

# Modeling and simulation of human crowds: the emergence of machine learning models and the question of training data.

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Collective Motions of Animals and Robots  
Cargese, May 28 2024

# Disclaimer

**This presentation is meant to be any-discipline-friendly**

**The title can be misleading – I won't talk about AI**

**I selected the most “exotic” results (2015-24)**

# VirtUs team



UMR IRISA



## Multidisciplinary team:

Computer Sciences, Motion Sciences and Psychology

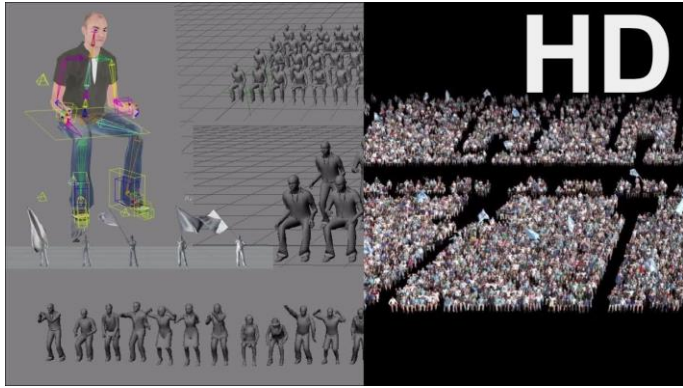
6 permanents, ~20 students, engineers, postdocs

## Research objective:

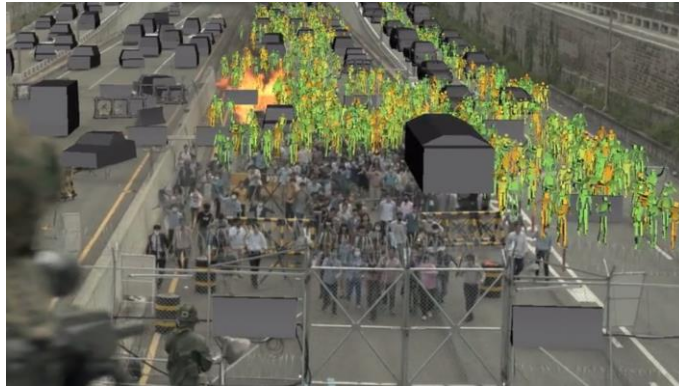
Create immersive simulation of populated environments for scientific purposes



# Context



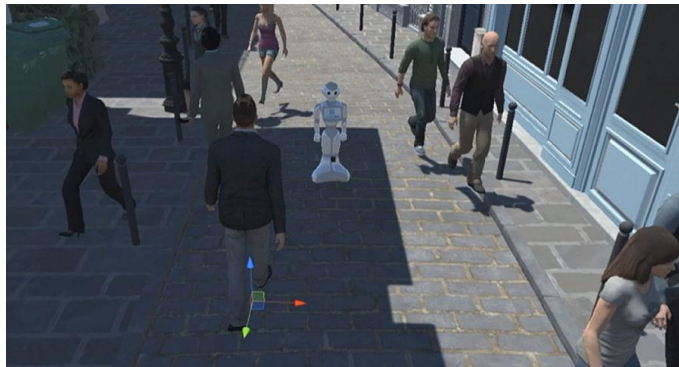
Crowd modelling and simulation for VFX in movies...



video games...



Immersive VR...



Evaluation & training platforms...



Events safety...



# Research topics

## Crowd simulation

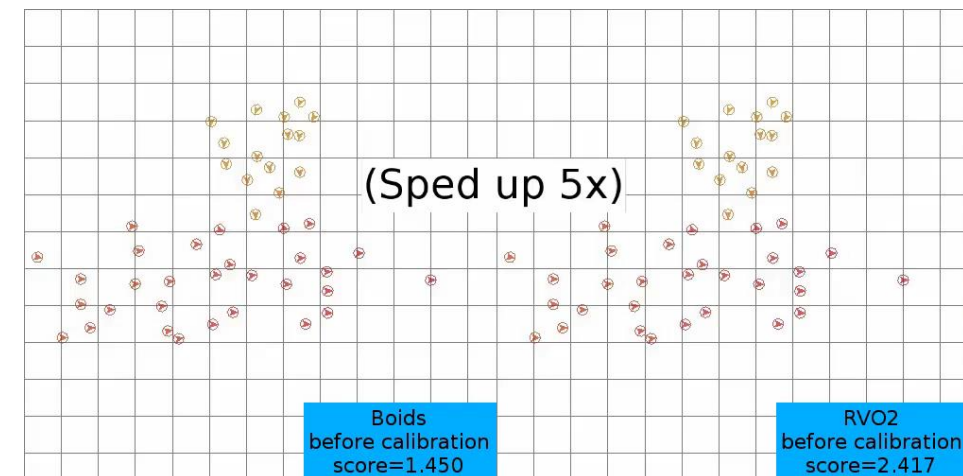
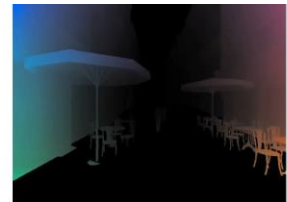
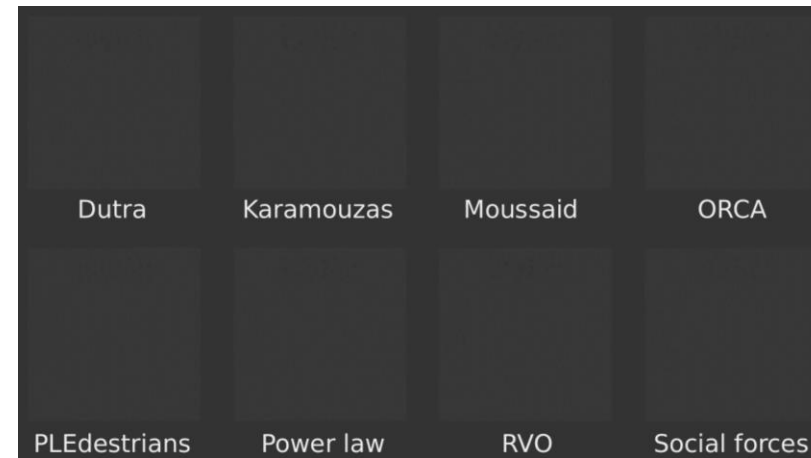
- 2D particles systems
- Machine Learning
- Vision agents
- Full-body crowd simulation

## Evaluation and calibration

- Evaluation of real vs. simulated data
- Estimation of simulation parameters
- Context dependent mixture models

## New experimental methodologies

- Laboratory experiments
- Field experiments
- Virtual Reality



# Human crowd data



[Lerner et al. 2008]



[Cao et al. 2017]



[Berton et al. 2020]





# Not a that recent idea actually

2009



2019



# Part 1

## VR for navigation data

How VR can be useful to understand locomotion and navigation strategies in crowds



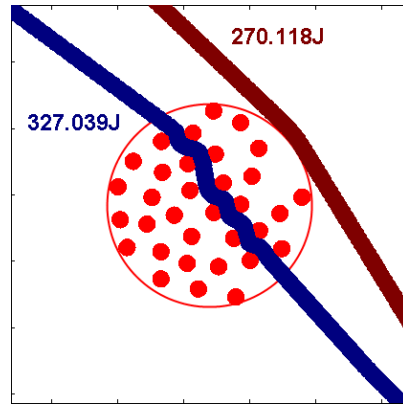
(to replace this kind of experiments)



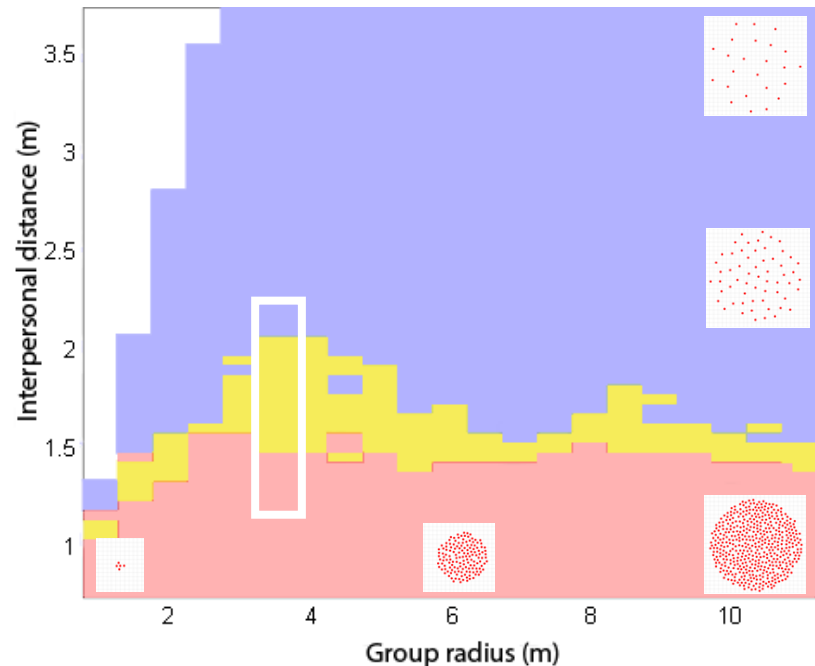
# Going through or going around?



