



# Axes and Coordinate Systems Representations for Immersive Analytics of Multi-Dimensional Data

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# Research Directions

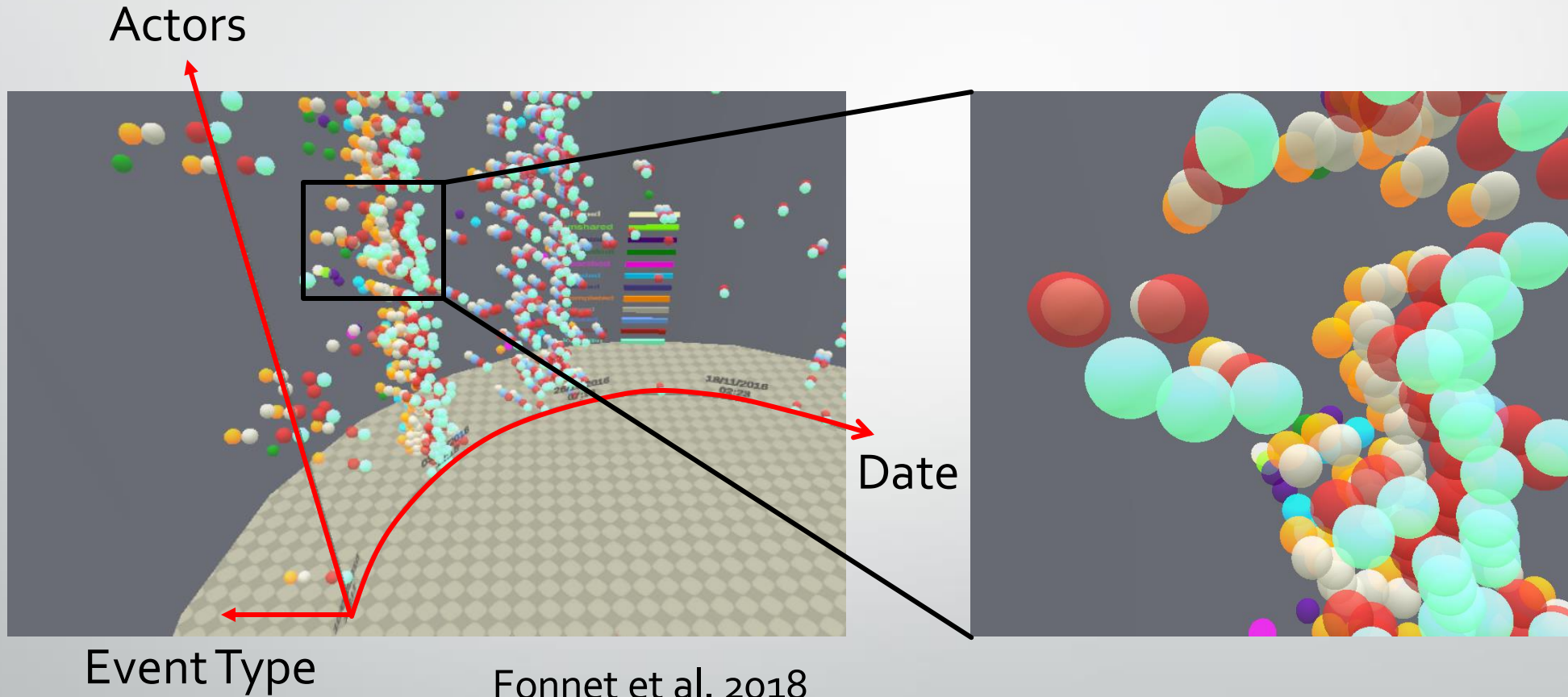
- Immersive analytics using virtual reality
- User immersed inside the data volume
- Multi-dimensional data



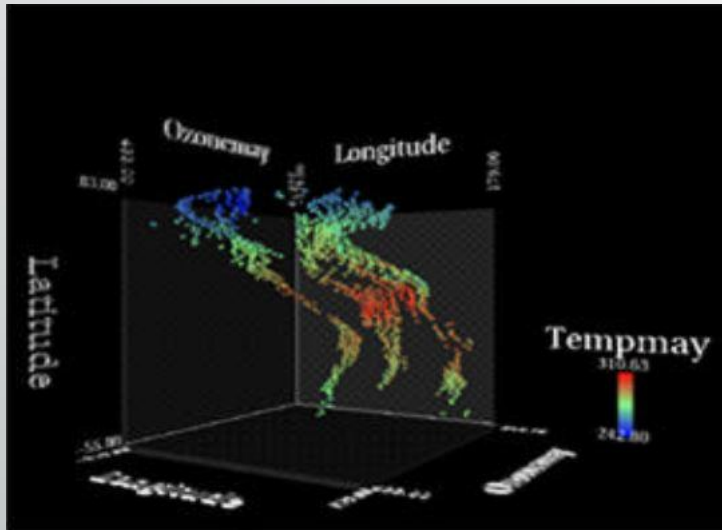
Ammoura et al. 2001

ID	name	main_cat	category	country	currency	launched	deadline	Duration (	goal	goal (n U	pledged	pledged (i	backers	state
379385592	le choccia	Food	Food	GB	GBP	05/01/2017 17:11	06/01/2017 17:11	1	1200	1655.88	1209	1668.299	1	successful
2112786846	ProVi Prof	Publishing	Academic	DE	EUR	02/01/2017 15:55	07/01/2017 15:55	5	1700	2087.583	0	0	0	failed
2076108142	Smul Pedit	Comics	Comics	US	USD	02/01/2017 03:00	09/01/2017 03:00	7	770	770	2237	2137	113	successful
1272003998	Does Trun	Film & Vid	Webseries	US	USD	02/01/2017 05:34	09/01/2017 05:34	7	5000	5000	175	175	4	failed
36762173	Digital Dist	Music	Hip-Hop	US	USD	05/01/2017 17:12	10/01/2017 17:12	5	220	220	0	0	0	failed
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435147728	The Foothi	Journalism	Print	US	USD	05/01/2017 01:52	12/01/2017 02:00	7	100	100	640	640	20	successful
171893227	Invisible Ci	Publishing	Zines	US	USD	04/01/2017 19:28	12/01/2017 03:00	8	50	50	207.66	207.66	104	successful
135103309	Existential	Art	Illustration	US	USD	05/01/2017 05:04	12/01/2017 18:00	7	300	300	449	449	27	successful
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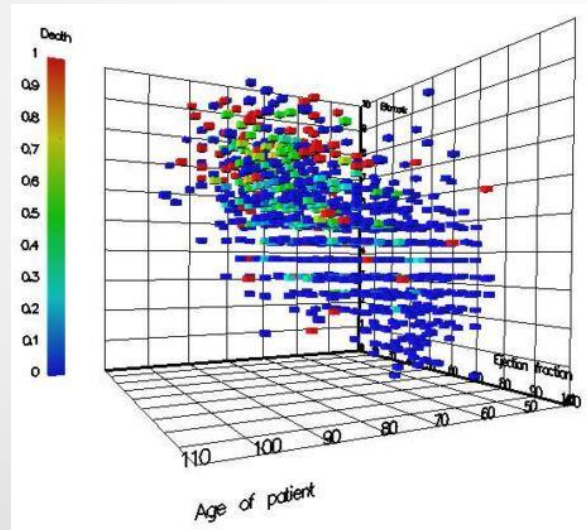
# Limitation of using classical axes representation: An illustration on the IDEA system



