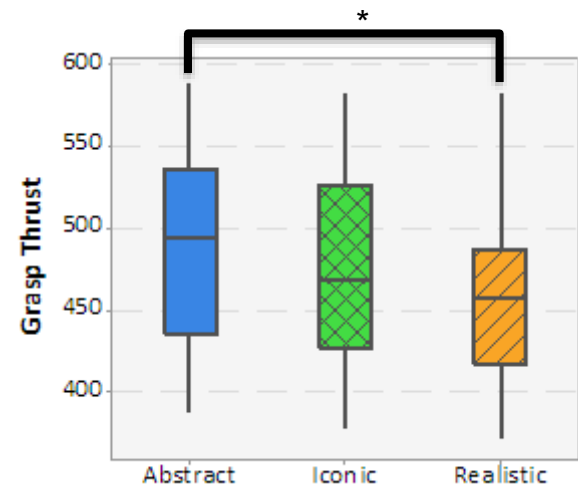
Experiment Summary



Results

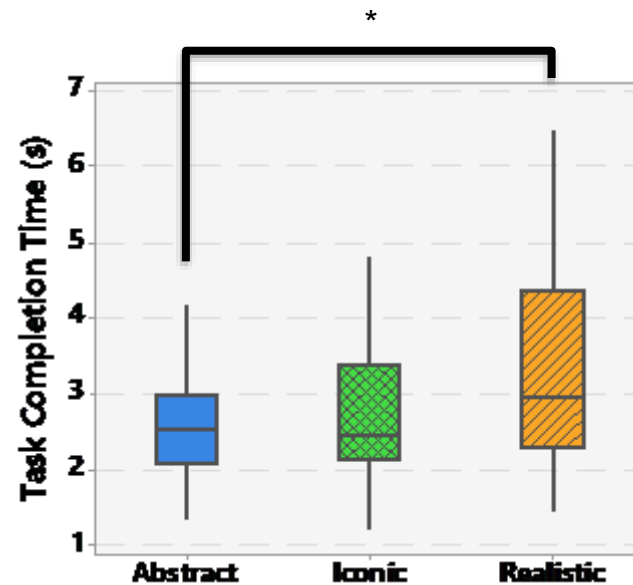
Results - Pick-and-Place Task (Agency)

- Simplified virtual hands are faster and more accurate
 - Increased learning time for the realistic virtual hand
- Insufficient **feedback** for the realistic virtual hand
 - Occlusions
 - No haptic feedback
 - Differences on the grasp thrust



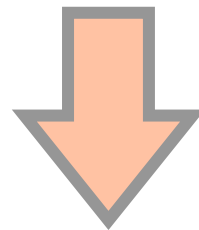
Results - Spinning Saw Task (Ownership)

- Participants required **more time** to place the realistic virtual hand on the designated spot