# Local interactions with groups



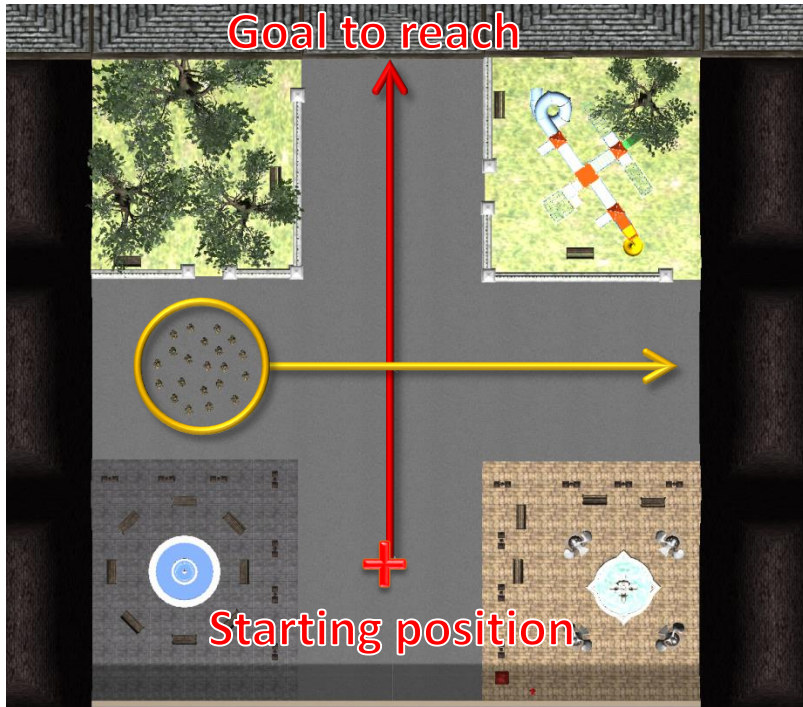
Groups of changing **radius** and **density**  
Simulate **two** strategies (around vs. through)  
Compute **energy** for each  
 $E = m \int (e_s + e_w |v|^2) dt$  [Whittle, 2003]



|              |                |
|--------------|----------------|
| High density | => Go around   |
| Low density  | => Go through  |
| In Between   | => Uncertainty |

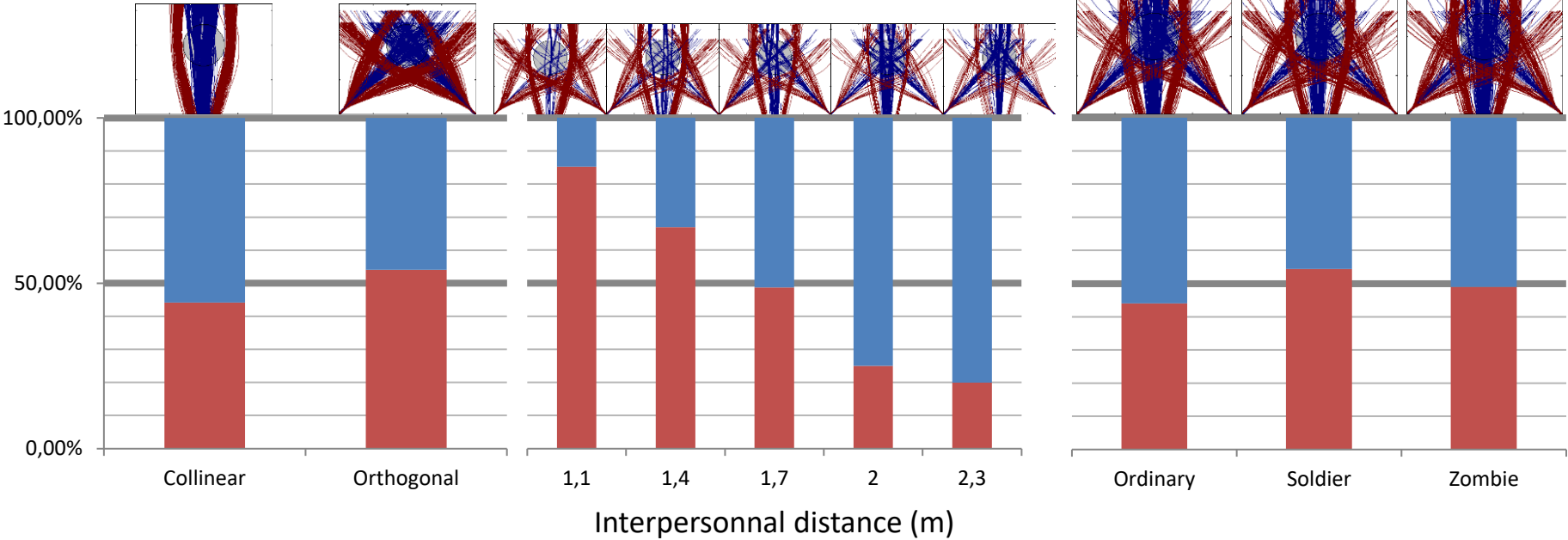


# Task and stimuli

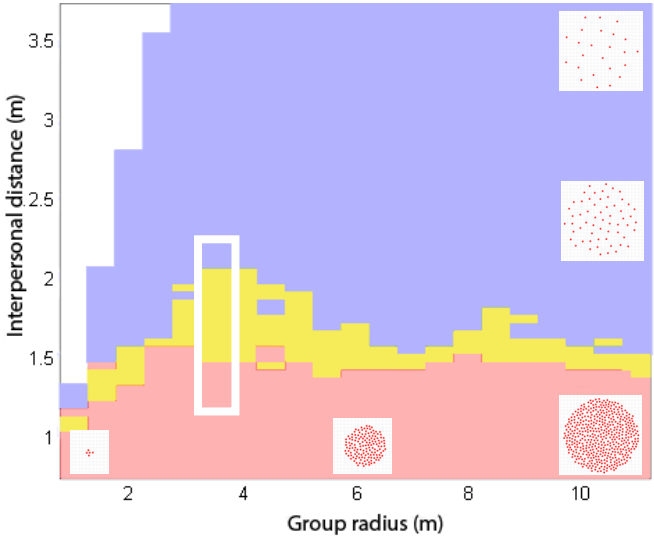


# Results

■ Going through



■ Going around



# Conclusion

VR delivers data **quickly** (need a single participant + no data postprocessing)

Logistical, ethical, legal, statistical aspects are **simplified**

Complete **knowledge** about the environment

**Note:** we did evaluate ecological validity + behavioral biases

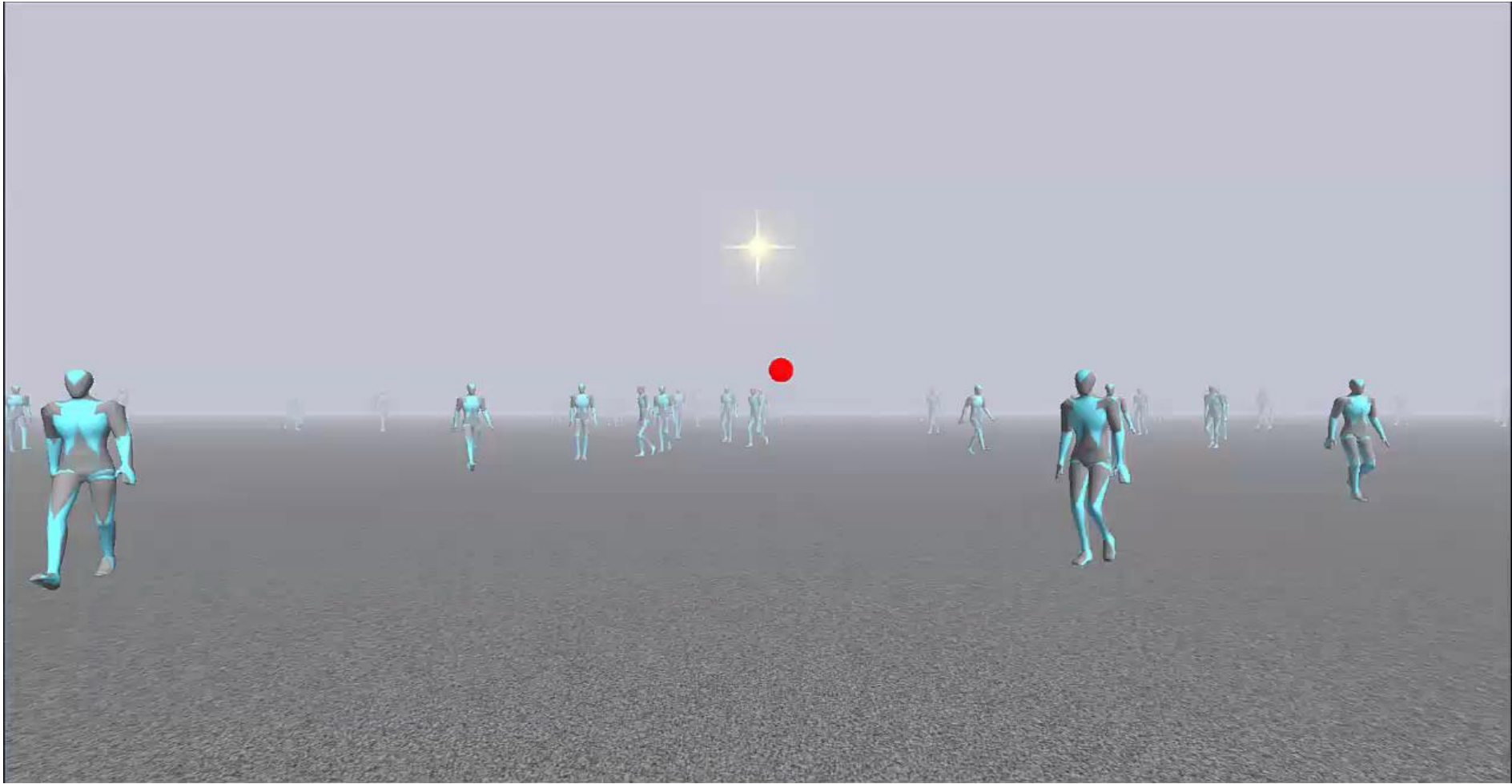
Can we go a bit further in the understanding of human behaviours?



