Anne-Hélène Olivier
anne-helene.olivier@univ-rennes2.fr

Se déplacer dans des espaces publics : variables de contrôle des trajectoires locomotrices, enjeux méthodologiques et perspectives ouvertes par la réalité virtuelle.

UNIVERSITÉ RENNES 2

Inria

VIRTUS

VIRTUS
the virtual us

Create and simulate immersive populated virtual spaces where both virtual and real humans coexist, with a sufficient level of realism so that the experience lived virtually and its results can be transposed to reality

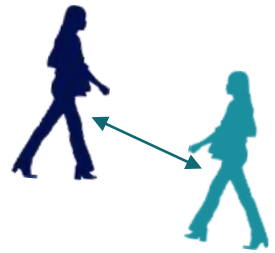
Inria

UNIVERSITÉ RENNES 2

Social navigation: navigating populated spaces

- What are the control variables that govern the generation of locomotor trajectories in populated spaces?
- What is the influence of individual factors on social navigation?
- Which methodologies can be used to measure social navigation?

https://www.youtube.com/watch?v=DFHGvmJIrN8



Jinni Harrigan, Robert Rosenthal, Klaus R Scherer, and Klaus Scherer. 2008. New handbook of methods in nonverbal behavior research

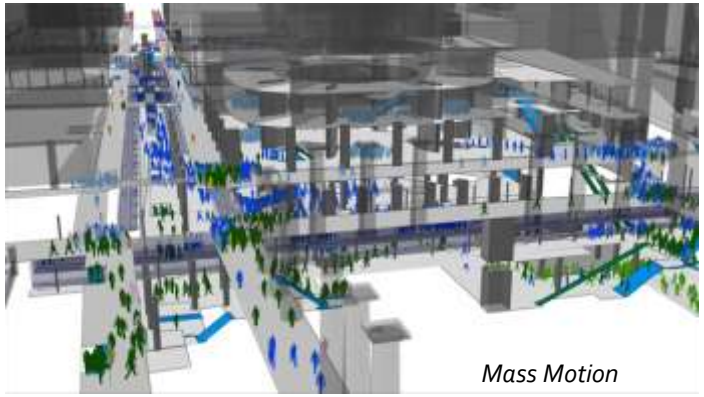
Applications

Source : https://psychcentral.com/

© Inria / Photo C. Morel

Source : Golaem

Source : Le Parisien



Mass Motion

© Inria / Photo C. Morel

From individual to collective motion

Model of local interactions

Collective behaviour emerges from local interactions between individuals

Potential fonction

… of the agent state

Cost or « satisfaction »

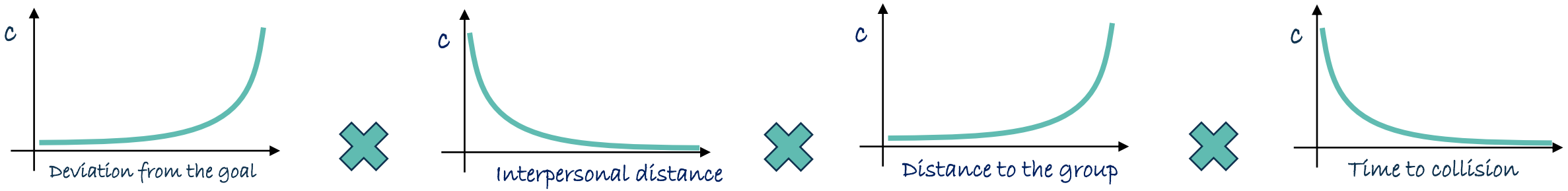
… state of its neighbors

… many parameters

For the « agent » i in the «state» s_i

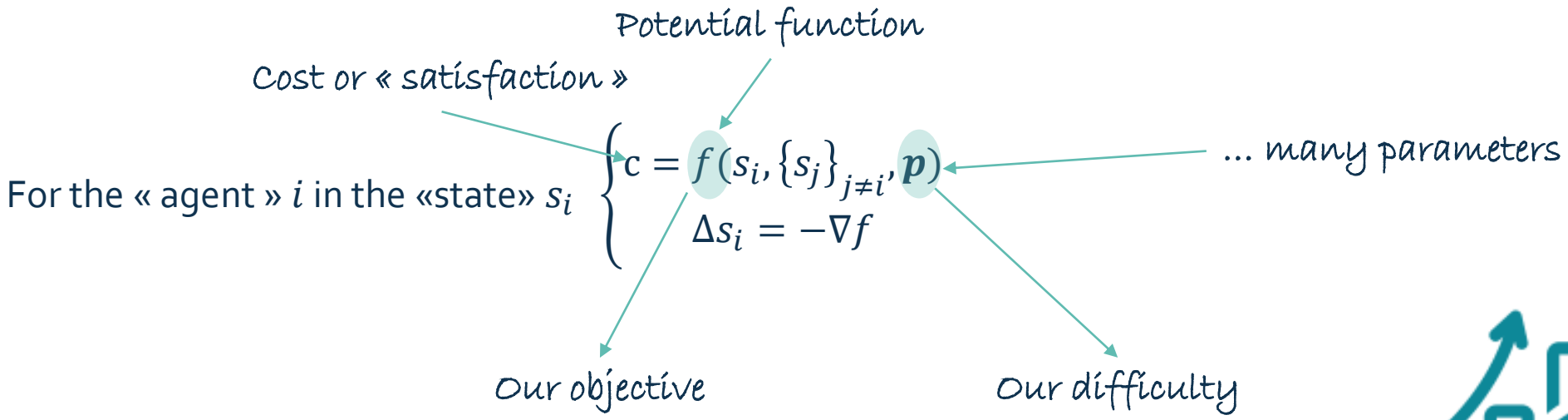
$$\begin{cases} c = f(s_i, \{s_j\}_{j \neq i}, \boldsymbol{p}) \\ \Delta s_i = -\nabla f \end{cases}$$

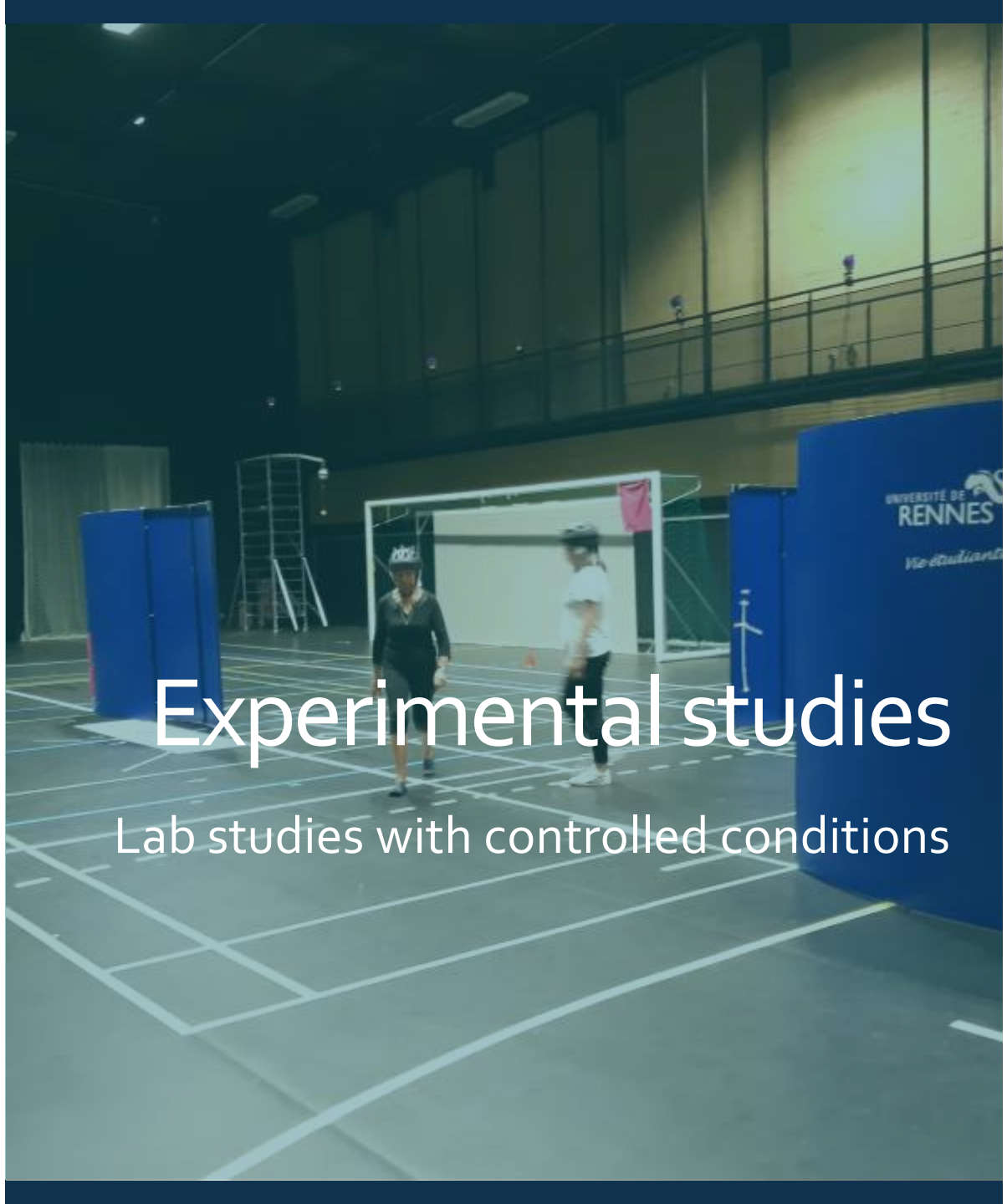
The agent adjusts its state to minimise c
(maximise its satisfaction)



Model of local interactions

Collective behaviour emerges from local interactions between individuals





Experimental studies

Lab studies with controlled conditions

Experimental studies: sampling f

Lab studies with controlled conditions

$$\begin{cases} c = f(s_i, \{s_j\}_{j \neq i}, \boldsymbol{p}) \\ \Delta s_i = -\nabla f \end{cases}$$

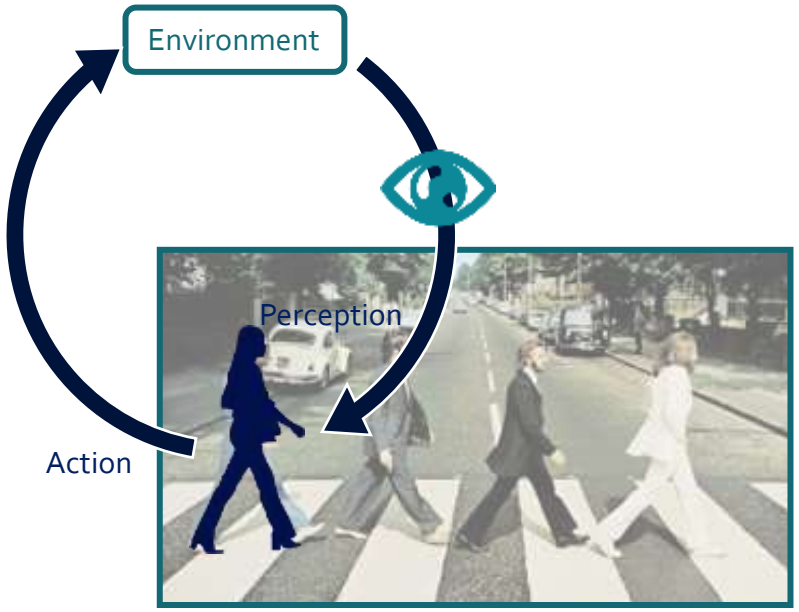
Seyfried – Sieben

Lemercier

Warren

Experimental studies: sampling *f*

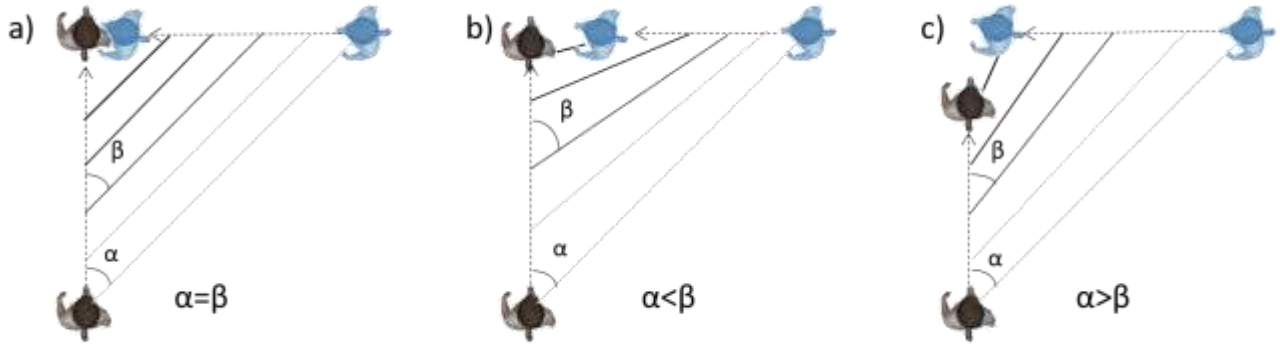
- Some theories and control variables for social navigation