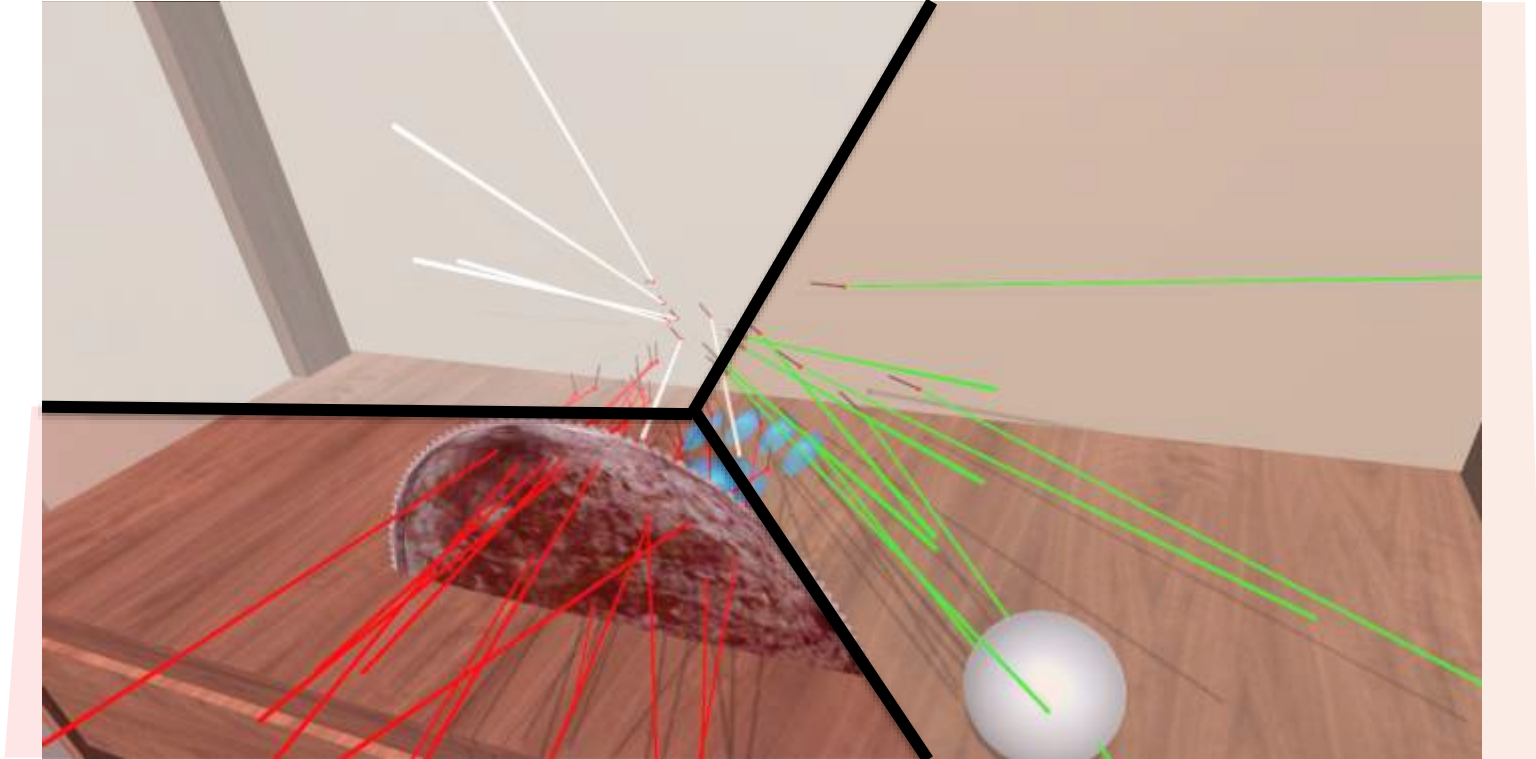
Agency Results - Discussion

- The realistic virtual hand was more difficult to **control**
 - Higher user **expectations**
 - Insufficient **feedback**
 - The task was perceived to be more difficult
- Correlation between agency and performance
 - Simplified virtual hands are faster and more accurate

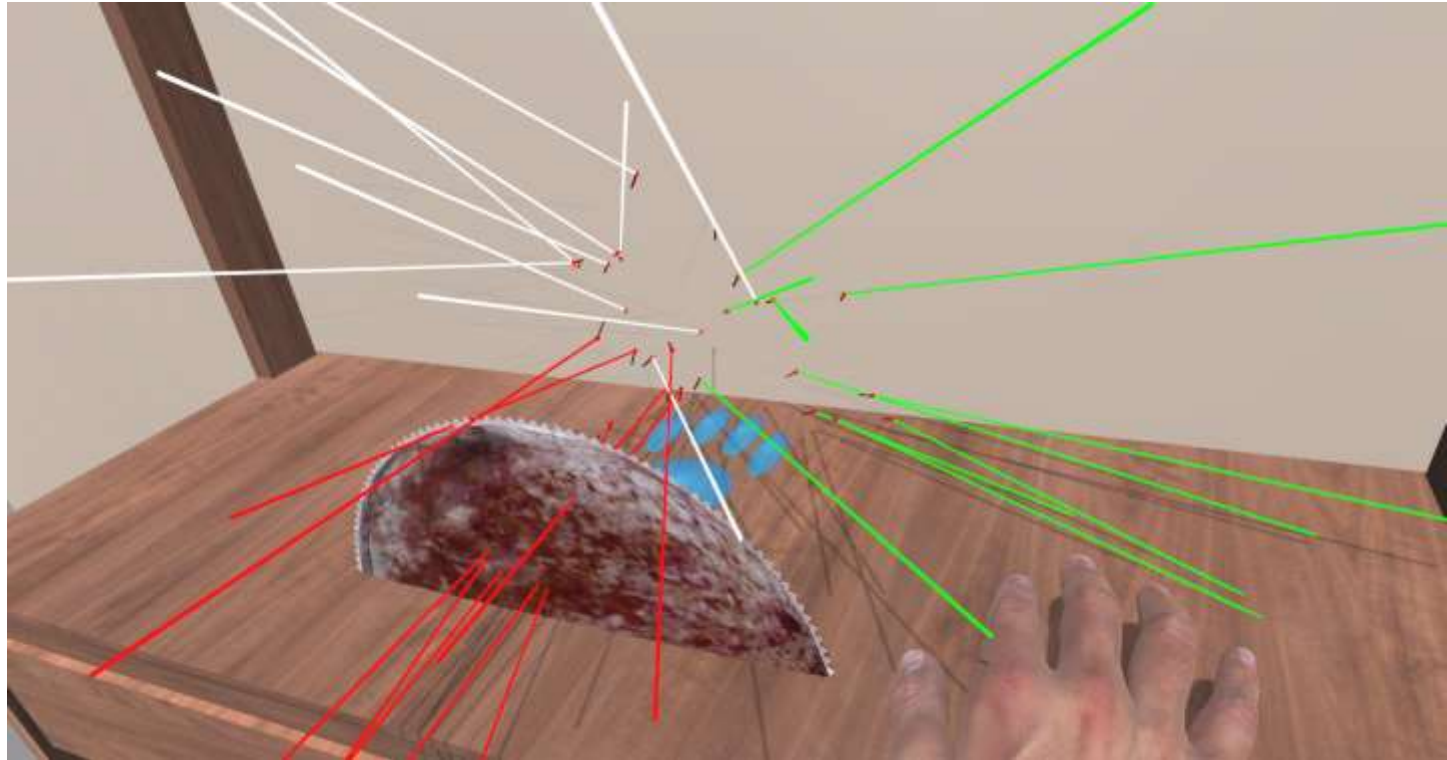


Decreased agency for the realistic virtual hand

Collision Avoidance Strategy (I)



Collision Avoidance Strategy (II)



Collision Avoidance Strategy (III)