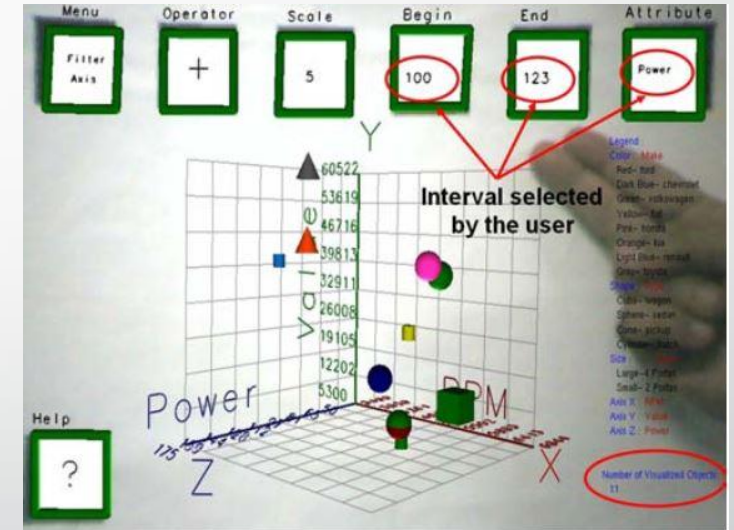
# Axes in immersive analytics literature



Sawant et al. 2000



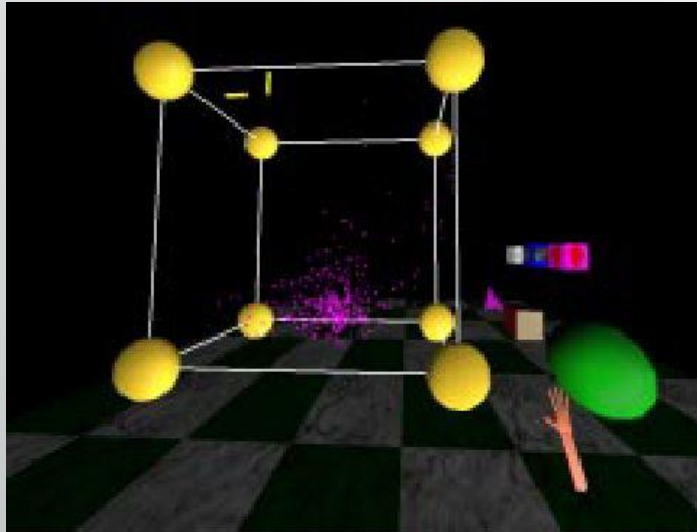
Nagel et al. 2001



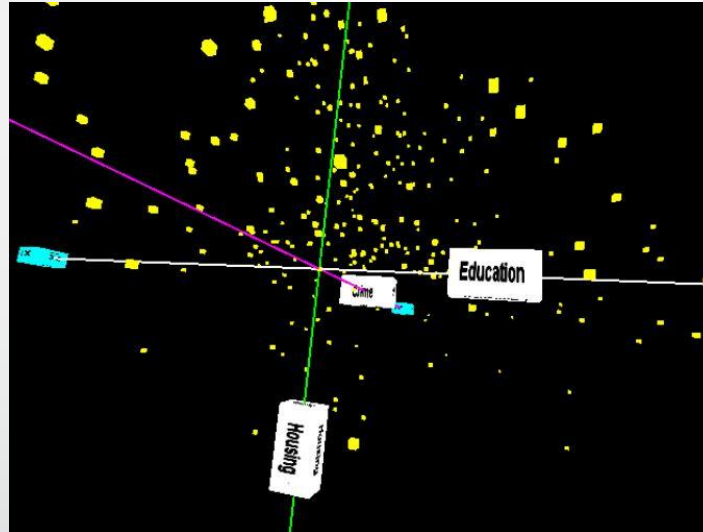
Meiguins et al. 2006



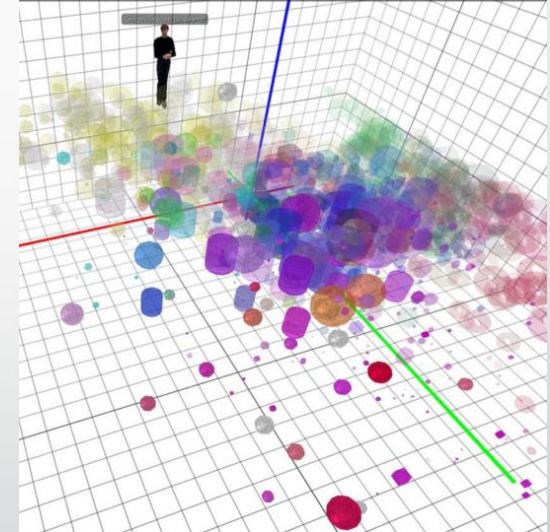
# Axes in immersive analytics literature