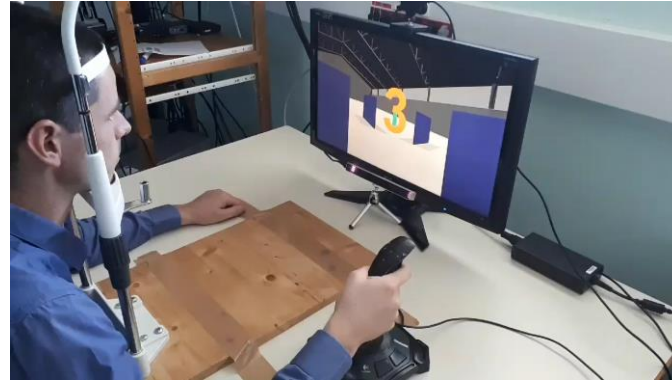
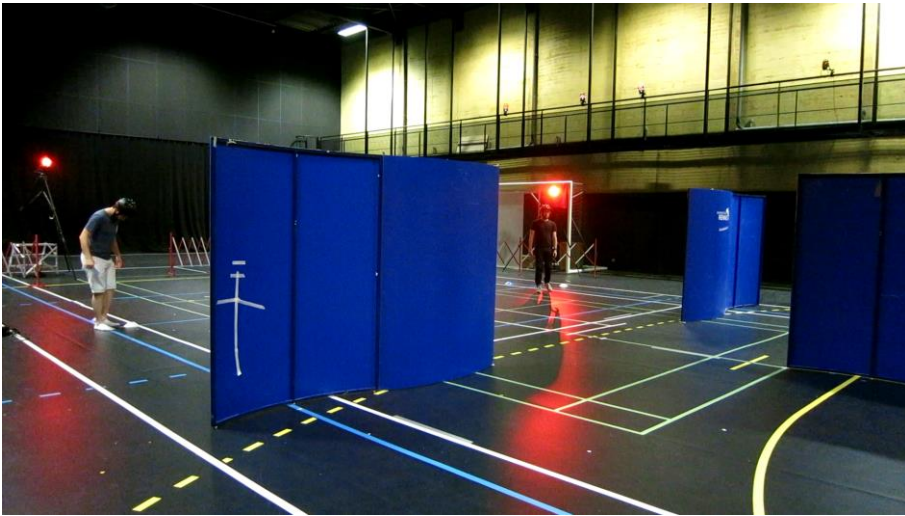
## Part 2

# VR for locomotion + eye-gaze data

How can VR help understanding deeper how humans form trajectories in crowds



# Can we use VR here?



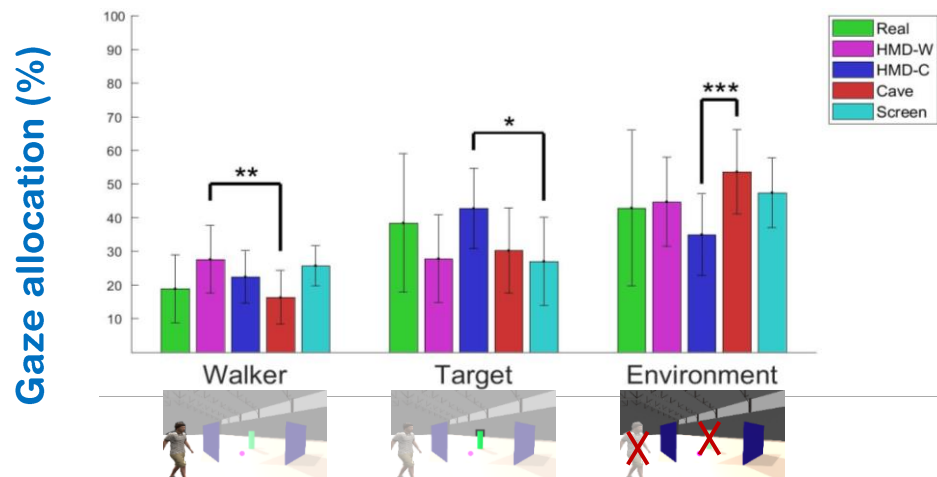
« VR » based approach facilitates  
Eye-gaze data collection  
Gaze data annotation  
Avoidance detection and analysis



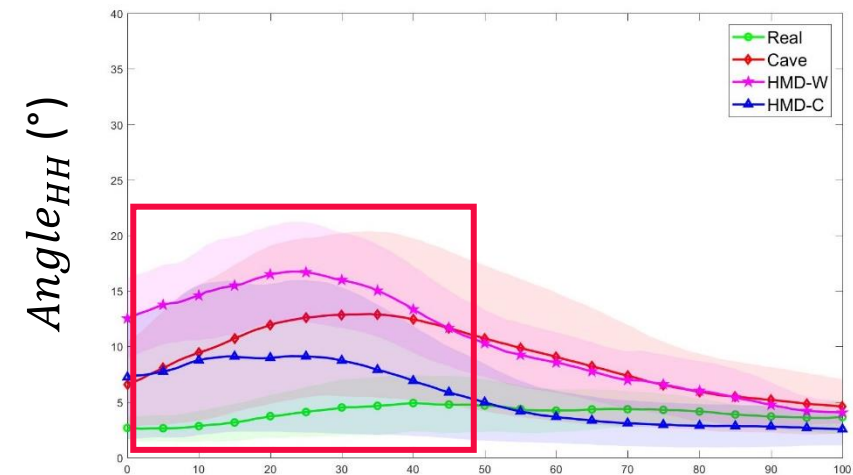
# Results

Participants have different head and eye motions...

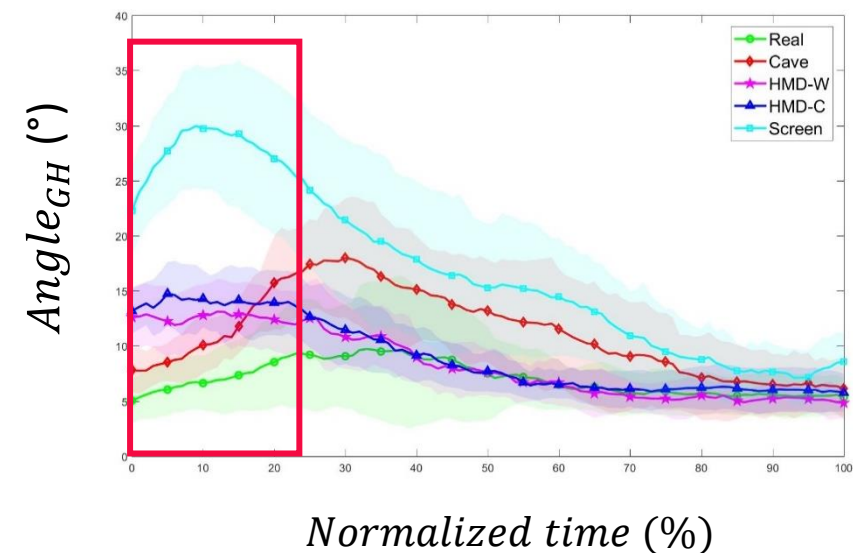
But look at the **same thing**.



## Head & Heading



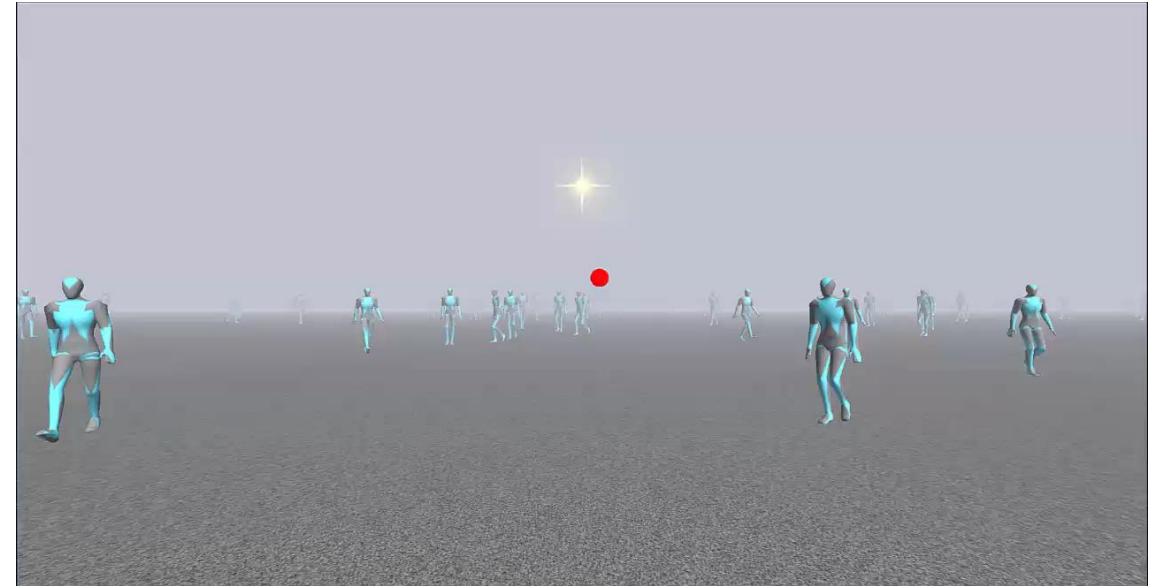
## Head & Gaze



# Gaze and interactions?

$$f: \mathbb{R}^n \rightarrow \mathbb{R}$$
$$f(s_{t,i}, \{s_{t,j}\}_{j \neq i}) = c$$

Can gaze reveal **neighborhood**?



# Gaze and interactions?

Is visual attention « **linked** » to collision avoidance?