Gibson 1986 Warren 1998, Patla 2004

Collision avoidance Cutting 1995

Collision ?
Derivative of gaze-movement angle

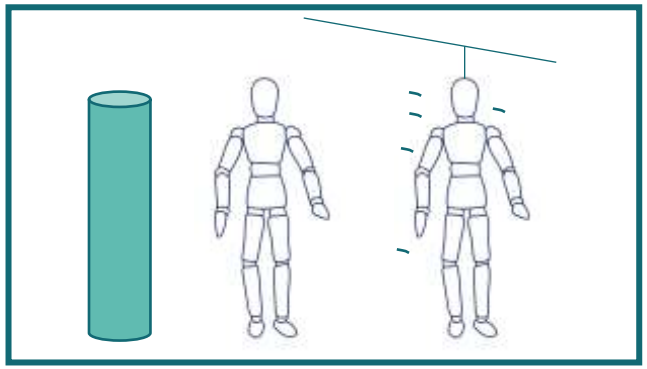


Collision Observer 1st Observer 2nd

When?
Time to contact
Tau Lee 1976

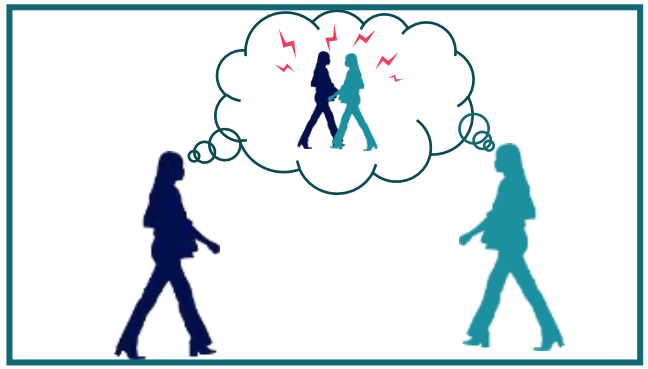
Experimental studies: sampling *f*

- Some theories and control variables for social navigation
  - Personal space and risk of collision



Vallis 2003, Gérin-Lajoie 2005, Cinelli 2007

Anticipatory locomotor adjustments
Personal space as a control variable

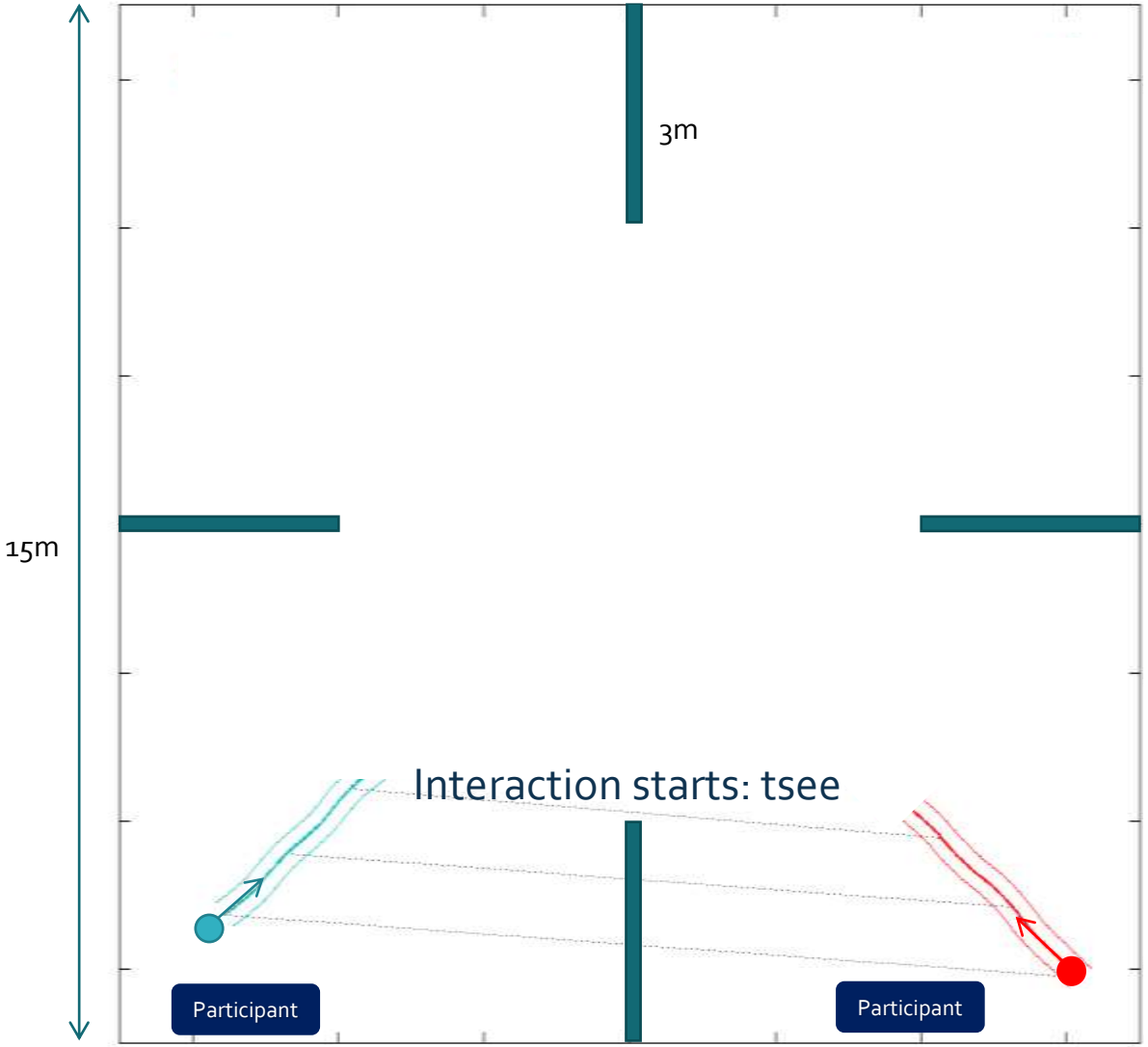


Olivier 2012, 2013

Proxemics in motion
Anticipatory locomotor adjustments
Role dependent strategies

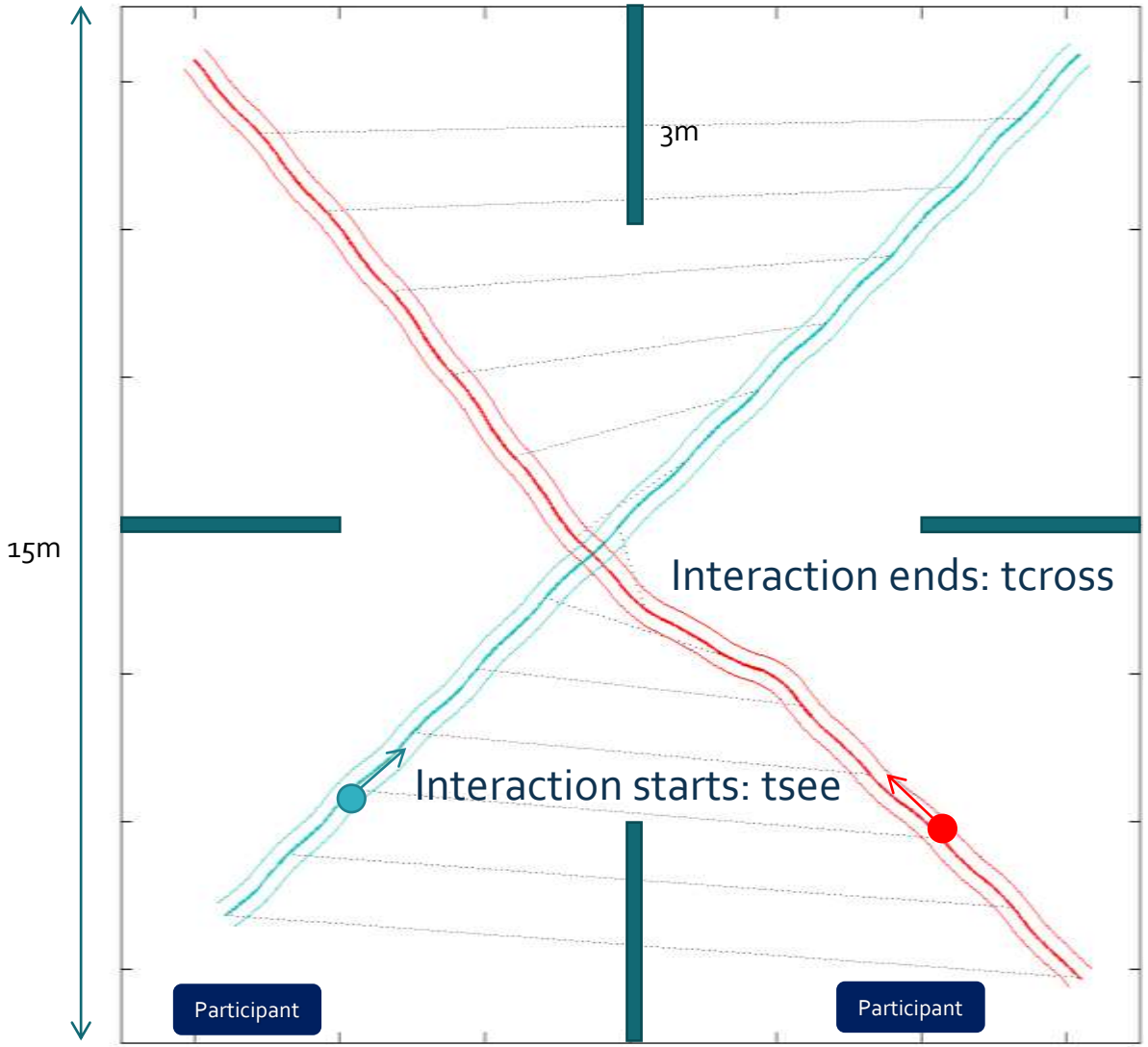
Olivier, A. H., Marin, A., Crétual, A., & Pettré, J. (2012). Minimal predicted distance: A common metric for collision avoidance during pairwise interactions between walkers. *Gait & posture*, *36*(3), 399-404.
Olivier, A. H., Marin, A., Crétual, A., Berthoz, A., & Pettré, J. (2013). Collision avoidance between two walkers: Role-dependent strategies. *Gait & posture*, *38*(4), 751-756.