Symanzik et al. 1996

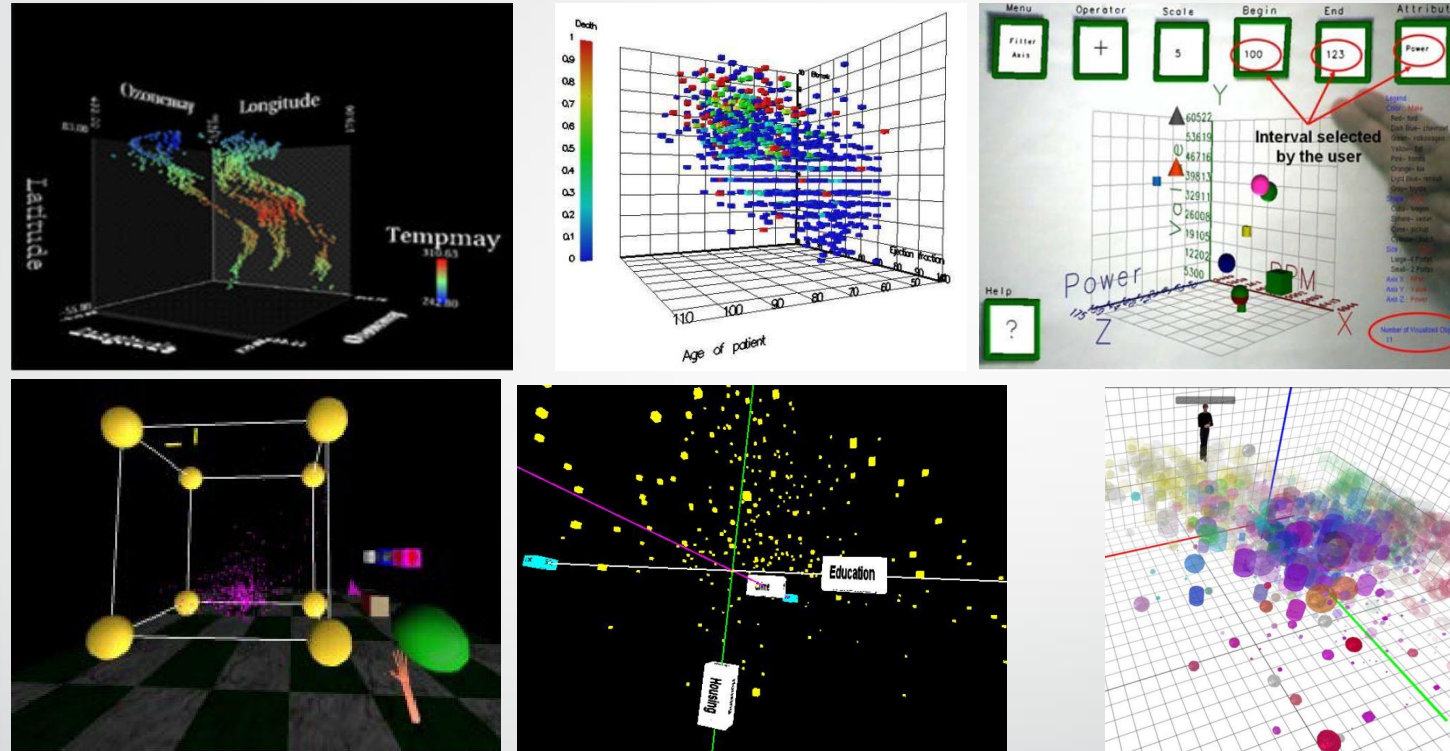


Datey et al. 2002



Donalek et al. 2014

# Axes in immersive analytics literature



Axes are considered self-evident,  
though they cannot be considered as such  
for immersive analytics

# Research Questions

- How to represent axes and coordinate systems in immersive analytics?
- What are coordinate system representations in immersive analytics used for?

# Contributions

1. Task-based definition of coordinate system representations
2. Design space for coordinate system representations in immersive analytics
3. Results of an exploratory study

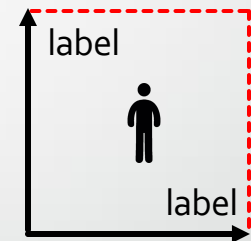


# A Task-Based Definition of Coordinate System Representation

A **Coordinate System Representation** is a component of a data visualization which serves as a tool for the reader to:

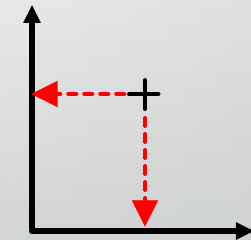
## 1- Understand the space

- Limits / Scale / Semantics
- Get ones position inside the space



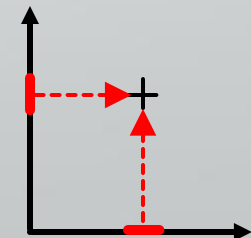
## 2- Get information about datapoints

- Coordinate of point / group of points
- Difference between point / group of points



## 3- Search for datapoints

- From a specific value(s) for one (several) attribute(s)
- From interval values for one (several) attribute(s)

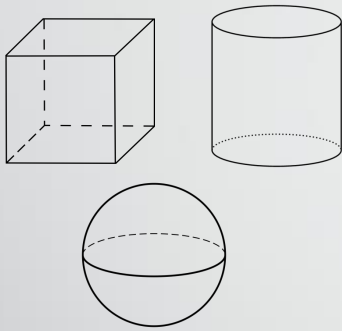


# Contributions

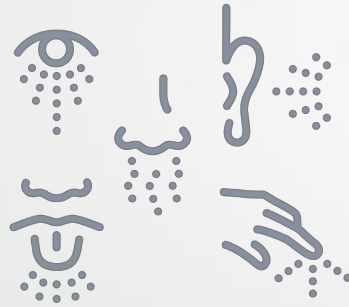
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# A 7-dimensions Design Space Proposal for Coordinate System Representation

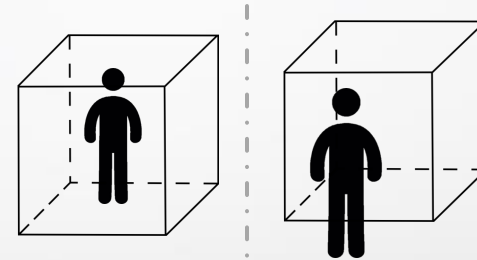
1- Type of  
coordinate system



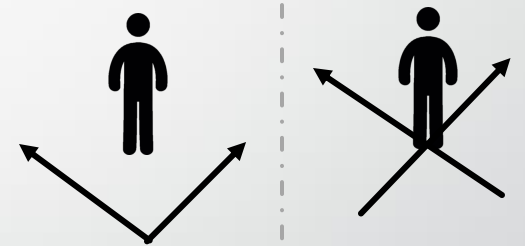
2- Modality of  
representation



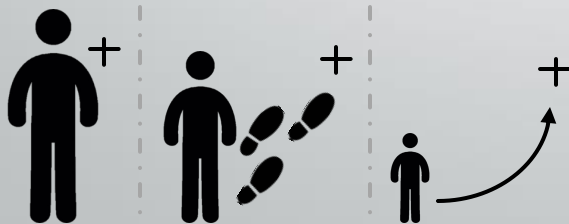
3- User positions with  
regards to the data