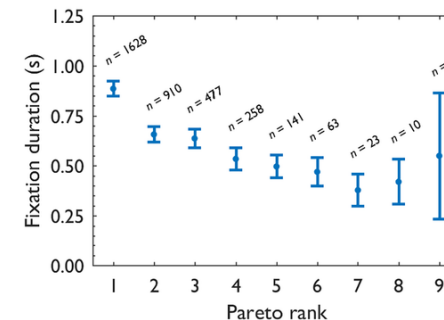
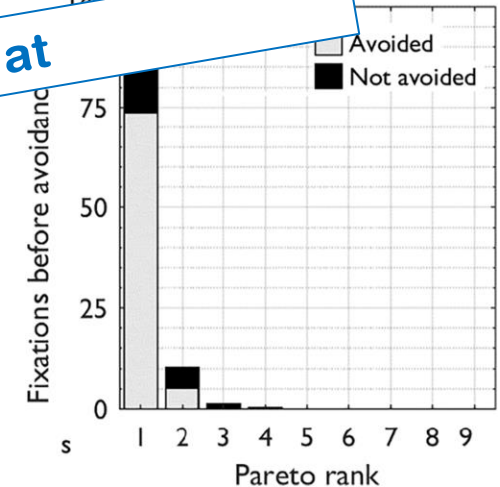
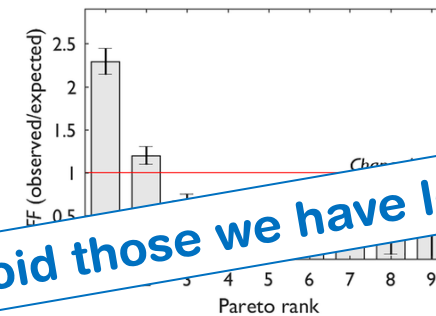
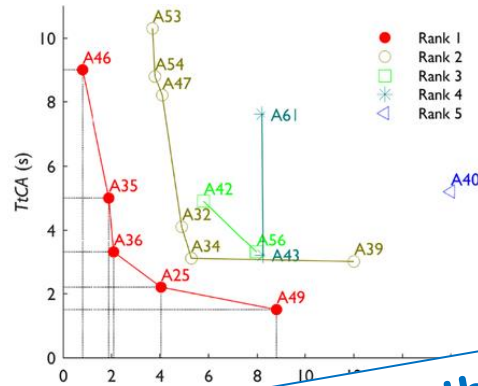
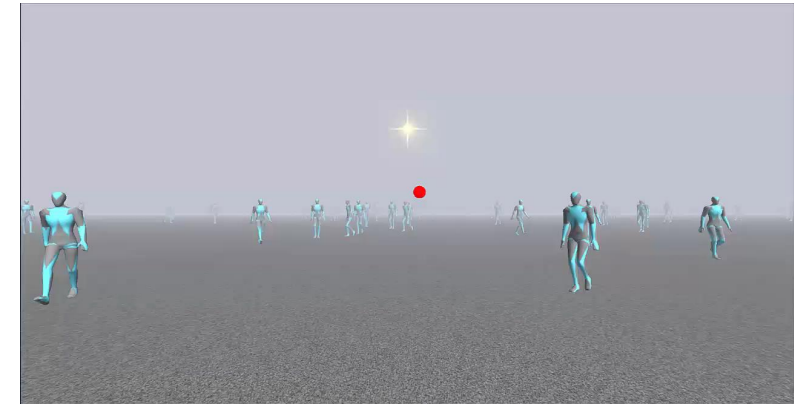
What is collision risk?

Small future distance of closest approach

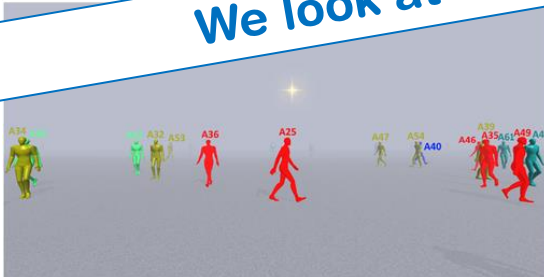
Small time to closest approach

Do we look more at characters of highest risk of collision?

Have we looked at characters we avoid?



We look at those we avoid and avoid those we have looked at





# Application: density-neighborhood

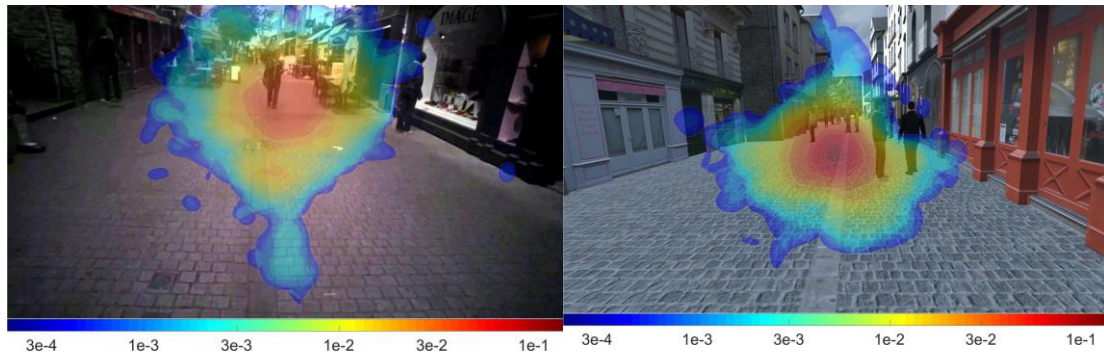


## Difficulties

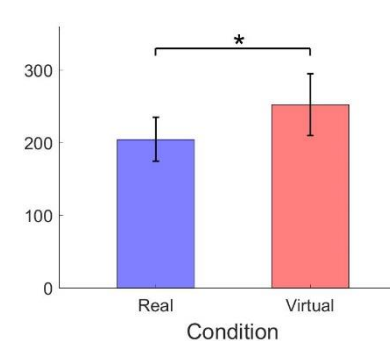
Ethical approval

Video analysis for semantics,  
geometry and motion

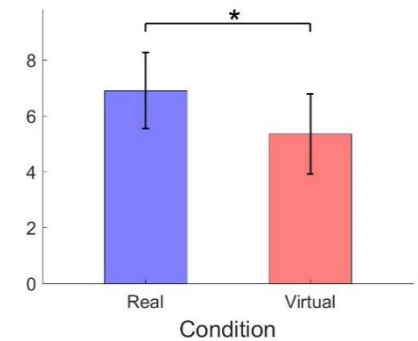
# Virtual replication of the vasselot street



Average fixation duration (ms)



Average saccade amplitude (°)

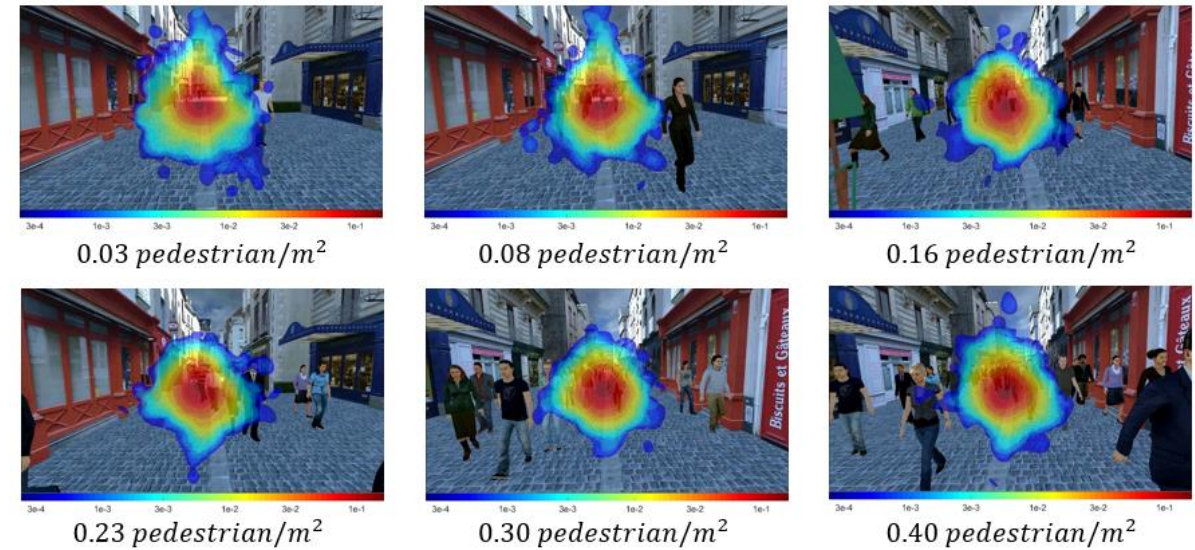




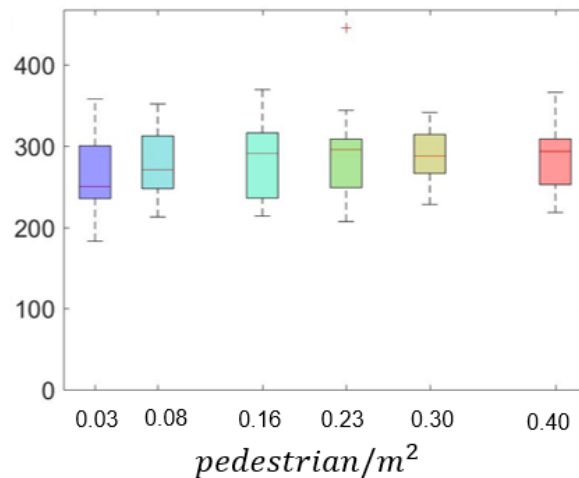
# Effect of density on gaze behaviors



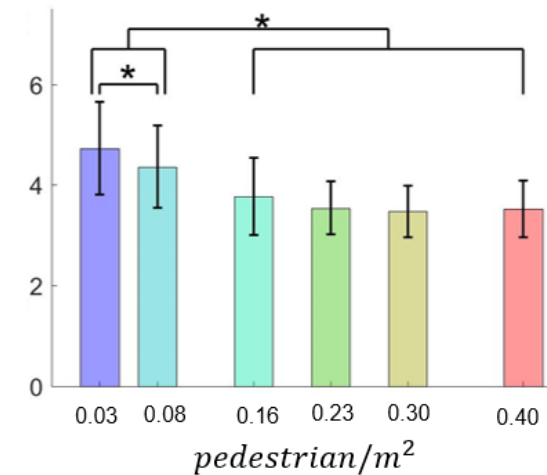
# Effect of density on gaze behaviors



Average Fixation Duration (ms)