Experimental studies: sampling *f*



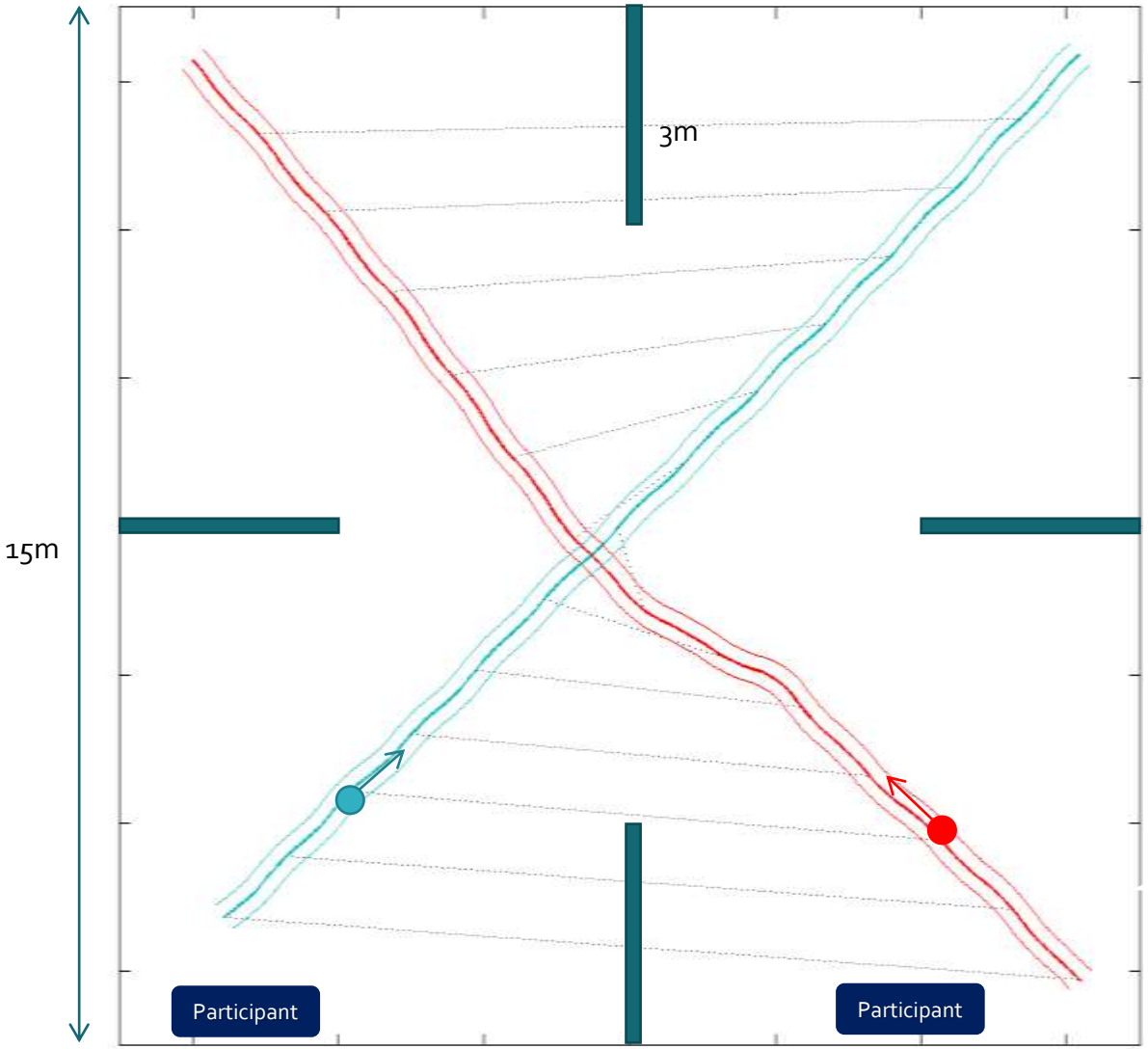
Olivier et al.
Gait Posture 2012-2013

Experimental studies: sampling *f*



Olivier et al.
Gait Posture 2012-2013

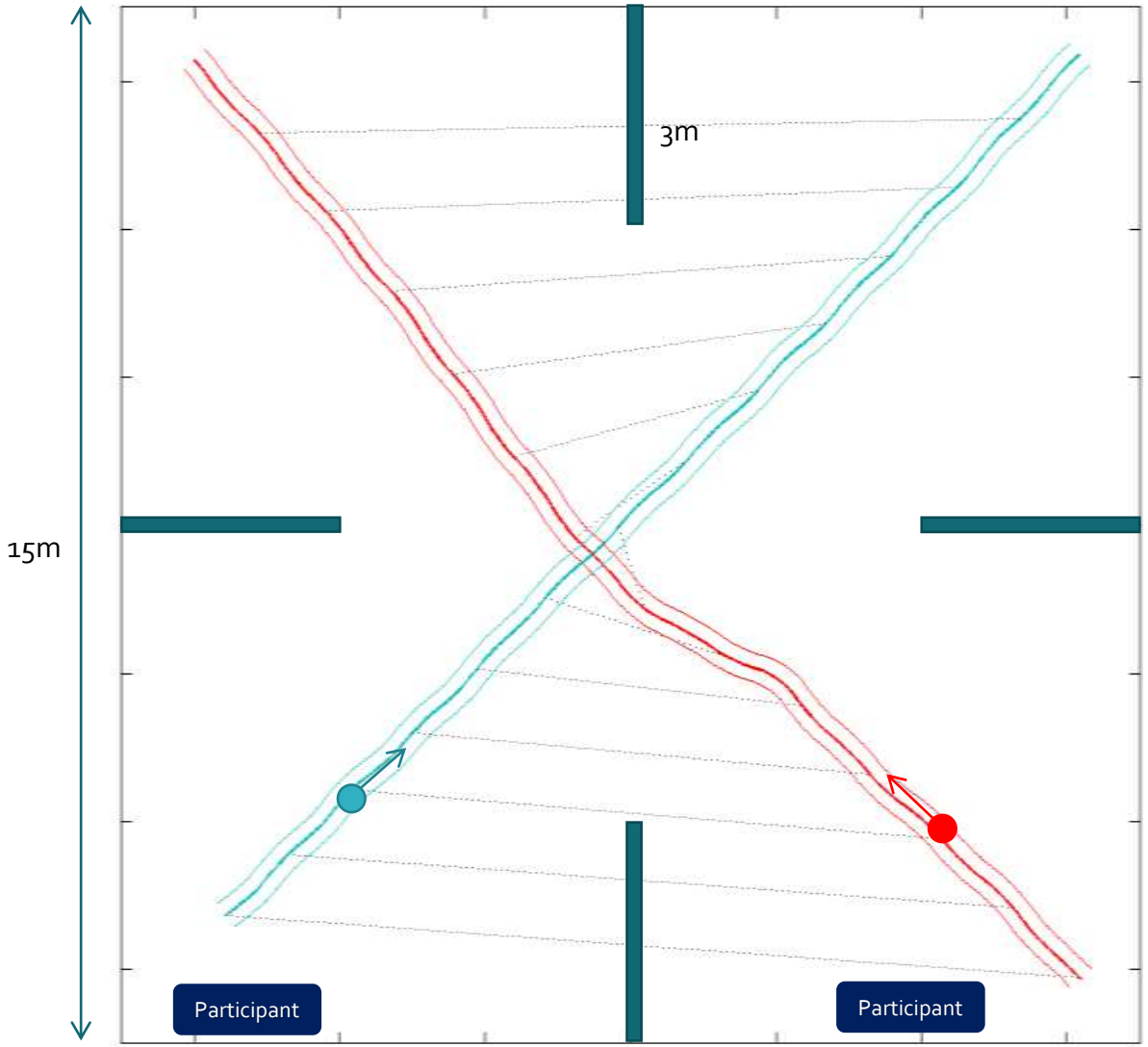
Experimental studies: sampling *f*



Olivier et al.
Gait Posture 2012-2013

Interaction metrics: *mpd – minimum predicted distance*

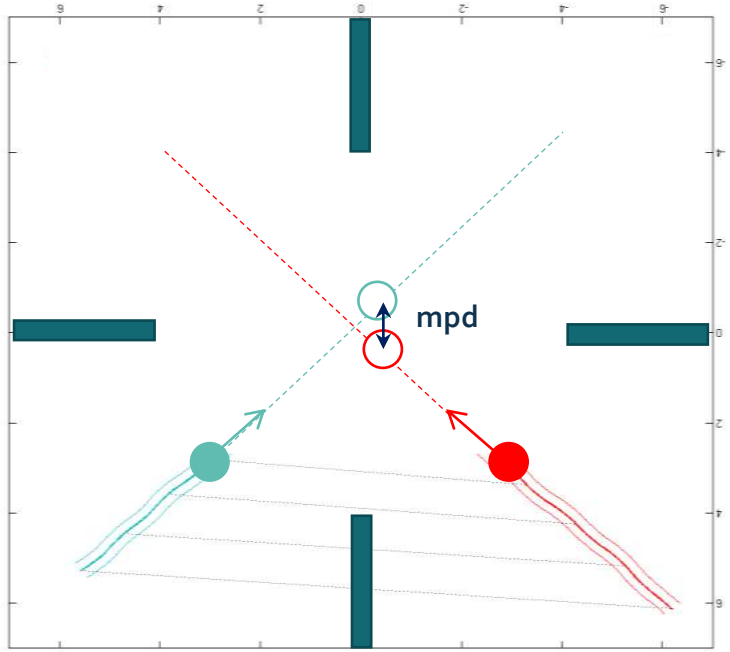
Experimental studies: sampling *f*



Olivier et al.
Gait Posture 2012-2013

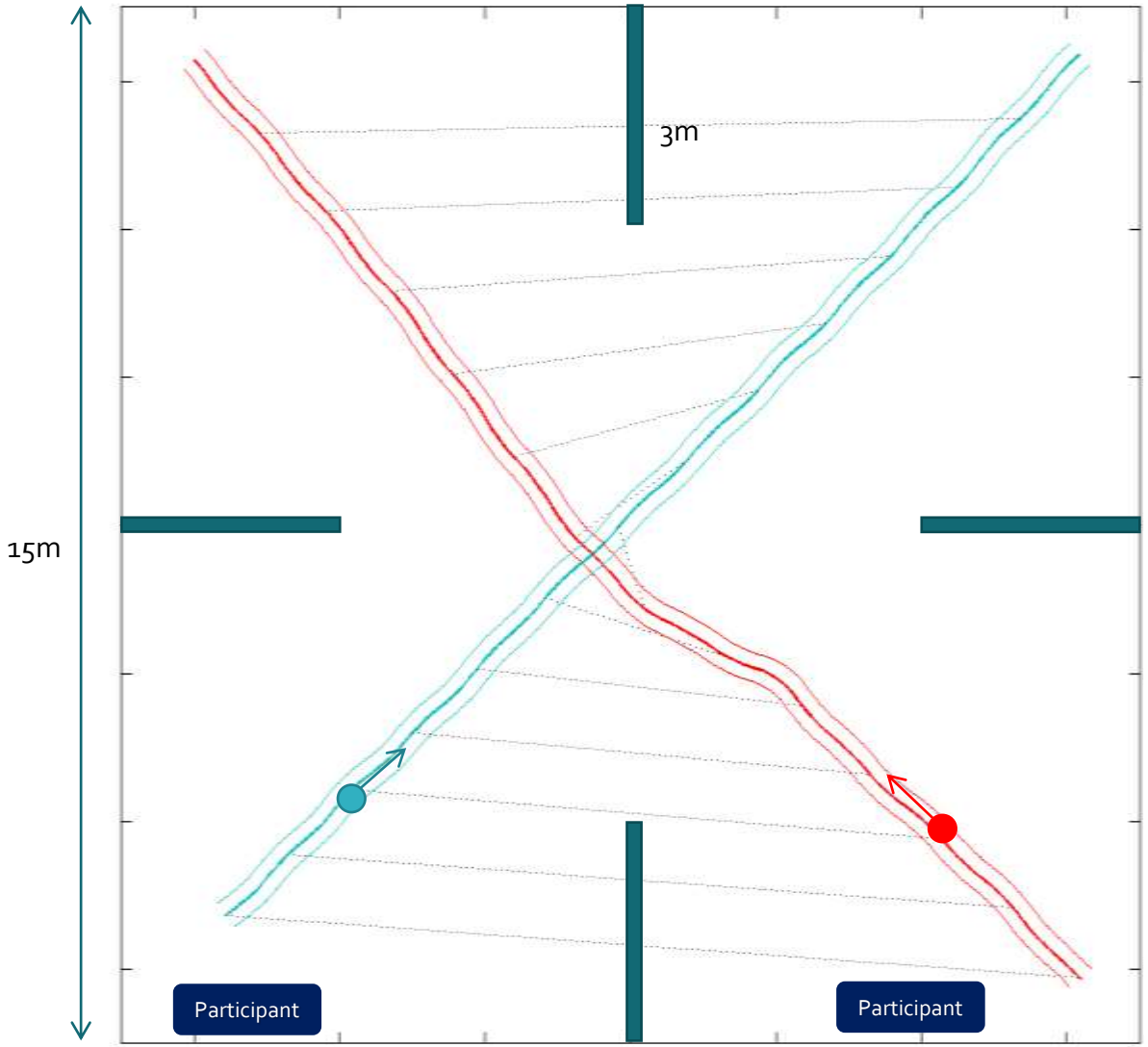
Interaction metrics: *mpd – minimum predicted distance*

Linear extrapolation of future crossing distance if no motion adaptation is performed.