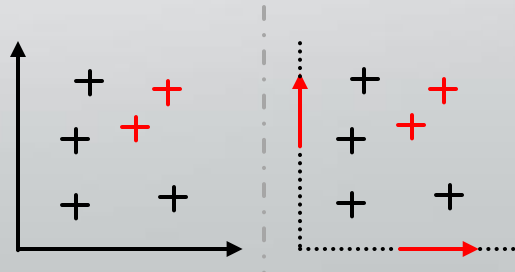
4- Dependency to  
user position



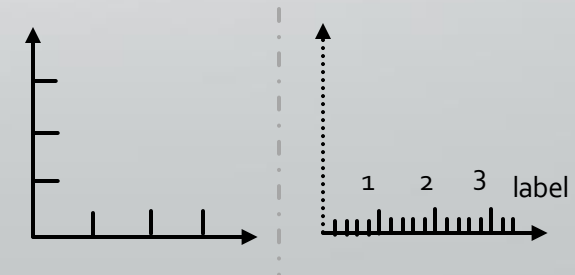
5- Data  
Reachability



6- Data orientation  
variability

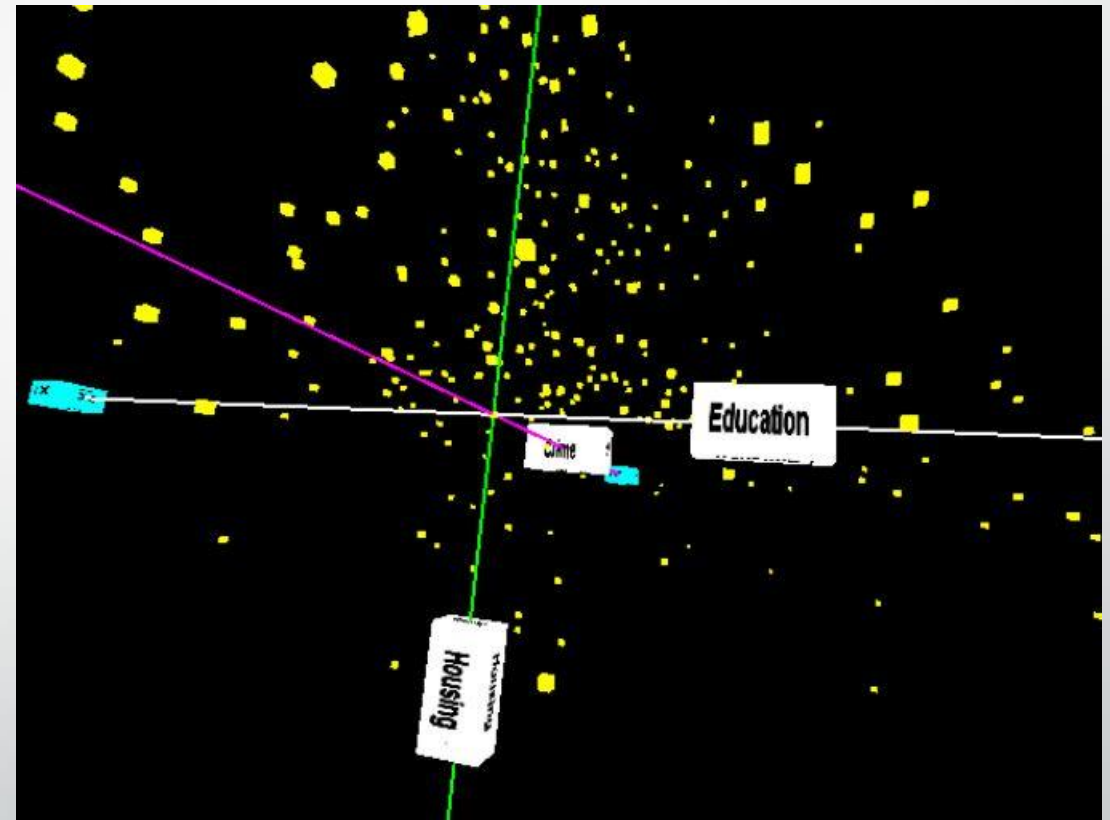
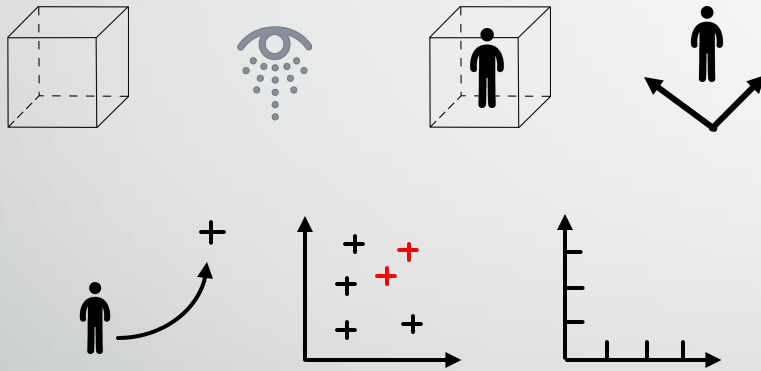


7- Complexity  
variability



# Design Space applied to the Wizard system

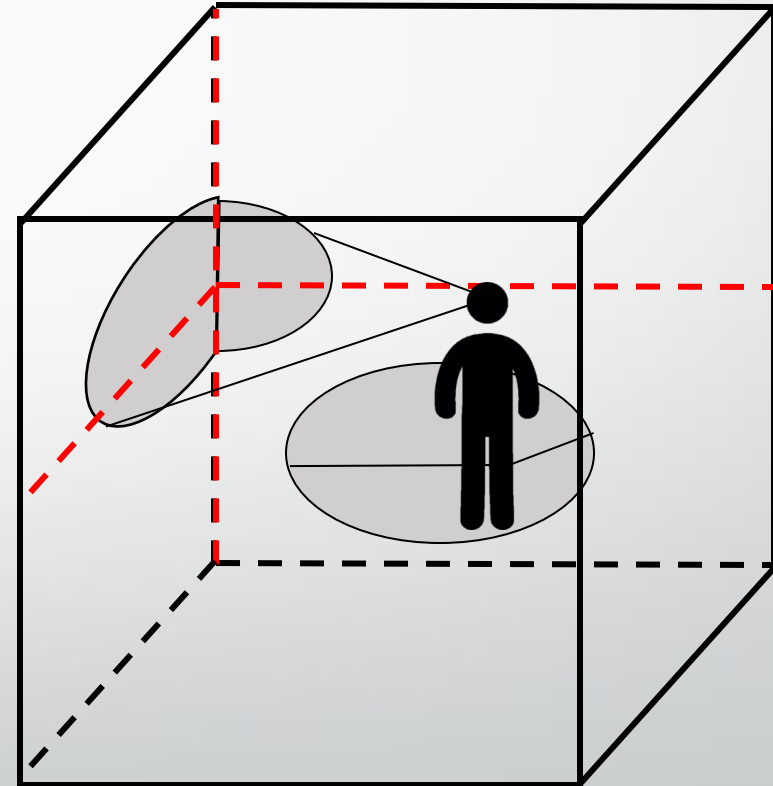
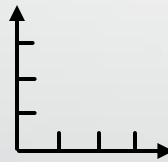
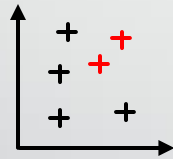
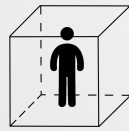
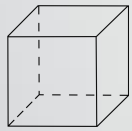
Dimensions:



Datey et al. 2002

# Prospective Illustration 1: "Mobile Axes"

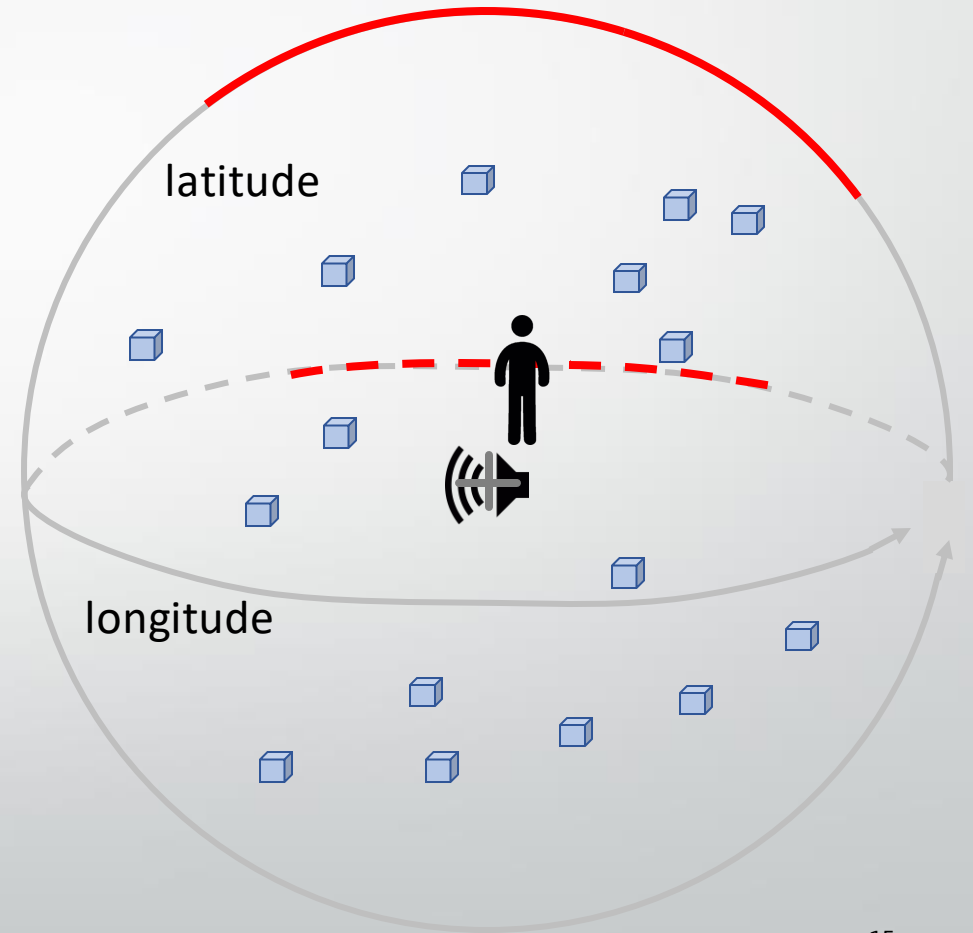
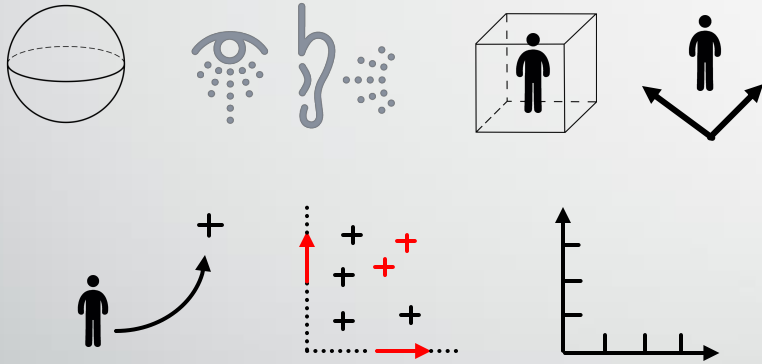
Dimensions:





# Prospective Illustration 2: "Selection Adapted Sphere"

Dimensions:



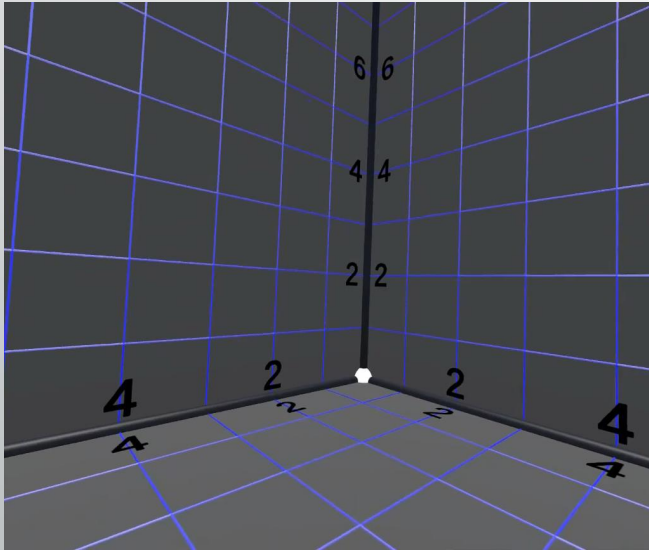
# Contributions

1. Task-based definition of coordinate system representations
2. Design space for coordinate system representations in immersive analytics
3. Results of an exploratory study

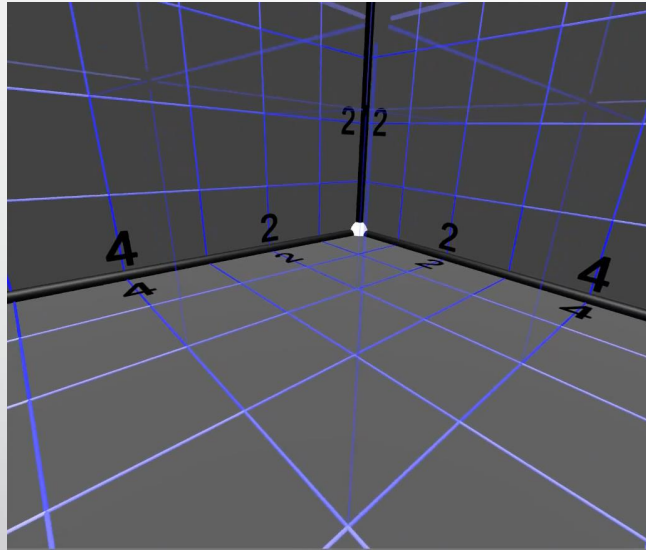
# Objective

How do users behave in 3 different coordinate system representations?