Average Saccade Amplitude(°)





# Conclusion

VR delivers **complex** data quickly

Experimental **opportunities** (difficult in real conditions)

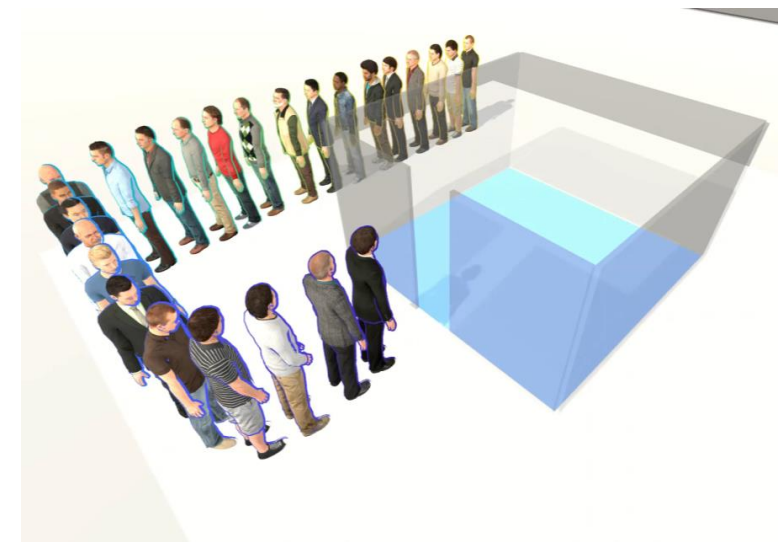
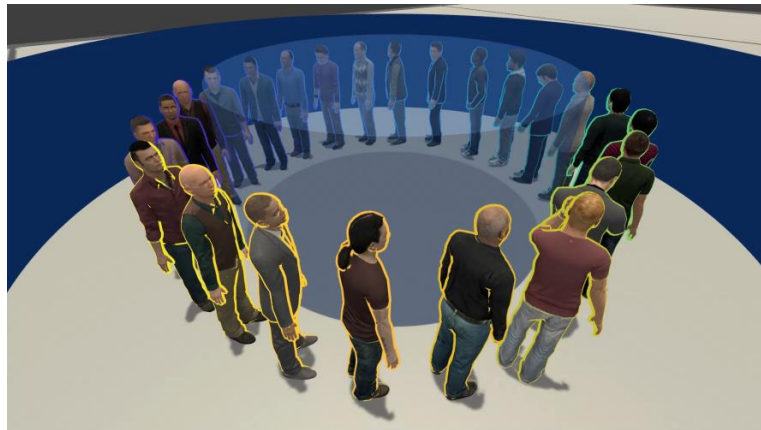
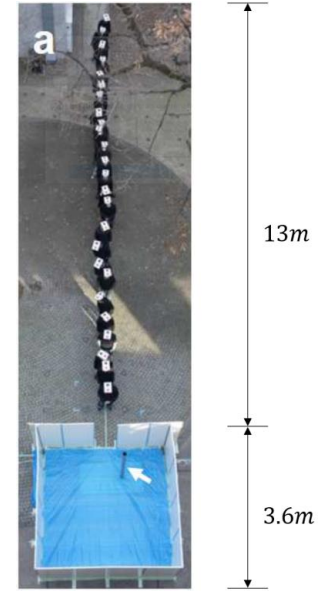
**Limited** capability to capture « collective » dataset

Can we still benefit from VR capabilities and capture **collective** behaviours?

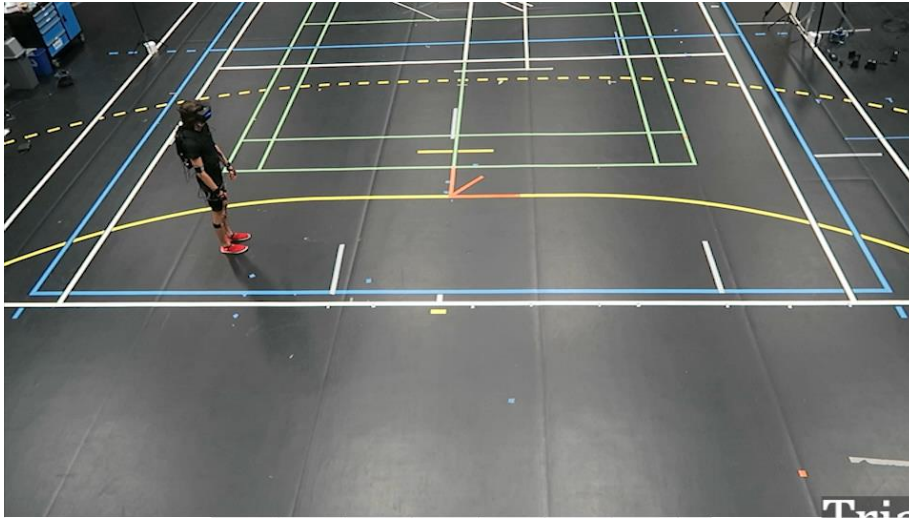
# Part 3

When you start your PhD on human crowds during COVID-19 lockdown...

# Example of VR replications

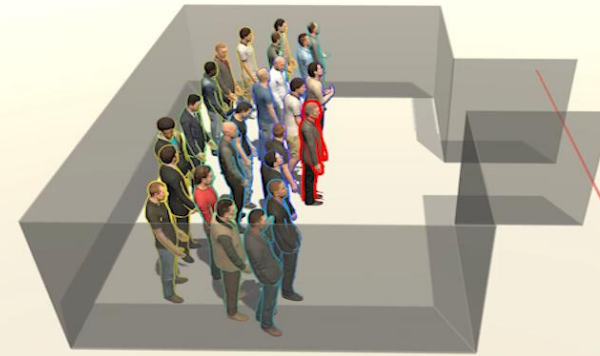


# One Man Crowd paradigm

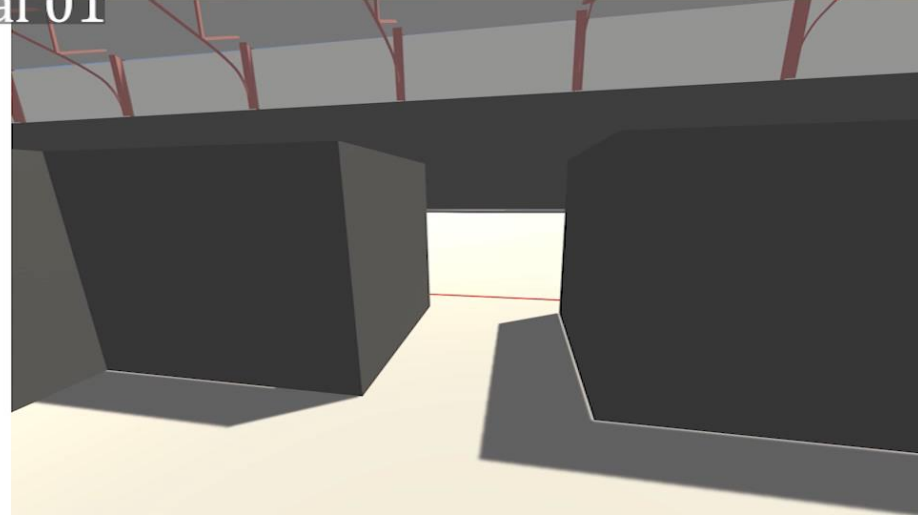


Trial 01

Head  
position  
on 2D  
plane



Blue outline: first to move  
Yellow outline: last to move





# Part 3

## One man crowd

When you start your PhD on human crowds during COVID-19 lockdown...