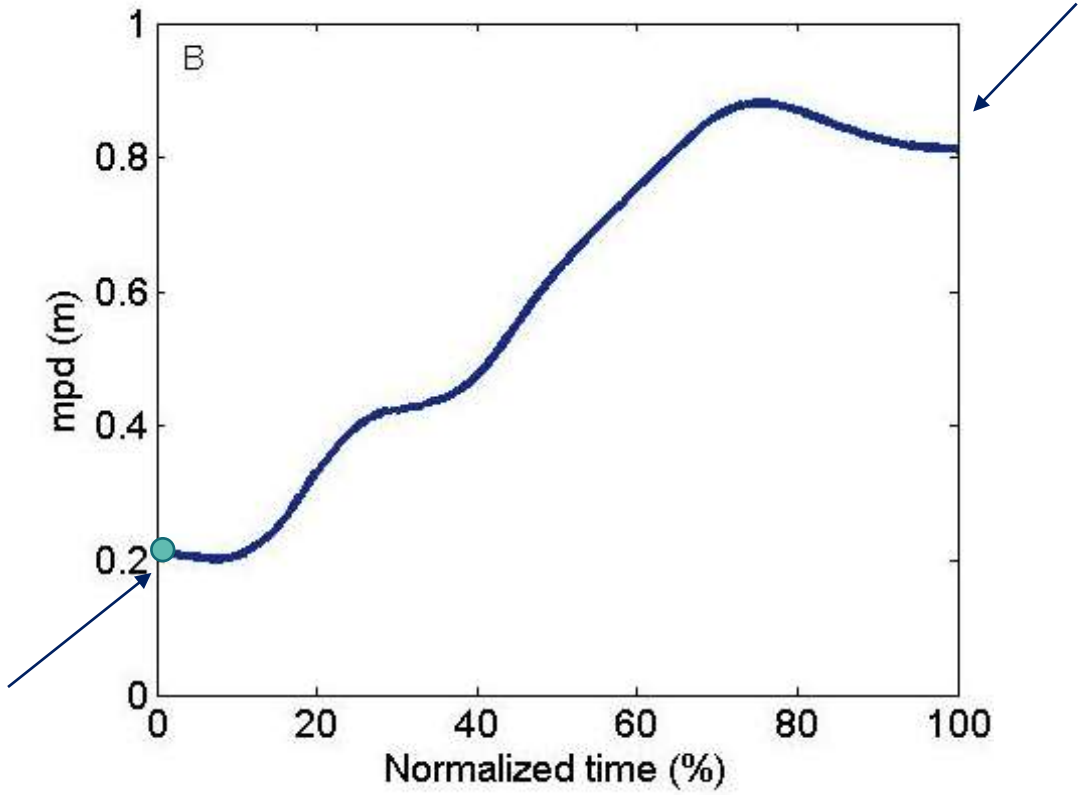
Time t

Experimental studies: sampling *f*



Olivier et al.
Gait Posture 2012-2013

Interaction metrics: *mpd – minimum predicted distance*

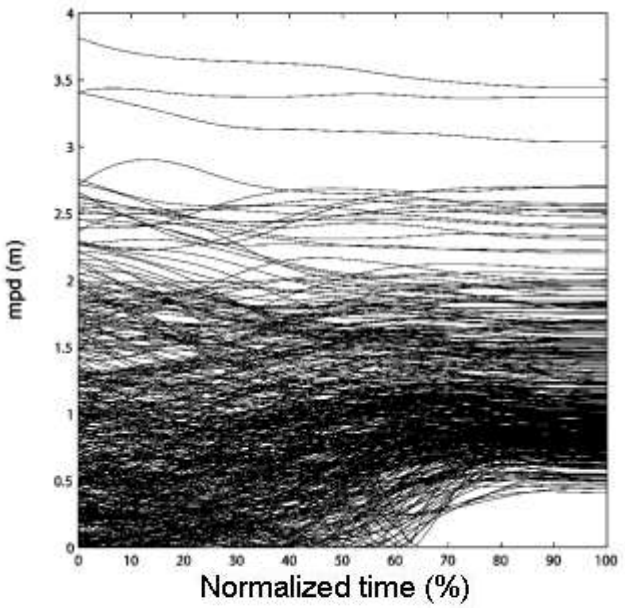


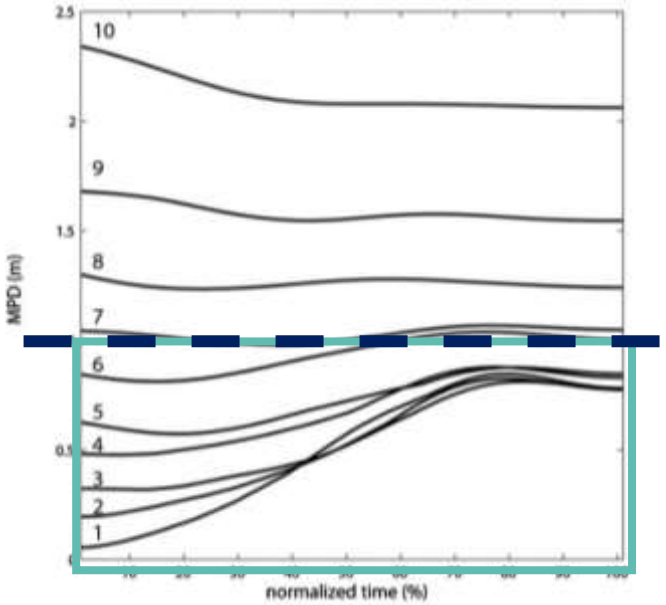
Experimental studies: sampling *f*

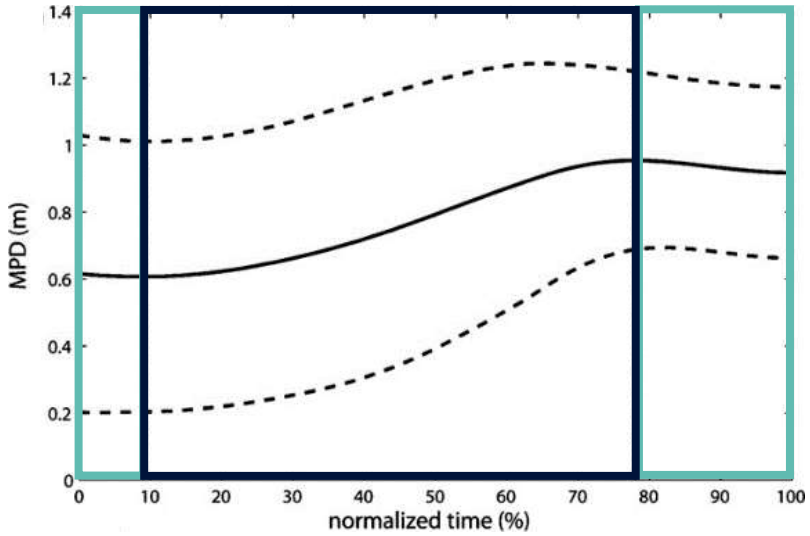
Regulation

Reaction

Observation







Characterizes the risk of collision
➔ Adaptation if mpd(tsee) <1m

Describes the temporal sequence of the interaction
➔ Collision **solved before** crossing
➔ Anticipatory locomotor adjustments
GérinLajoie 2005, Vallis 2003

+ Role dependent strategies : Higher contribution from Walker 2

Experimental studies: sampling f

Lab studies with controlled conditions

$$\begin{cases} c = f(s_i, \{s_j\}_{j \neq i}, \boldsymbol{p}) \\ \Delta s_i = -\nabla f \end{cases}$$

Aging
Rapos Gait Posture 2019, 2021

Concussion
Snyder Gait Posture 2022

Wheelchair
Olivier SOFPEL 2019, SOFMER 2022

Emotions
Perrinet SAP 2013

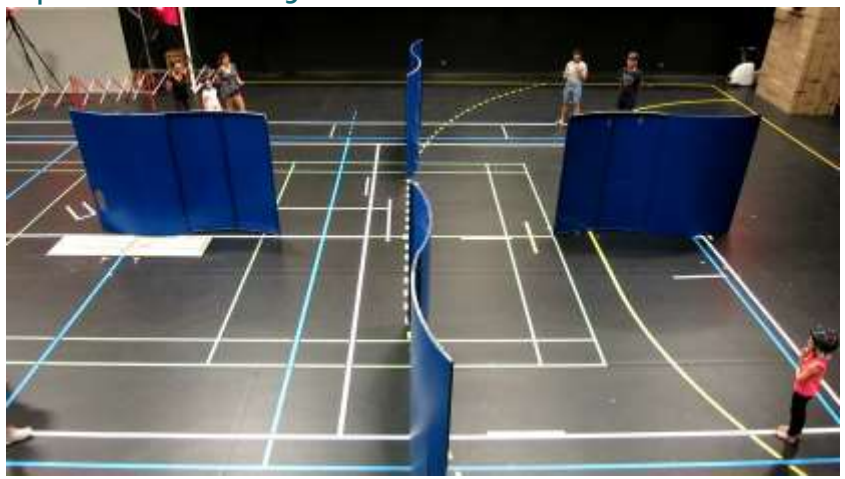
Body dimensions
Bourgaize Hum Mov Sci 2023

Experimental studies: sampling *f*

- **Highlight: Effect of normal aging**

8-12 ans

Rapos Gait Posture 2019



- Development of strategies similar to those of adults to mutually contribute to collision avoidance
- Effect of body dimensions

65-74 ans

Rapos Gait Posture 2021

- Deficits in visuomotor skills
  - Adaptation to less risky situations
  - Higher rate of crossing order inversion
  - Shorter crossing distance
- Affordances in a social context?
  - Greater contribution by the young adult when facing an elderly person

Rapos, V., Cinelli, M., Snyder, N., Crétual, A., & Olivier, A. H. (2019). Minimum predicted distance: Applying a common metric to collision avoidance strategies between children and adult walkers. *Gait & posture*, *72*, 16-21.
Rapos, V., Cinelli, M. E., Grunberg, R., Bourgaize, S., Cretual, A., & Olivier, A. H. (2021). Collision avoidance behaviours between older adult and young adult walkers. *Gait & Posture*

Experimental studies

Out of the lab studies with conditions difficult to control

Experimental studies: sampling f

Out of the lab studies with conditions difficult to control

$$\begin{cases} c = f(s_i, \{s_j\}_{j \neq i}, \boldsymbol{p}) \\ \Delta s_i = -\nabla f \end{cases}$$

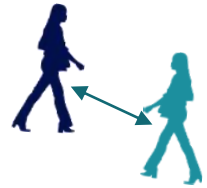
Shopping Mall
Joshi EBR 2022

Train station vs Football stadium
Duverné EuroVR 2020

Museum
Olivier SOFPEL 2022

Experimental studies: sampling *f*

Out of the lab studies with conditions difficult to control



- **Highlight: Effect of social context**


Duverné EuroVR 2020

- 2 types of places according to level of symbolization and sociality (Augé, 1992)
  - **Stadium** : « Anthropological place » **,** shared identity
  - **Train station**: « Non-place », anonymous, utilitarian function

➔ Higher sensitivity to proxemics norms in a non-place (more discomfort, more attempt to dissimulate their discomfort in the train station)

Duverné, T., Rougnant, T., Le Yondre, F., Berton, F., Bruneau, J., Zibrek, K., ... & Olivier, A. H. (2020). Effect of social settings on proxemics during social interactions in real and virtual conditions. In *Virtual Reality and Augmented Reality: 17th EuroVR International Conference, EuroVR 2020*

Experimental studies

Studies in Virtual Reality

Experimental studies: sampling f

VR studies to investigate local interactions and sample f

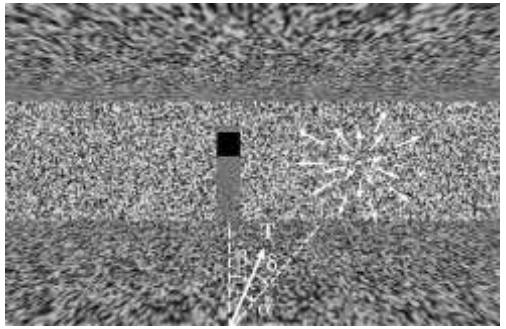
$$\begin{cases} c = f(s_i, \{s_j\}_{j \neq i}, \boldsymbol{p}) \\ \Delta s_i = -\nabla f \end{cases}$$

Virtual reality

VR studies to investigate local interactions and sample f

$$\begin{cases} c = f(s_i, \{s_j\}_{j \neq i}, \boldsymbol{p}) \\ \Delta s_i = -\nabla f \end{cases}$$

- Controlled experimental possibilities that overcome the constraints of reality
  - Manipulation and standardization of environmental characteristics…



[Warren et al. 2001] Manipulation of optic flow

[Lynch et al. 2019] Sports, deceptive motion, expertise

  - …while preserving the security of participants/patients

https://www.youtube.com/watch?v=DFHGvmJIrN8

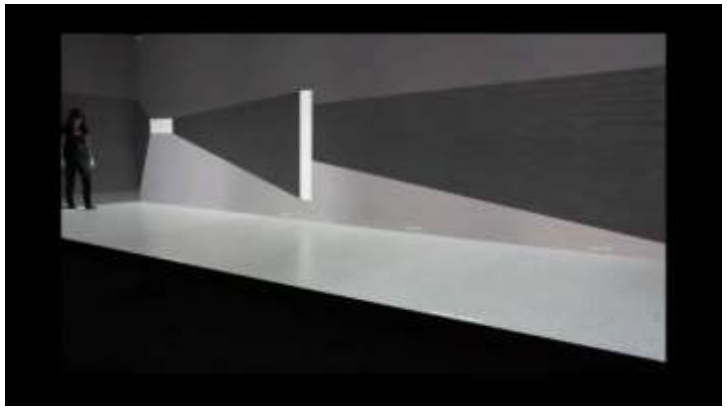
Immersive technologies

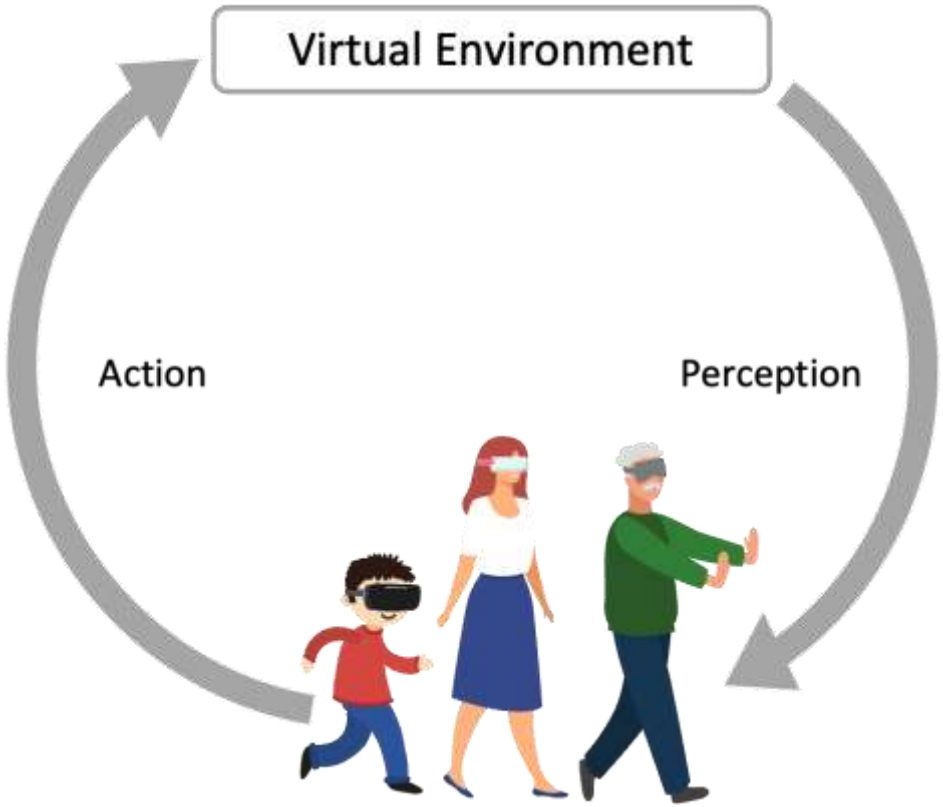
Picture of macrovector in Freepik

Can VR allow to reproduce real world pedestrian's behaviour?