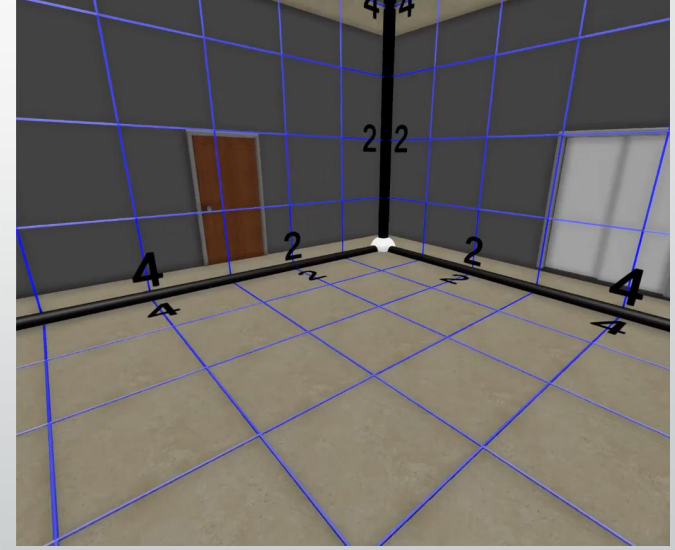
Condition 1:  
2D grid



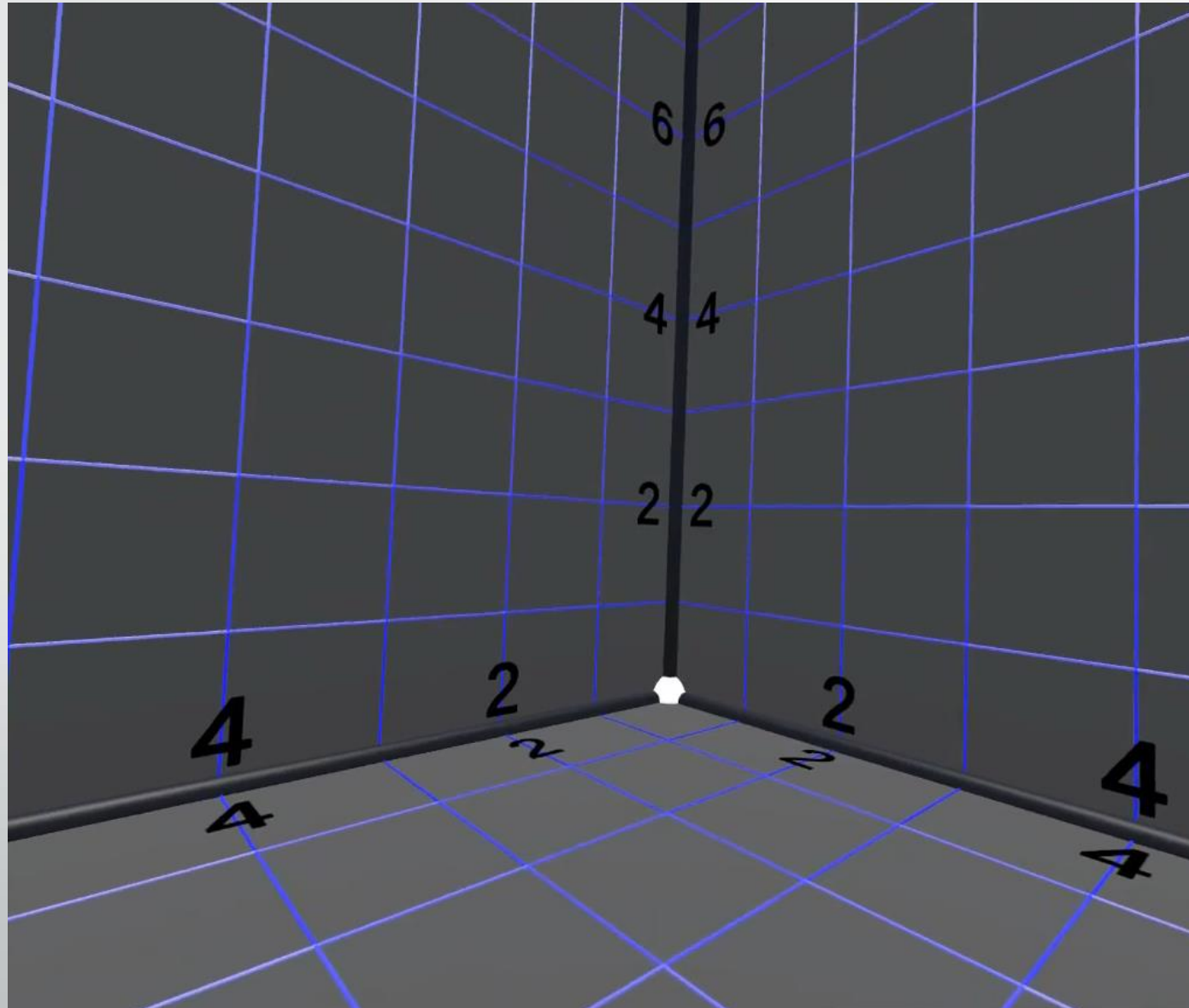
Condition 2:  
3D grid



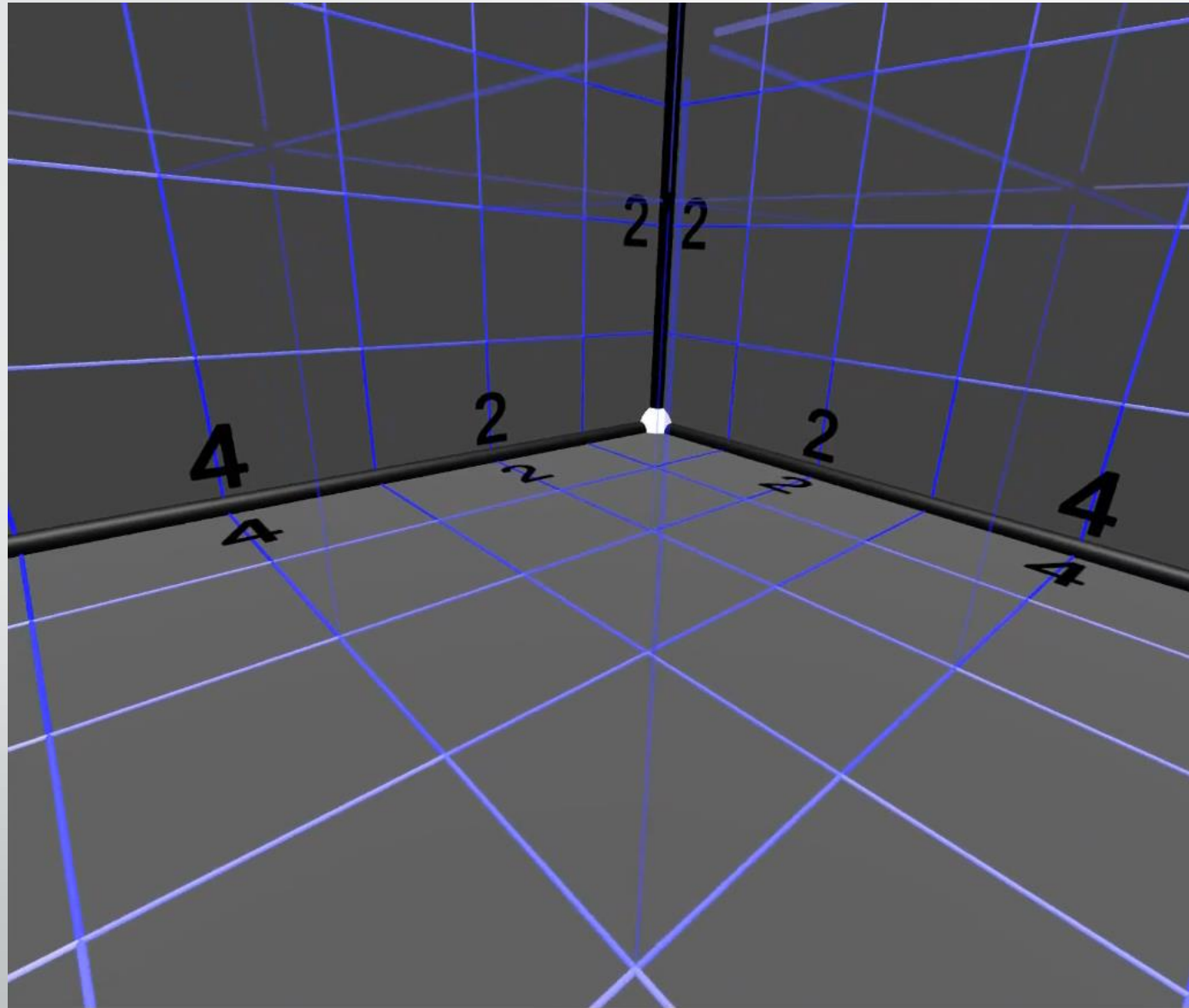
Condition 3 :  
Apartment hall



# Condition 1: 2D grid

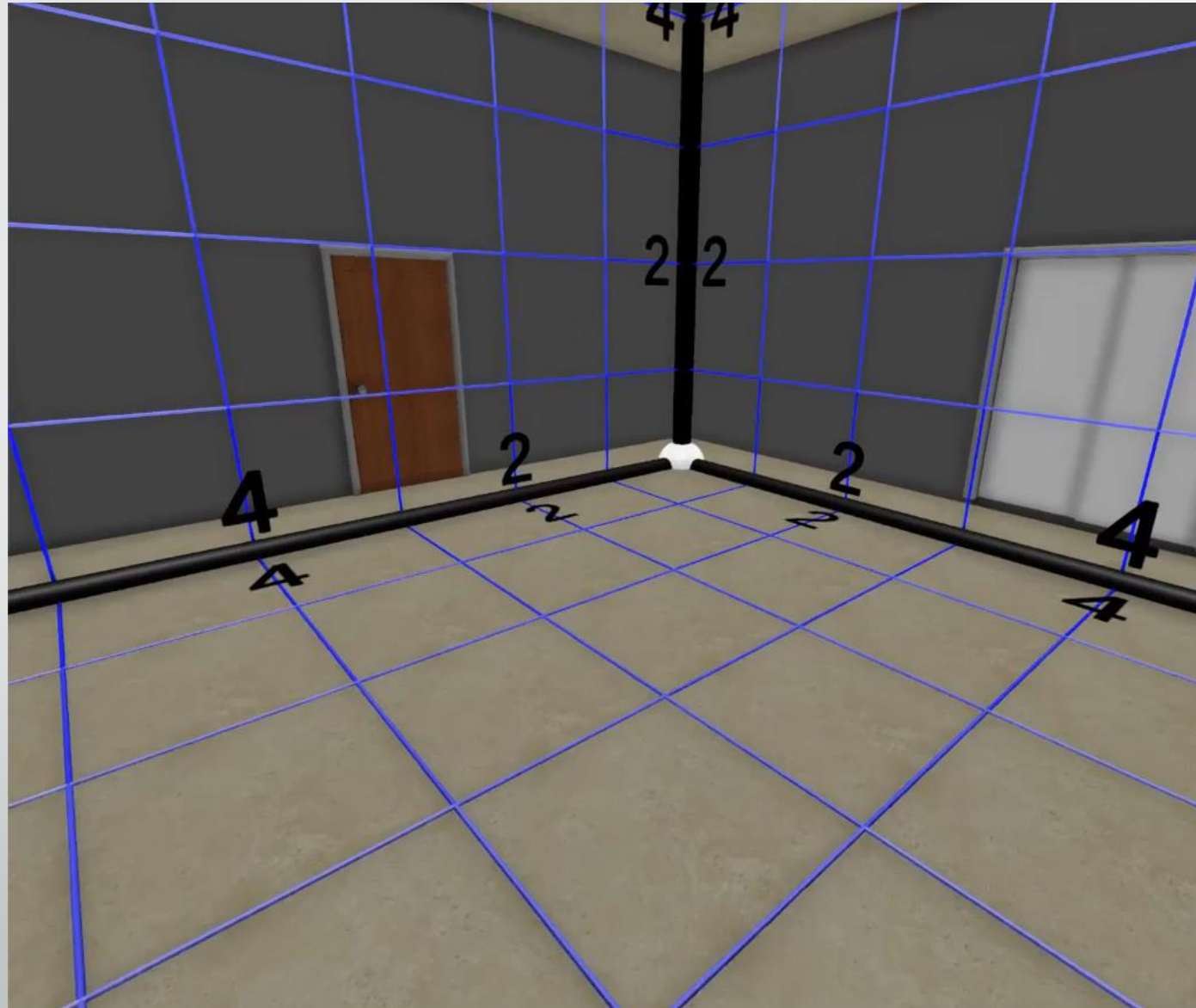


## Condition 2: 3D grid



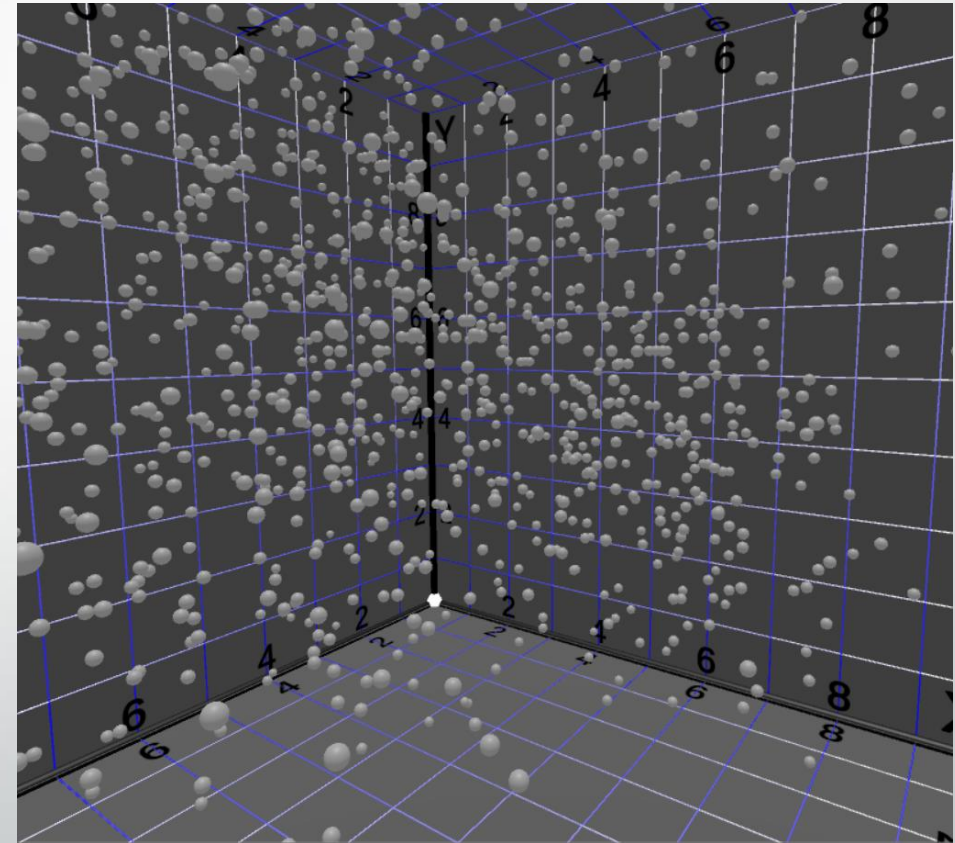