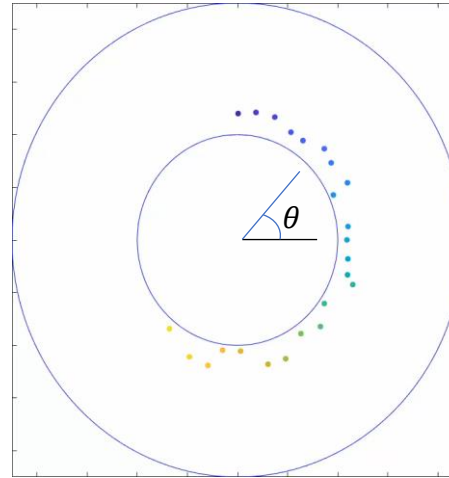
# OMC vs. real data

Scene

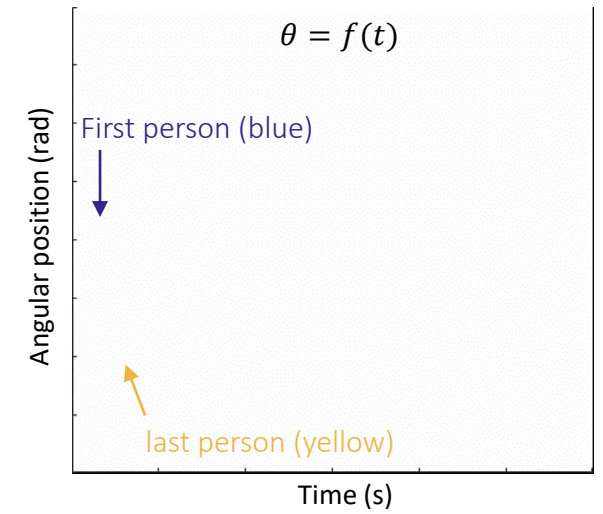


Lemerrier et al.  
2012

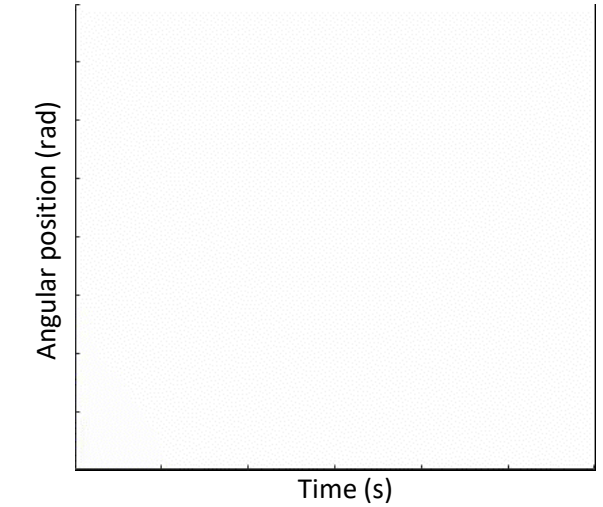
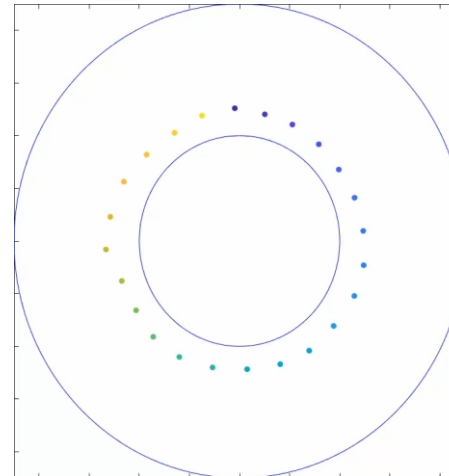
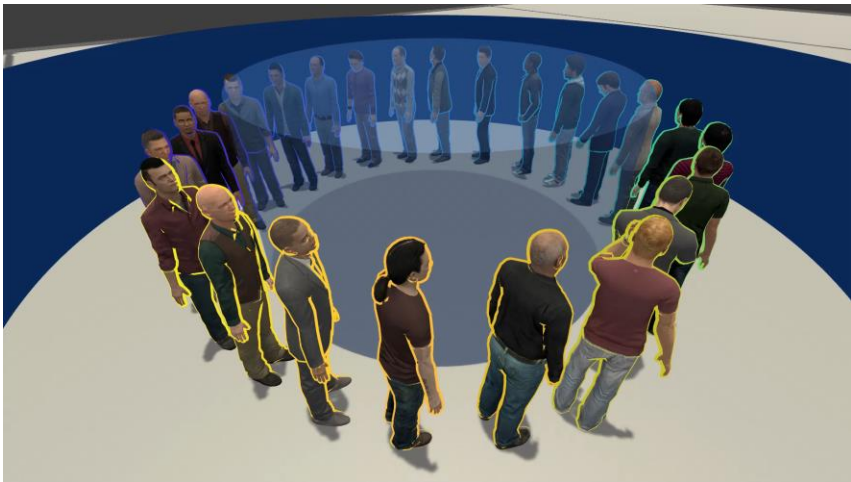
Aerial view of the scene



Visualization of the waves

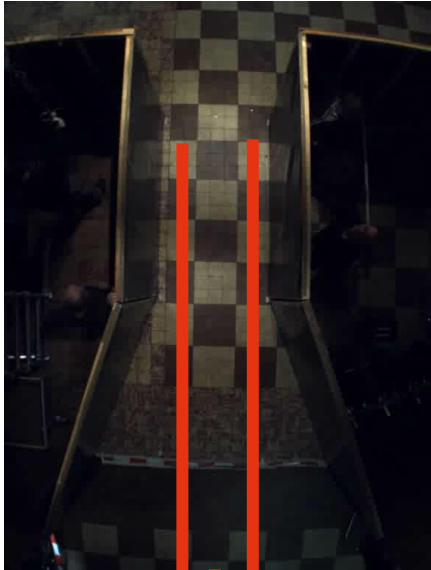


Our result (S2N)



# OMC vs. real data

Real-world experiment



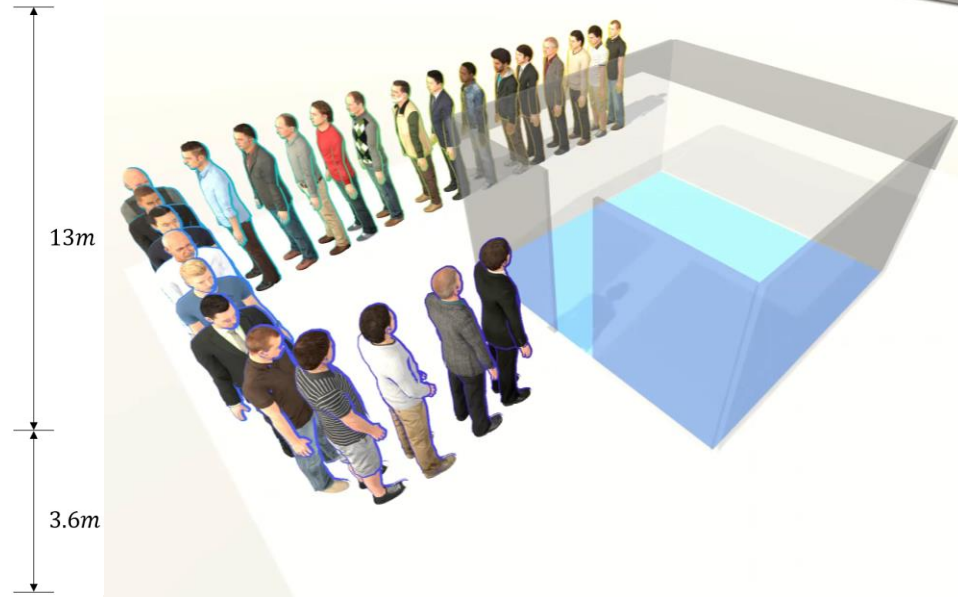
One result



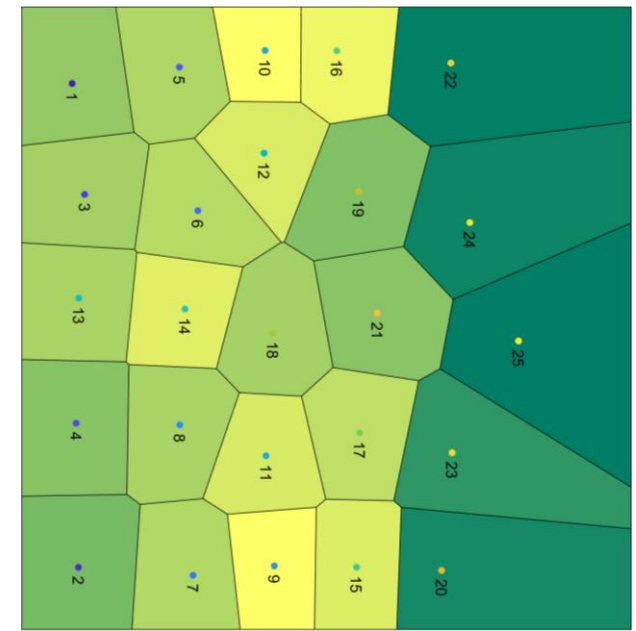
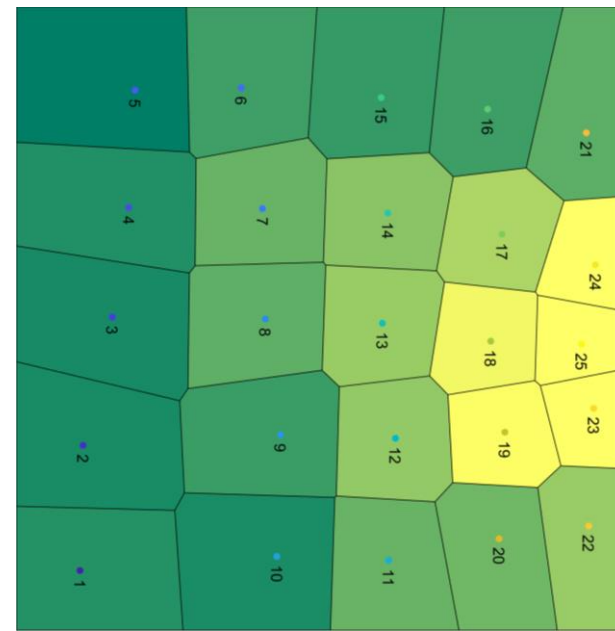
Another result