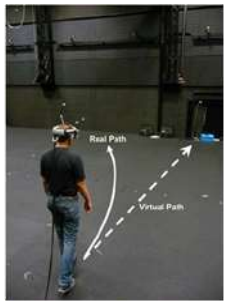
Credit : https://ghitaelhaitmy.medium.com/the-other-realities-you-need-to-explore-types-of-immersive-tech-and-what-they-

Perception-action loop in VR





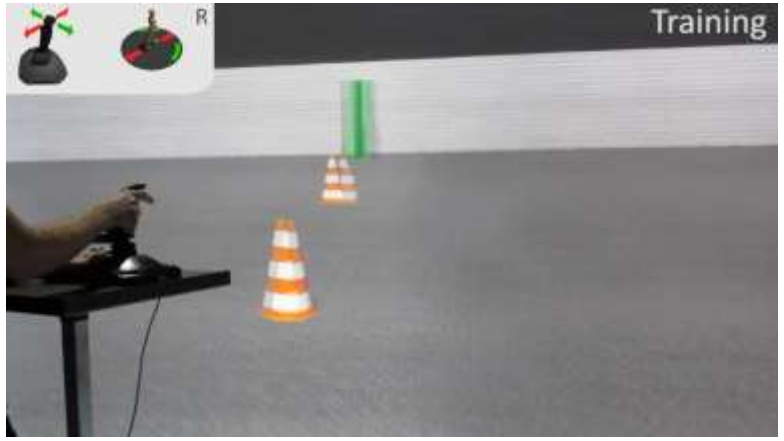
Joystick
Olivier 2017



Redirected walking
Neth2012

Joyman
Marchal2011

Experimental studies in VR: validation



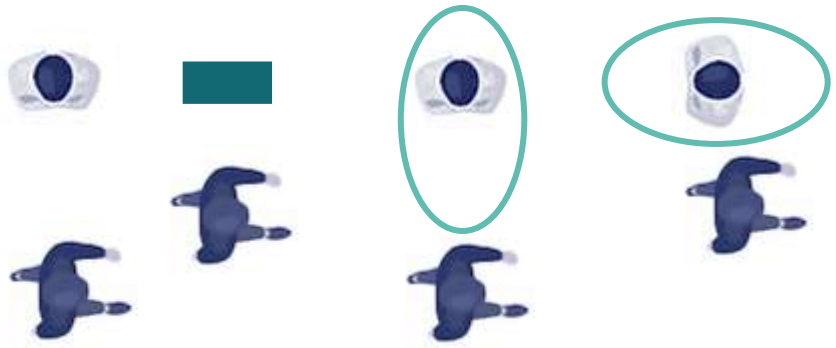
Sanz
IEEE VR 2015

Olivier
TVCG 2017

Berton
IEEE VR 2020

Experimental studies in VR: validation

Similar social norms



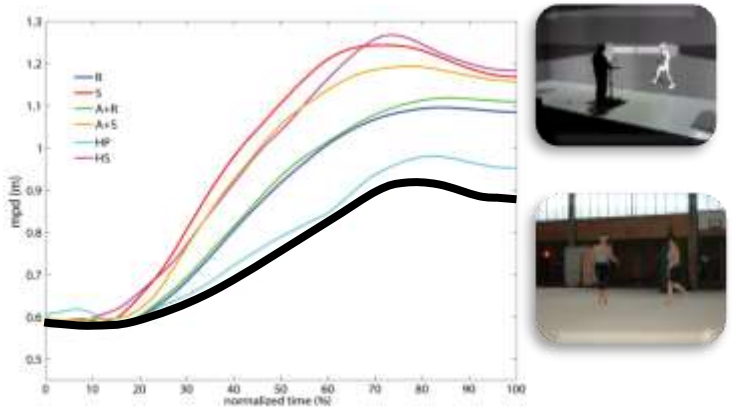
Sanz
IEEE VR 2015

Iachini
J. Env. Psychol. 2016

Leblong
VRST 2024

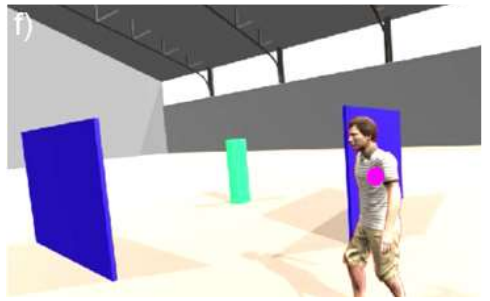
Similar temporal sequence of collision avoidance

Olivier
TVCG 2017



Similar gaze allocations

Berton
IEEE VR 2019, 2020

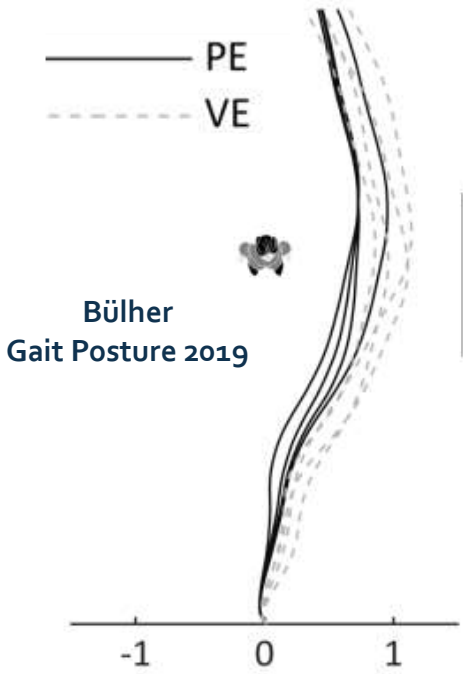


Rubo
ETRA 2018

Raimbaud
IEEE VR 2022
SAP 2023

Experimental studies in VR: validation

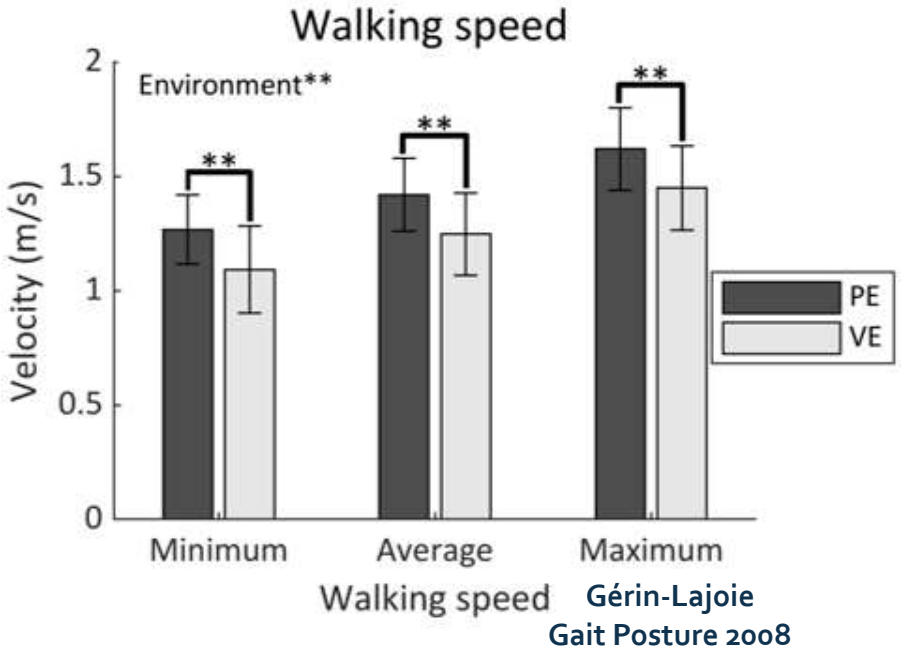
Some quantitative differences



Bülher
Gait Posture 2019

Increase of interpersonal distances

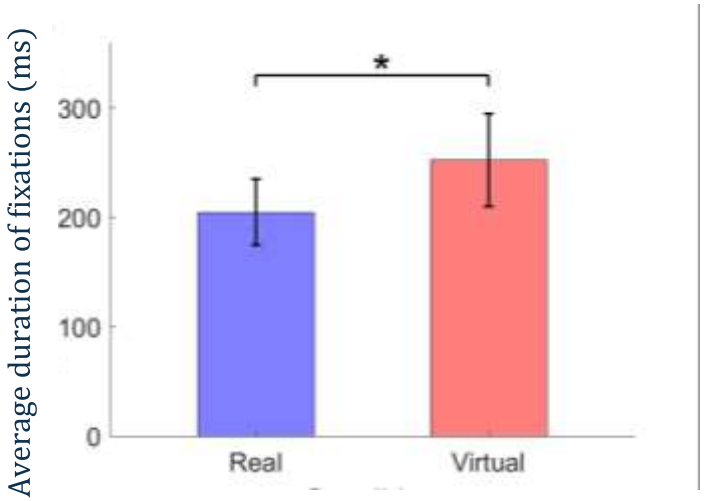
Bülher Gait Posture 2019, Sanz IEEE VR 2015, Gérin-Lajoie Gait Posture 2018, Olivier TVCG 2017, Iachini J. Env. Psychol. 2016



Gérin-Lajoie
Gait Posture 2008

Decrease of walking speed

Gérin-Lajoie Gait Posture 2008
Bülher Gait Posture 2019, Sanz IEEE VR 2015, Palmisano Front. Hum. Neurosci. 2022, Berton IEEE VR 2019



Duration of fixations real < virtual

Berton
IEEE VR 2020

Pairwise Experimental studies in VR: validation

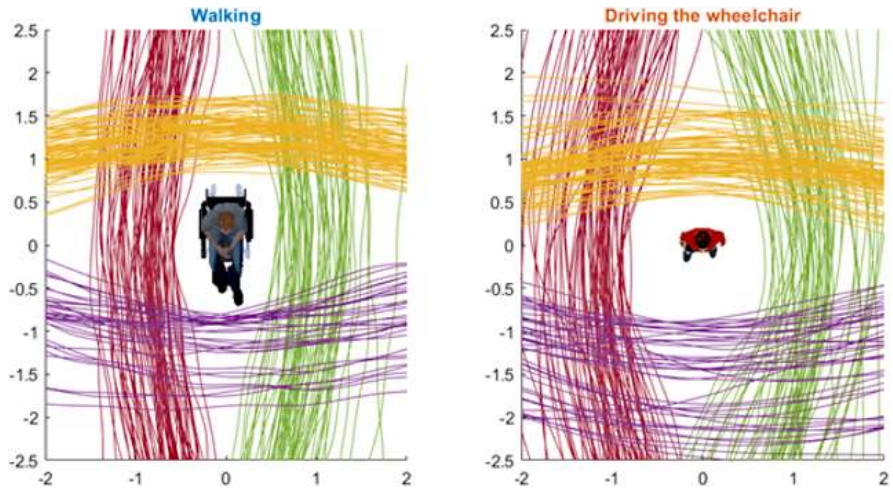
- **Highlight: Interaction between a pedestrian and a wheelchair user**

Leblong
VRST 2024

Leblong, E., Grzeskowiak, F., Thomas, S., Devigne, L., Babel, M., & Olivier, A. H. (2024, October). Wheelchair Proxemics: interpersonal behaviour between pedestrians and power wheelchair drivers in real and virtual environments. In *Proceedings of the 30th ACM Symposium on Virtual Reality Software and Technology* (pp. 1-12).