## Condition 3: Apartment hall



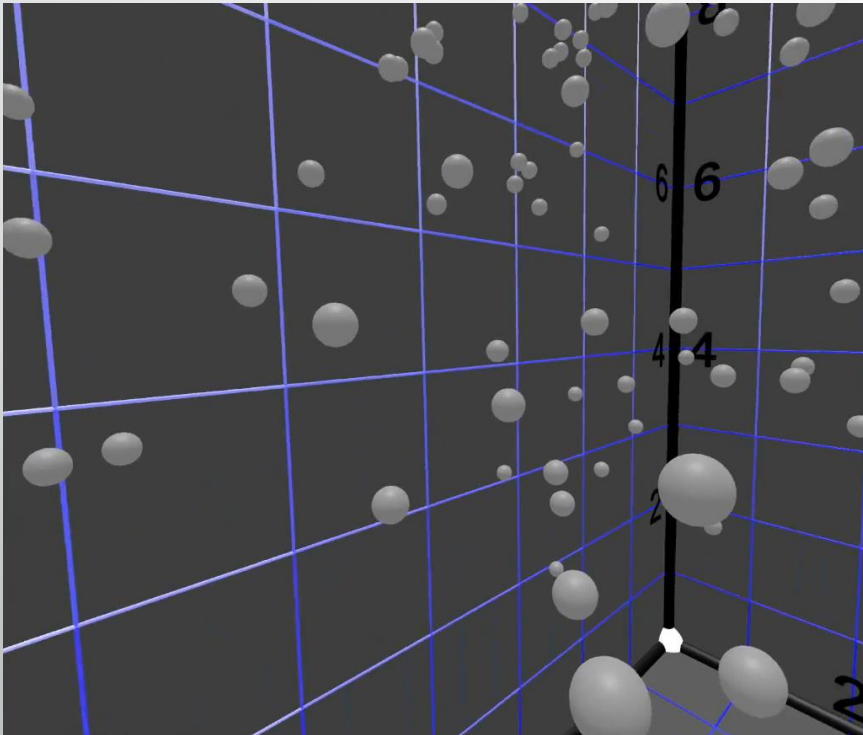
# Experimentation Material

- Dataset: 1000 datapoints from the “wine” dataset, 3 attributes (pH, alcohol, and total sulfure dioxyde)
- Data Mapping: spheres, coordinates from 0 to 10
- Unity3D, HTC Vive

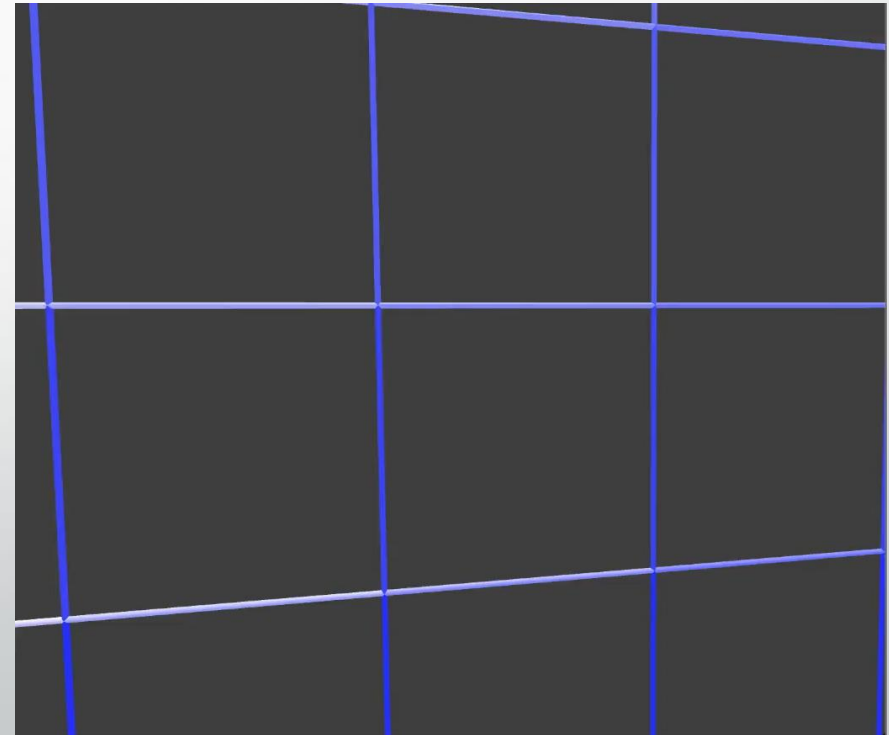


# Experimental Protocol

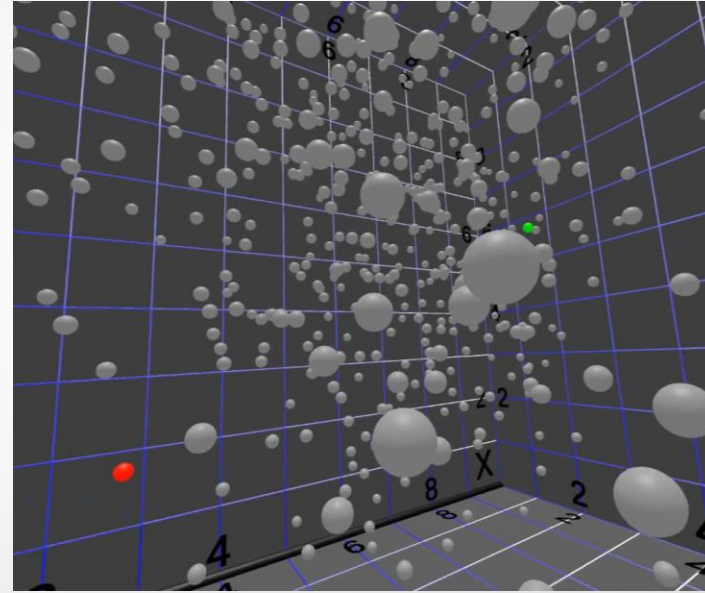