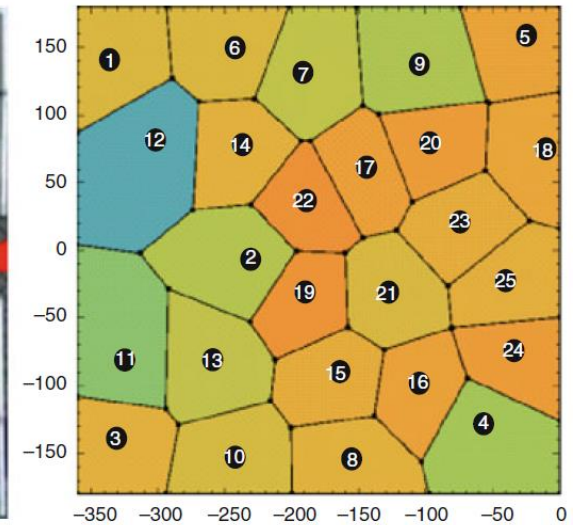
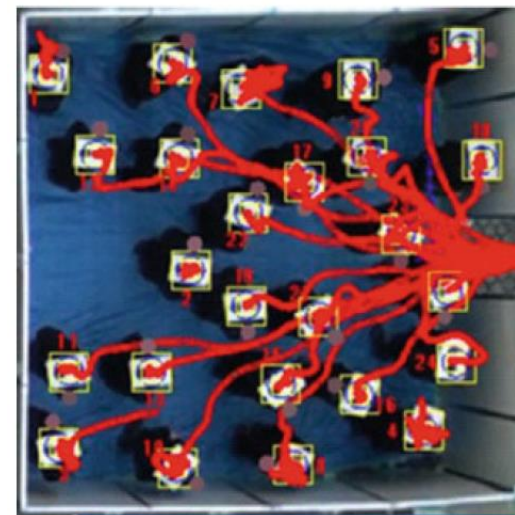
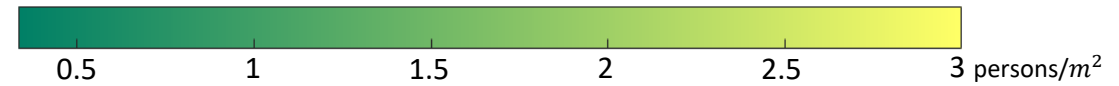
# OMC vs. real data



Ezaki et al. 2015



Each **point** represents final position  
Each **cell** is colored by local density

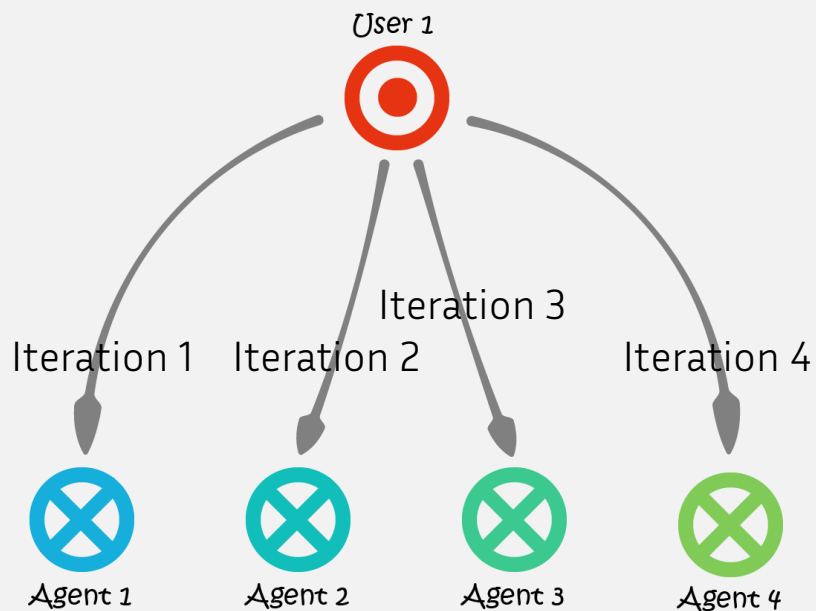




# How to break singularities (and keep OMC)?

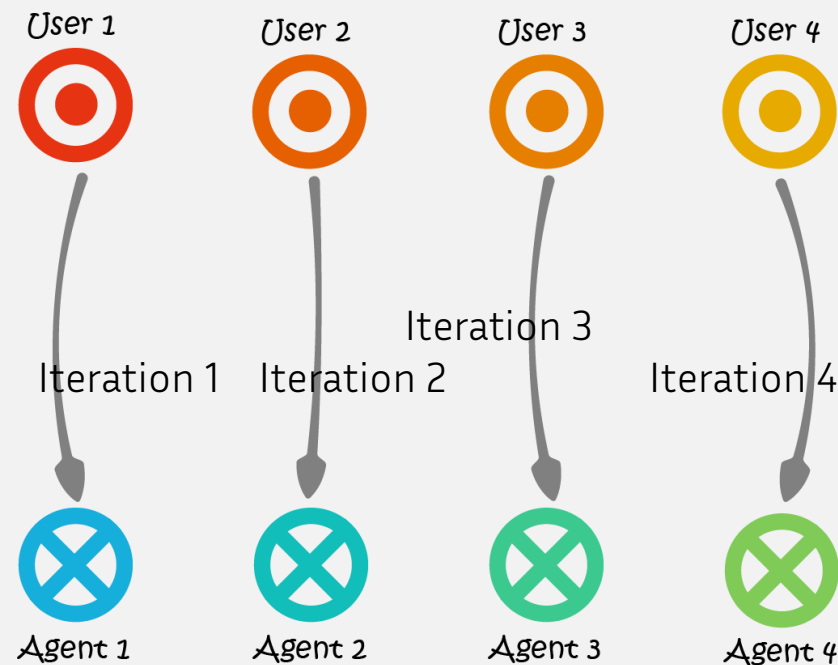
S2N

Single user to capture N characters



N2N

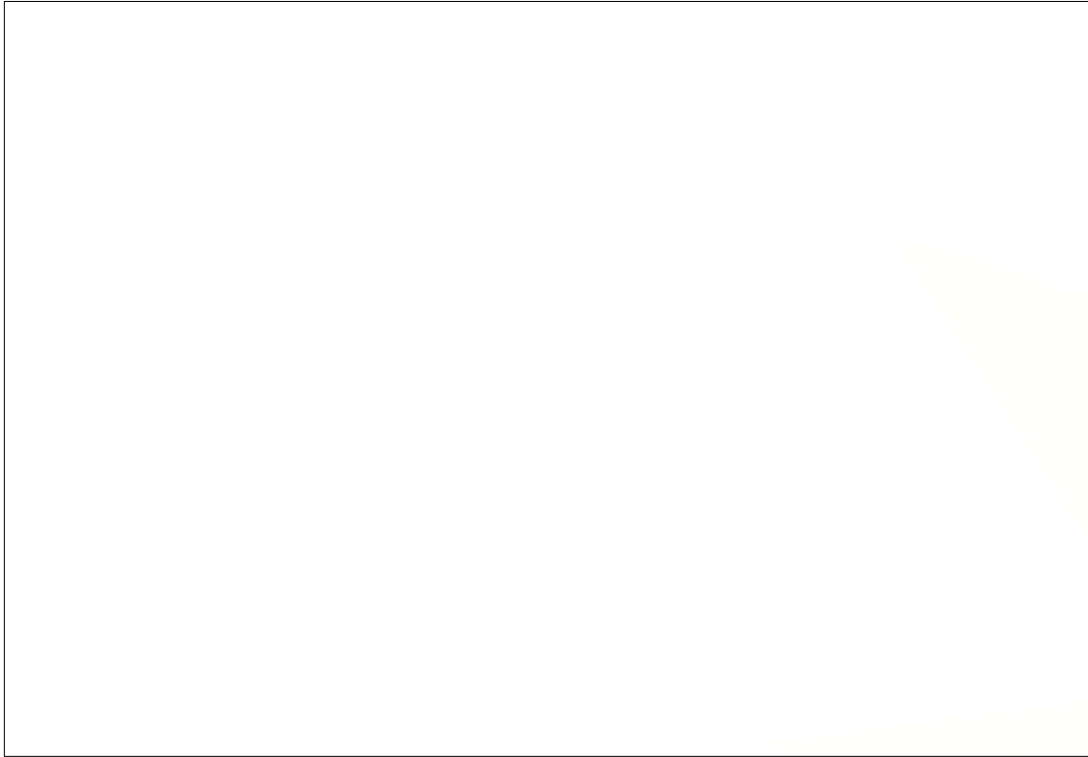
N users to capture N characters



# « Complex » interactions ?



# Updated OMC (with or without you)



# Conclusion



# What can or can't VR do for us?

Expose a **large number** of people to the **exact same situations**

- Help understanding variety in humans, intra or inter people
- Help understanding the « perception-action » loop
- Help understanding one's perception of a situation
- Help understanding how we eventually can control crowds

VR **still limited** in many aspects

Not always able to convey the « context », and reproduce its effects

Not easy to render physical interactions in crowds (haptics)

# Social Settings and Proxemics



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

# Social Settings and Proxemics



**Real:** higher sensitivity to proxemics norms in a non-place (more discomfort, more attempt to dissimulate their discomfort in the train station)

**Virtual:** Confirmation that social norms still exist in VR but no effect of social setting

# What can or can't VR do for us?

**There are pure « graphics-VR » questions**

**Modeling and simulation of virtual humans: to act and interact more naturally**

**Adding sound and haptics**

**Hybrid data to continuously record data in VR and fine-tune VR models (continuous learning)**

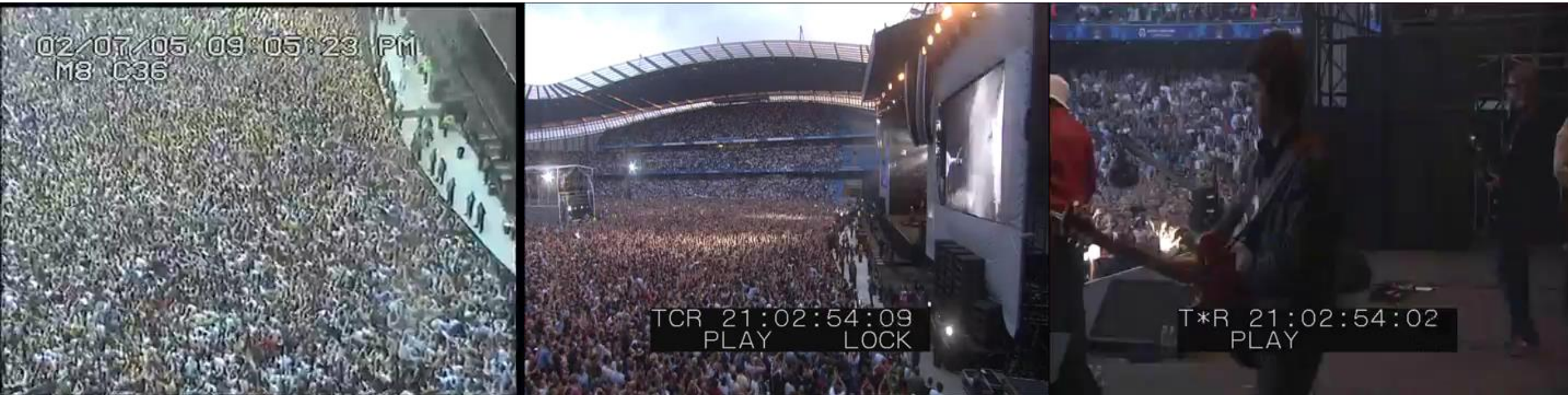


# Bonus slides

What to do when VR does not apply?