Pairwise Experimental studies in VR: validation

- **Highlight: Interaction between a pedestrian and a wheelchair user**
  - Walking vs. Driving in real conditions

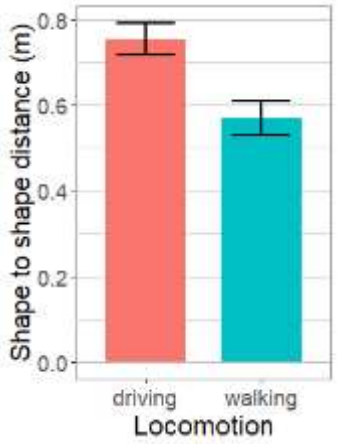


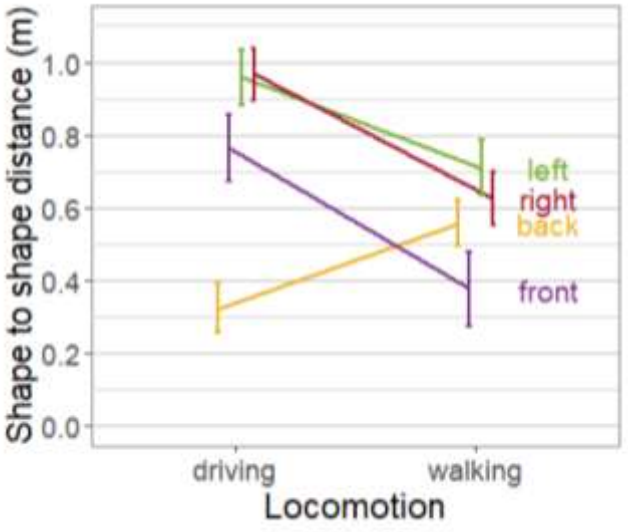
- **The mode of locomotion affects interpersonal distances**

Distance when using a wheelchair > when walking

- **Asymmetry of personal space shape**
  - Influence of the person' orientation, specific to the mode of locomotion

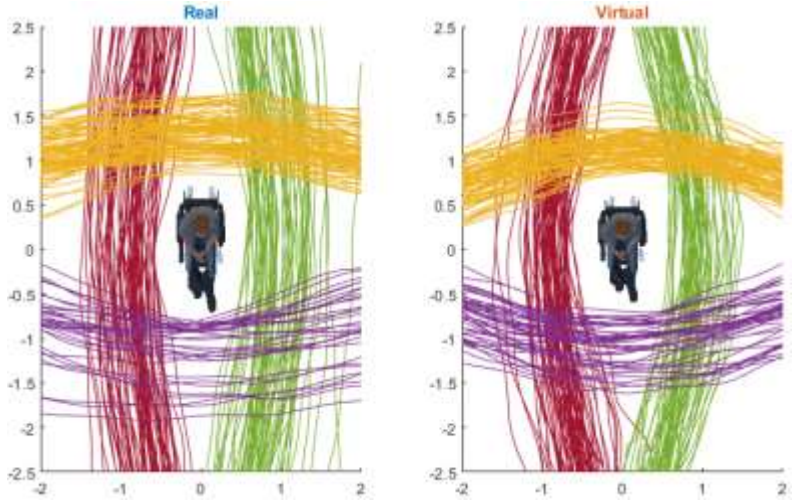
- **Avoidance Strategy**
  - Left-right same proportions
  - More to the back than to the front





Pairwise Experimental studies in VR: validation

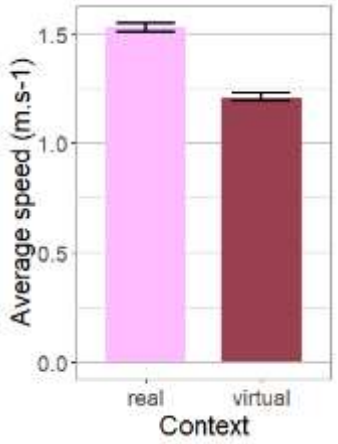
- **Highlight: Interaction between a pedestrian and a wheelchair user**
  - Real vs. VR conditions when walking and avoiding a wheelchair

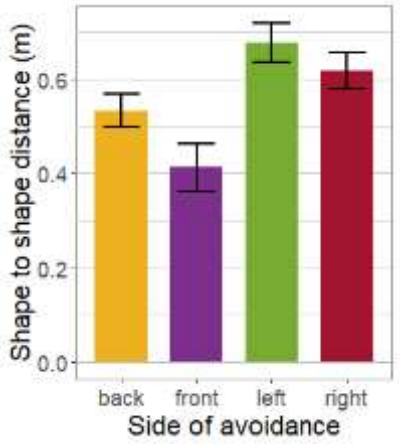


- **Walking speed is slower in VR**

- **Distances influenced by orientation and slightly increased in VR (2cm)**

- **Similar avoidance strategies RE-VR**
  - Left-right same proportions
  - More to the back than to the front

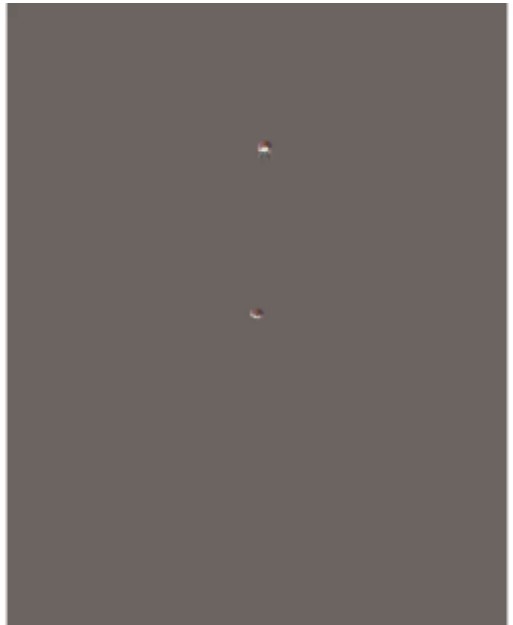


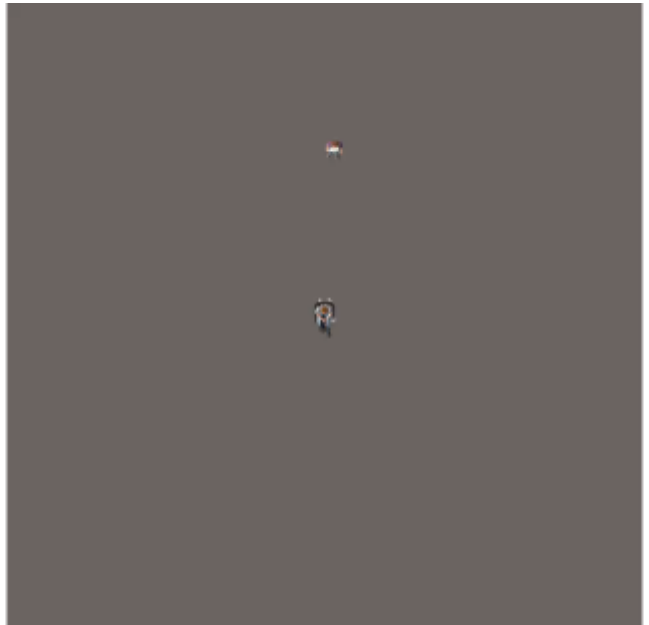


Pairwise Experimental studies in VR: validation

- **Highlight: Interaction between a pedestrian and a wheelchair user**
  - Several guidelines for designing VR environments to improve accessibility, featuring virtual humans with realistic social behaviors
    - Personal space with an elliptical shape
    - Specific interpersonal distances for PWC user interactions
    - Preferential choice for pedestrian to pass behind
    - No preferential right or left strategy

Adaptation of RVO algorithm

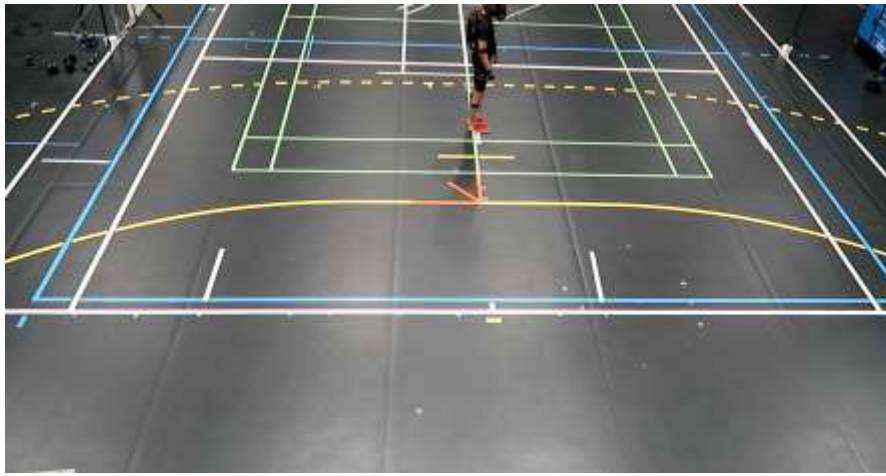




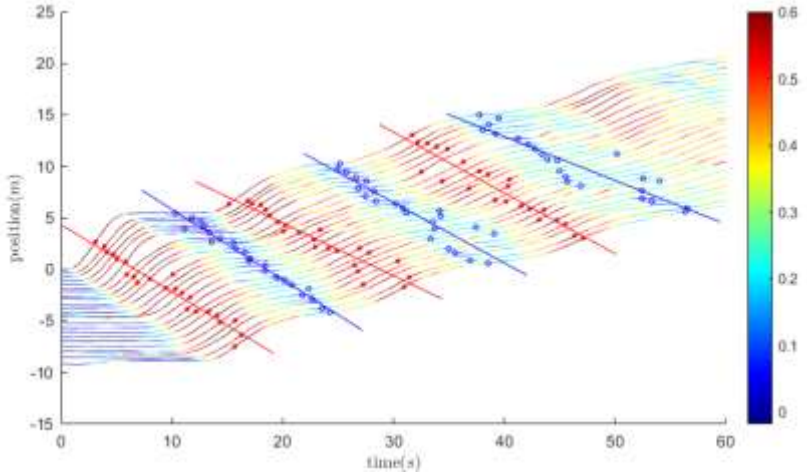
Experimental studies in VR: validation

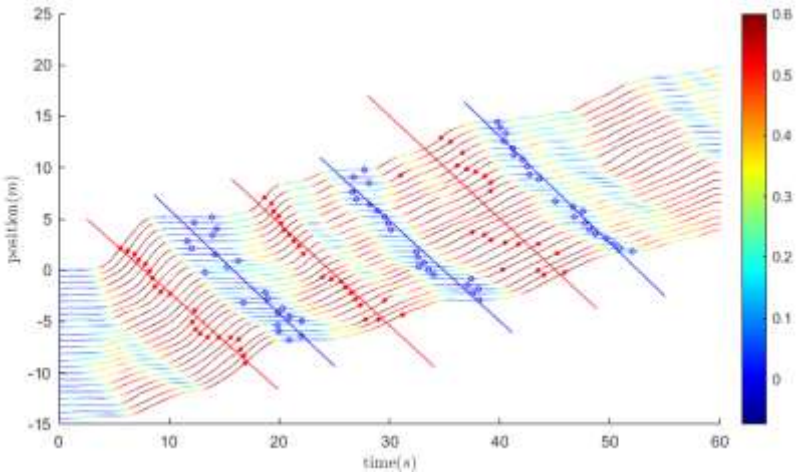
- One man crowd

Yin
IEEE VR-TVCG 2022



« Collective » motion exhibits similar emergent patterns





Experimental studies in VR: validation

- Some technical considerations: haptic rendering of collision

Arm-mounted vibrotactile device

- Preservation of global trajectory characteristics
- Modification of avoidance behavior
  - More shoulder rotation
  - Less collisions
  - Slower walking speed

Berton
TVCG 2020

Yun
IEEE VR 2024

Expecting a real person in the scene with a physical bump pre-cueing

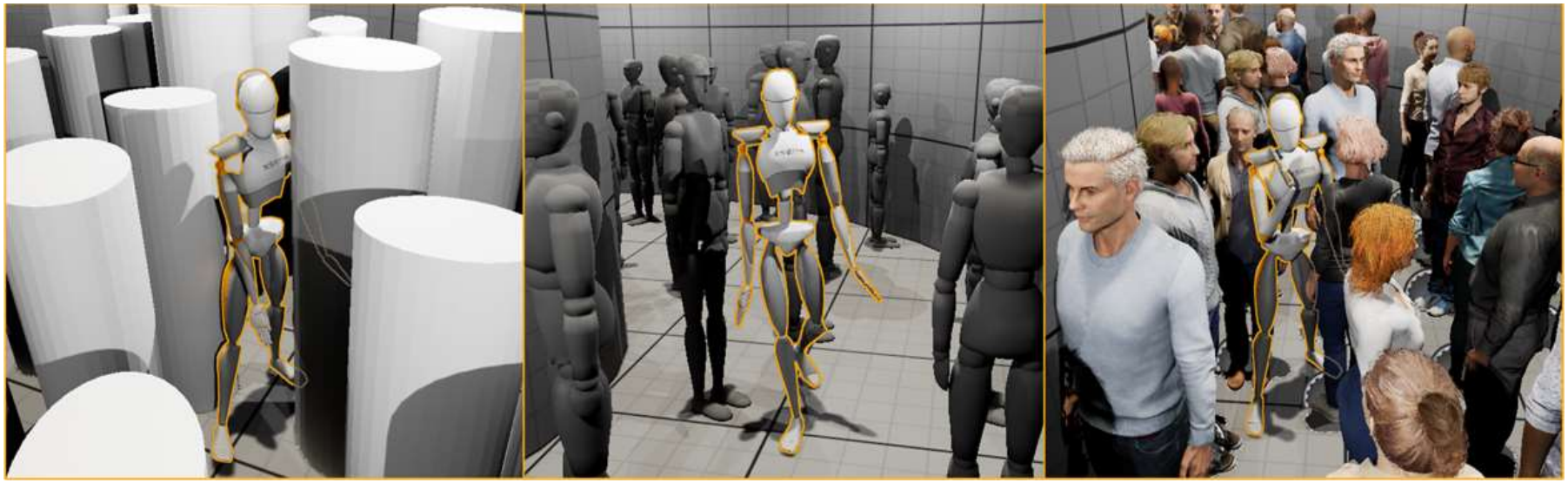
- Affects global navigation strategies
- Increases the sense of presence