H2020 CrowdDNA project « best of »

# Keeping an eye on the real world

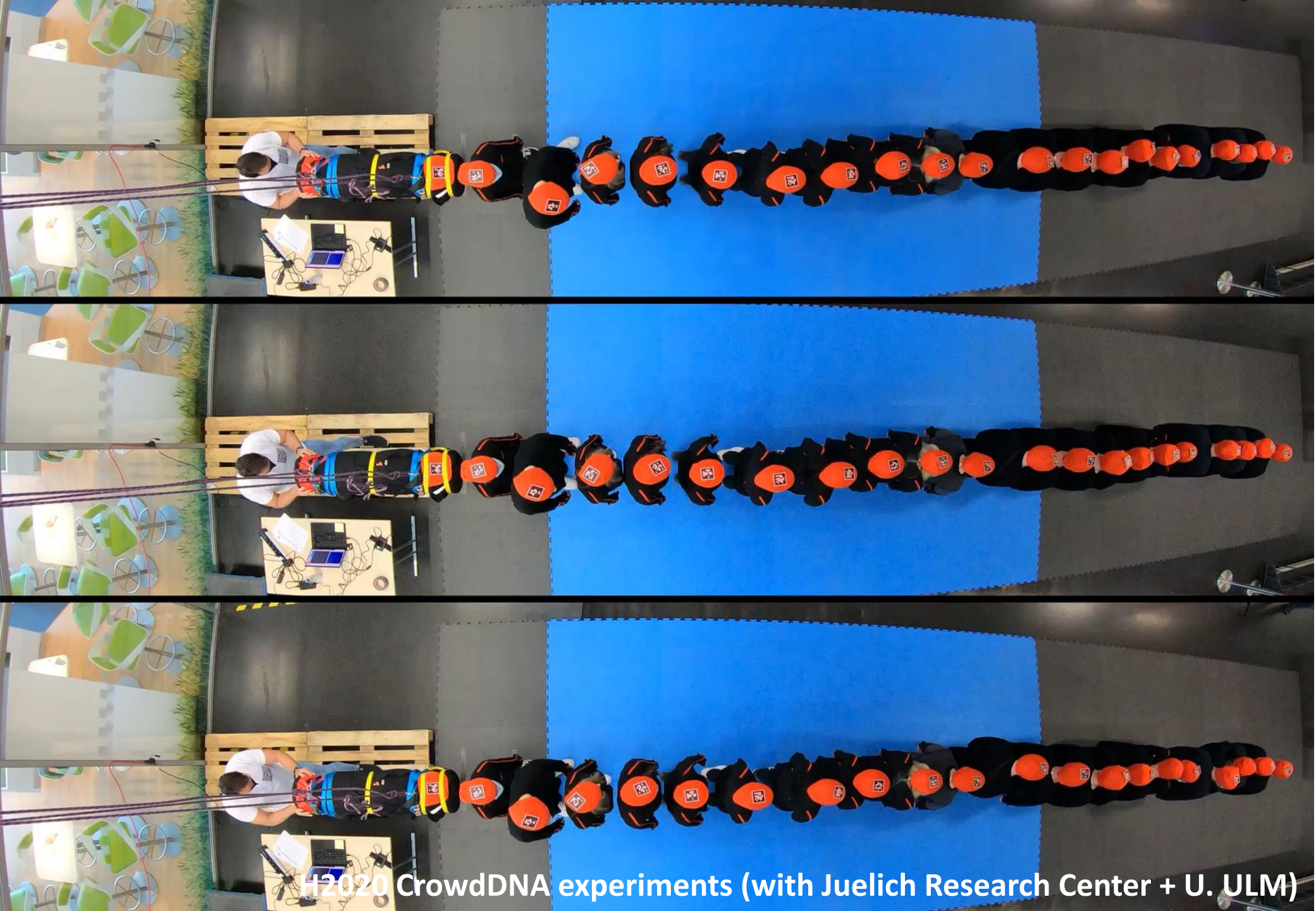


Crowd Surge, Oasis concert, Manchester, 2005



H2020 CrowdDNA experiments (with Juelich Research Center + U. ULM)





H2020 CrowdDNA experiments (with Juelich Research Center + U. ULM)

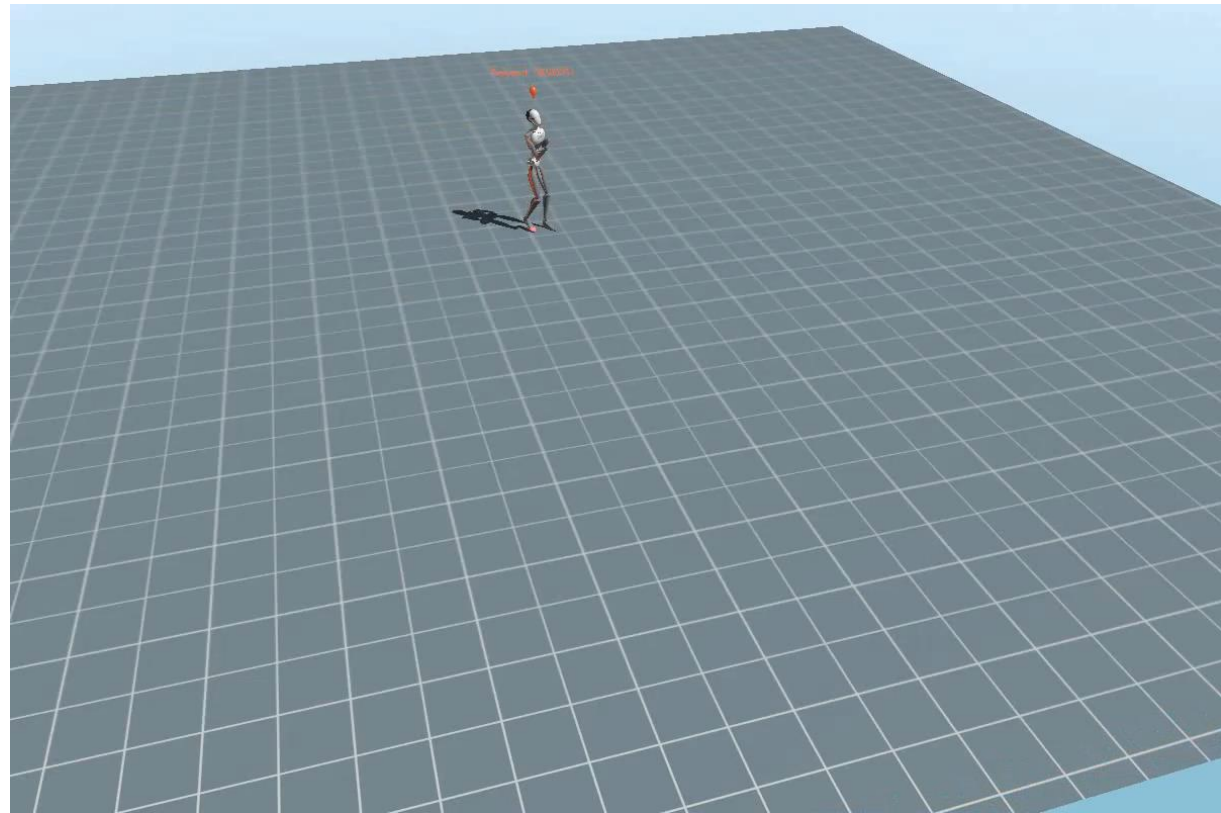
















SRF

NZZ  
format



WELCOME TO  
**INFERNOPOPOLIS**

27 > 30

**HELLFEST**

JUNE 24

CLISSON FRANCE

THU 27

**AVENGED  
SEVENFOLD**

**MEGADETH**

**VERY  
SPECIAL  
GUEST**

SLAUGHTER TO PREVAIL  
ASINHELL

FRI 28

**MACHINE  
HEAD**

TOM MORELLO

**FEAR  
FACTORY**

KARNIVOOO  
ORDEN OGAN - LOVEBITES  
+ 2 BANDS

SAT 29

**METALLICA**  
**MASS  
HYSTERIA**

**EXTREME**

MAMMOTH WVH - BLACK STONE CHERRY  
THE DEAD DAISIES  
ALIEN WEAPONRY - DARKEN

SUN 30

**FOO  
FIGHTERS**

**QUEENS OF THE  
STONE AGE**

**ROYAL BLOOD**

HEART - NOVA TWINS  
HIGH ON FIRE  
COSMIC PSYCHOS

MAINSTAGE 01

**Thank you**