Yun
IEEE VR 2024

Experimental studies in VR: validation

- Some technical considerations: visual representation of the crowd

➔ Question of the computational cost of showing a crowd in VR

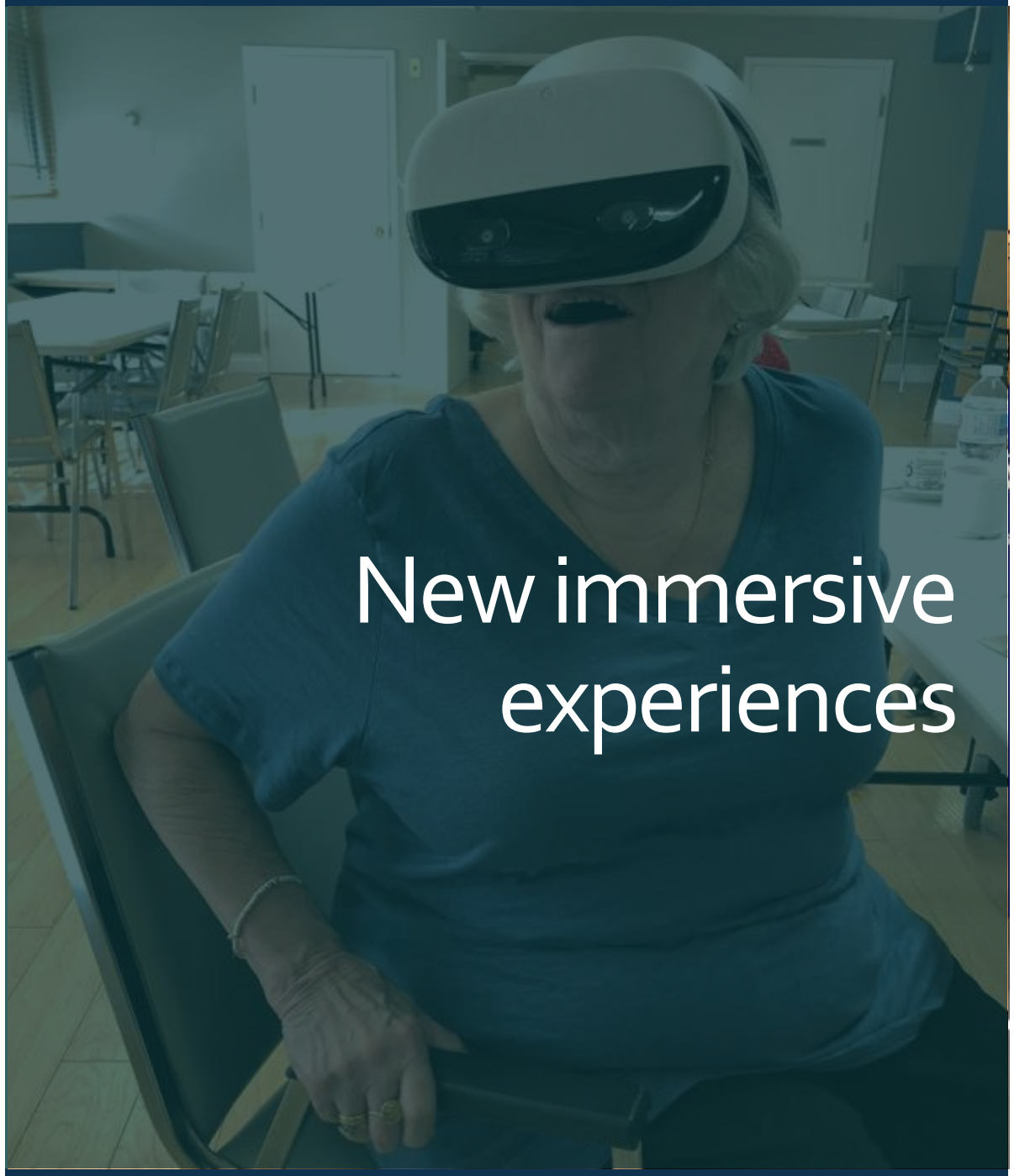


Martin
IEEE ISMAR 2024

- The use of anthropomorphic representations is sufficient to guarantee the ecological validity for studying crowd navigation
- However, there is an interest of using detailed realistic representation when user behaviour is studied in more details

Virtual reality : a relevant tool to study local interactions

- Preserves social interaction features
- Preserves the nature of collision avoidance behaviour as well as the content looked at
- Some quantitative differences ➔Evaluation of our experimental platforms is then fundamental

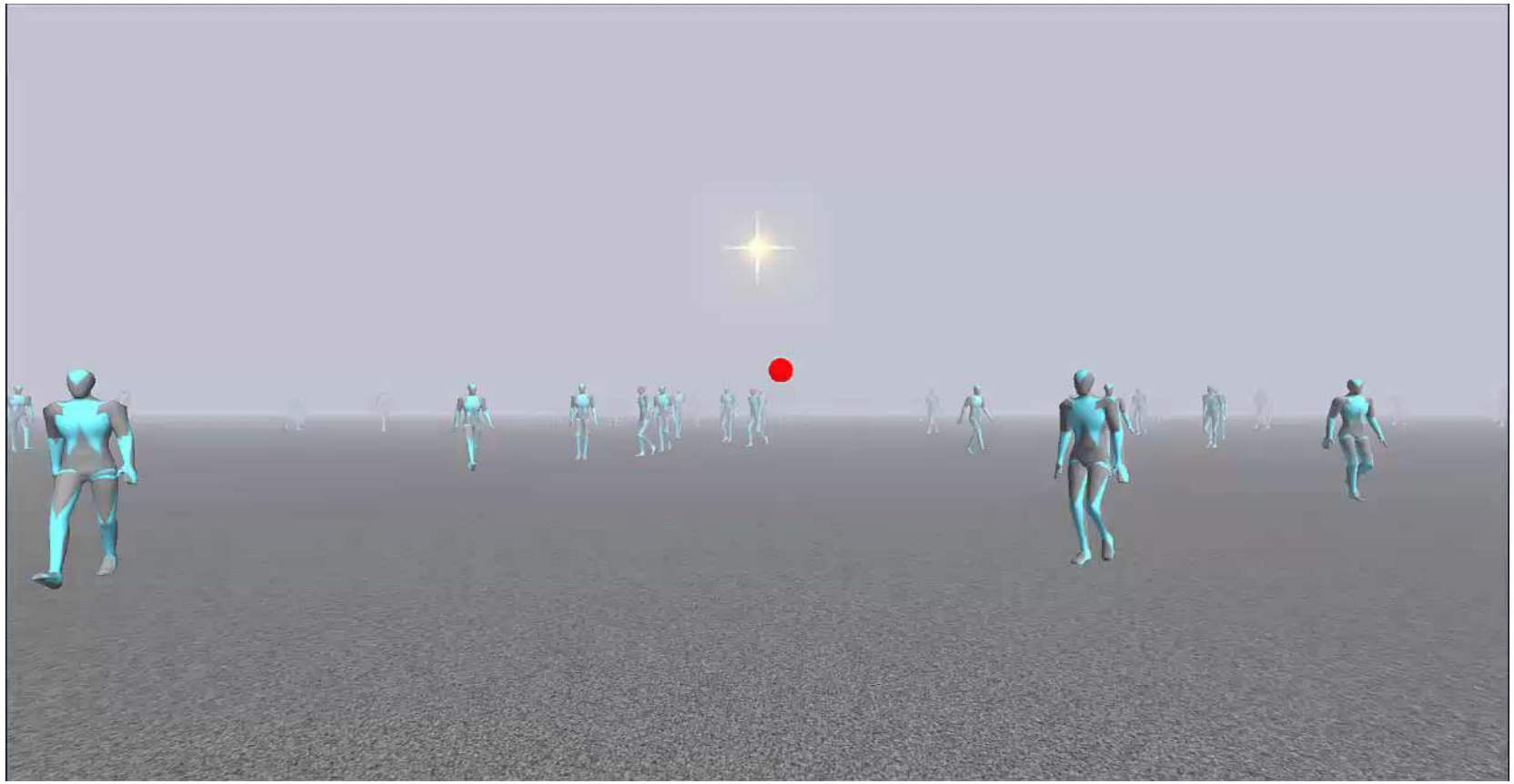


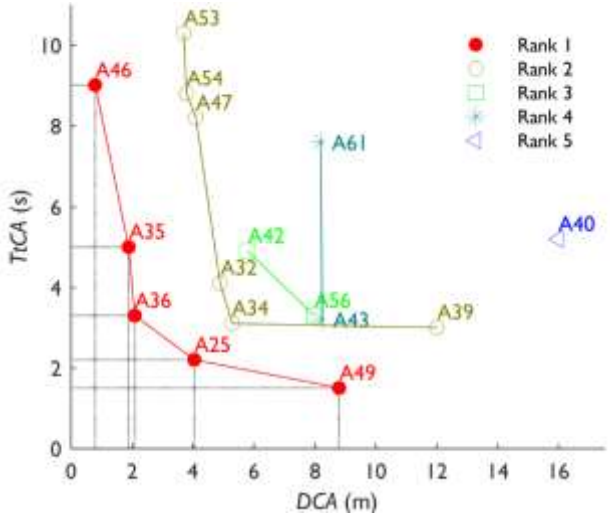
New immersive experiences

New immersive experiences: control variables

Further evidence supporting the role of collision risk in locomotor trajectory control

- Gaze  Meerhoff Acta Psychologica 2018



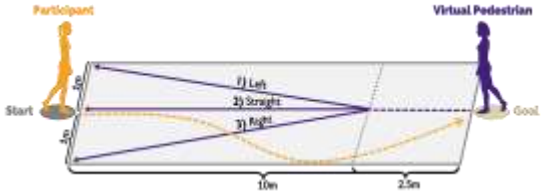


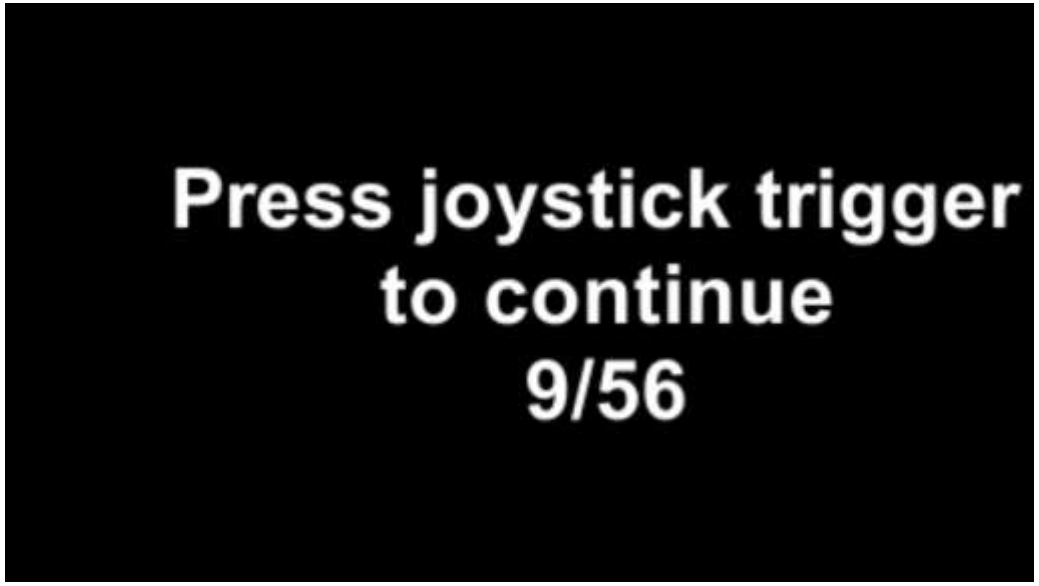
New immersive experiences: individual characteristics

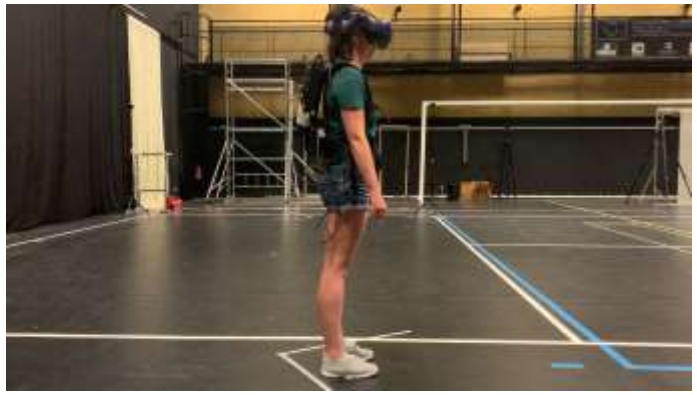
Effect of aging

Young Adult

Older Adult







- Clearance larger when the virtual pedestrian
  - Looked like an OA
  - Walked like an OA

Bourgaize
ISPGR 2023
SAP 2024

LIFESPAN
PSYCHOMOTOR
BEHAVIOUR LAB

New immersive experiences to assess clinical population and propose innovative interventions

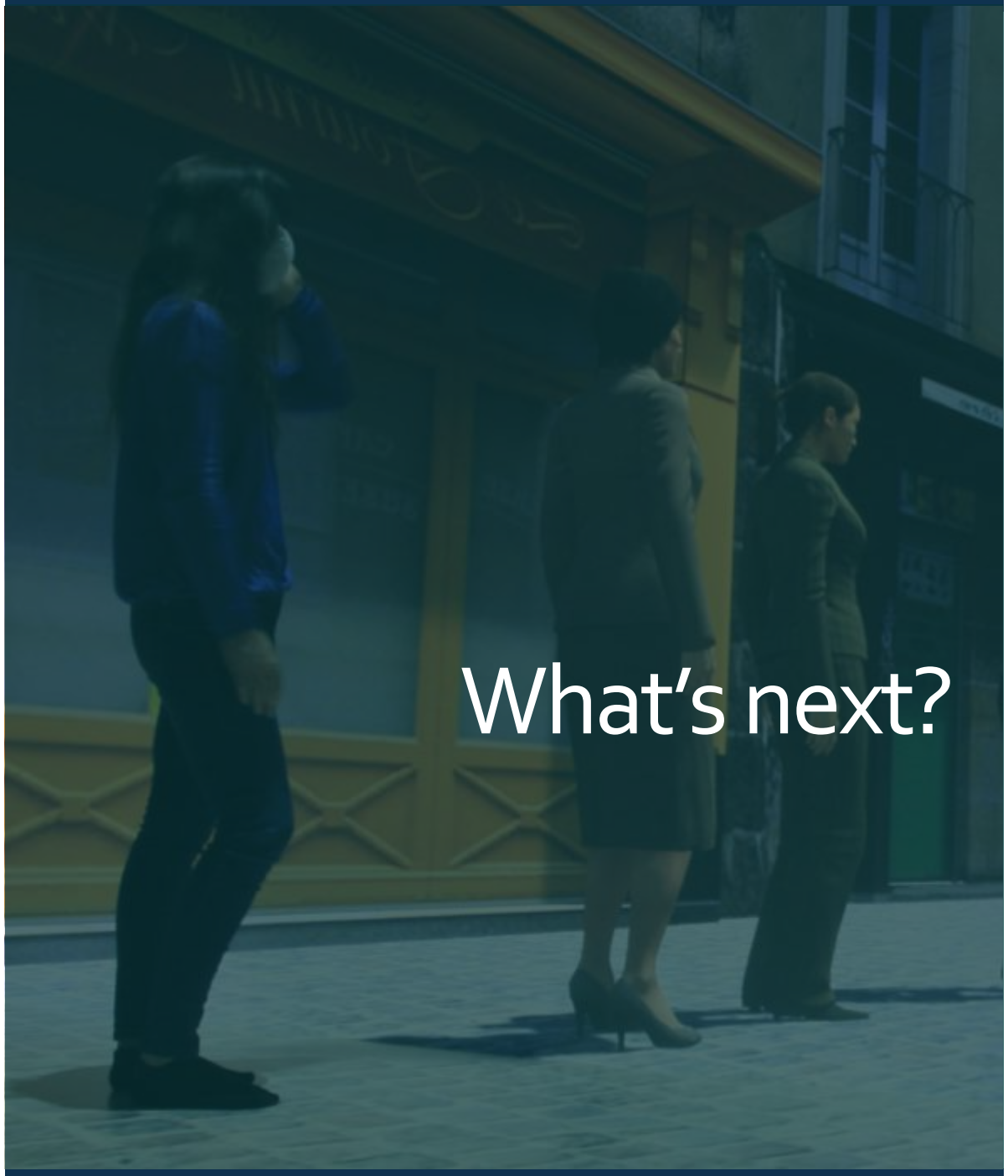
SocNav

- Traumatic Brain Injury population and navigation within a crowd

Logvs

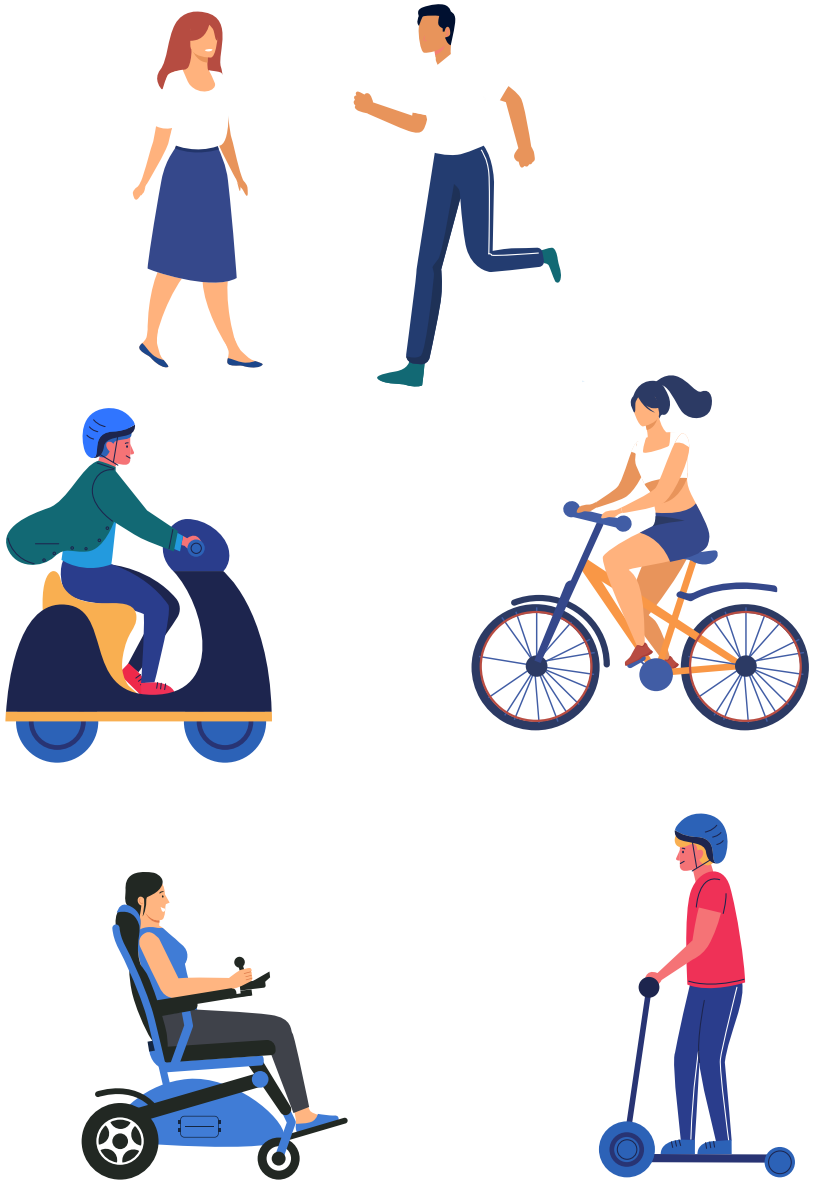
UMANS
Unified Microscopic Agent Navigation Simulator

Inria Cirris · Université Rennes 2 · Université Laval · aIH2A · Fondation Saint-Hélier



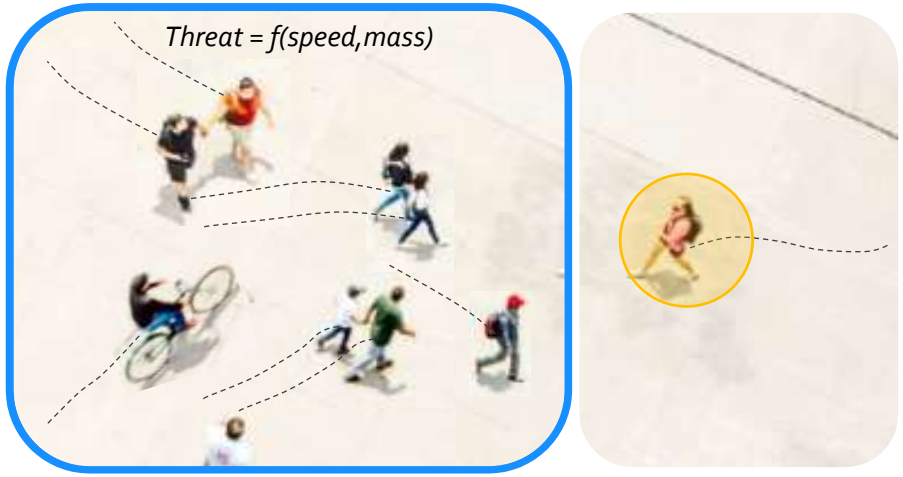
What's next?

Exploring new control variables



Go beyond interpersonal distances and consider threats to physical safety

Trajectory= f (Environment, Individual)



Interactions PIéton-Cycliste dans les espaces urbains partagés (IPiC)

IPiC

SÉCURITÉ ROUTIÈRE VIVRE, ENSEMBLE

Université Gustave Eiffel

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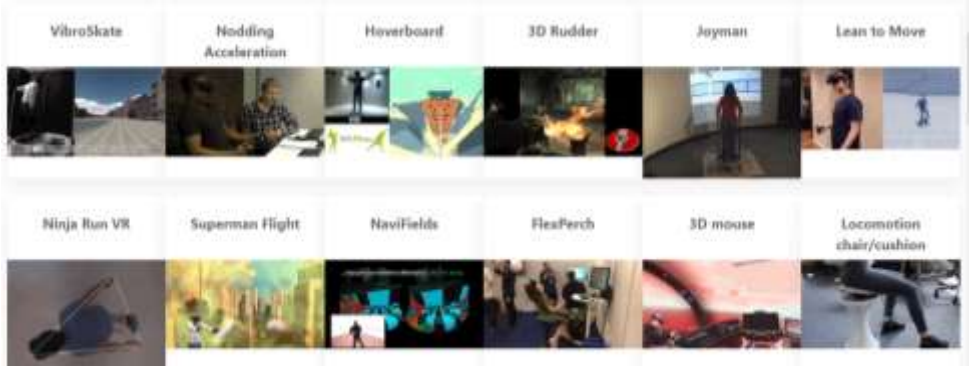
Inria

RENNES MÉTROPOLE

Technical considerations



Locomotion interface and control laws
https://locomotionvault.github.io/

Representation of the virtual body

Perspective in AR?

Estimating Distances in Action Space in Augmented Reality

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CARLOS SALAS ROSALES, Vanderbilt University, USA
RYAN MILERIS, JEANINE K. STEFANUCCI, and SARAH H. CREEM-REGEHR, University of Utah, USA
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The Perception of Affordances in Mobile Augmented Reality

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ABSTRACT

Today, augmented reality (AR) is most easily experienced through a mobile device such as a modern smartphone. For AR to be useful for applications such as training, it is important to understand how people perceive interactions with virtual objects presented to them via mobile AR. In this paper, we investigated two judgments of action capabilities (affordances) with virtual objects presented through smartphones: passing through an aperture and stepping over a gap. Our goals were to 1) determine if people can reliably scale these judgments to their body dimensions or capabilities and

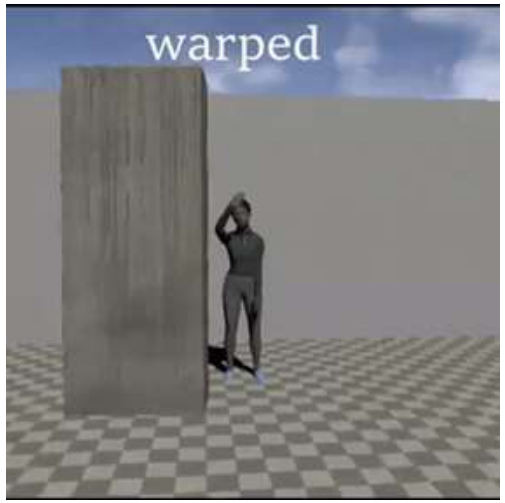
KEYWORDS

augmented reality, perception, affordances, mobile devices

ACM Reference Format:

Yu Zhao, Jeanine Stefanucci, Sarah H. Creem-Regehr, and Bobby Bodenheimer. 2021. The Perception of Affordances in Mobile Augmented Reality. In *ACM Symposium on Applied Perception 2021 (SAP '21), September 16–17, 2021, Virtual Event, France.* ACM, New York, NY, USA, 10 pages. https://doi.org/10.1145/3474451.3476259

(Virtual) Humans considerations



Virtual Humans reactivity and expressivity

Jovane MIG 2022

Usability
Acceptability
Accessibility

More diversity

Leblong VRST 2024

Towards more ecological contexts

Collaborative work

Anne-Hélène Olivier

anne-helene.olivier@univ-rennes2.fr

Thank you!

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