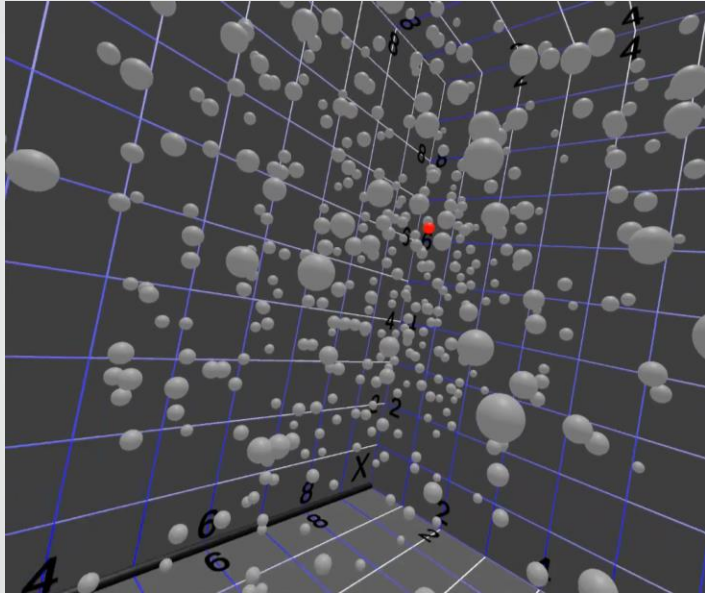
Task 1: Determine coordinates  $(x,y,z)$  of a point  
(10 times per condition)



Task 2: Determine delta coordinates  $(x,y,z)$  between a couple of points  
(5 times per condition)



# Data Collected



- User's answer (accuracy)
- Completion time
- User's feedback through Likert Scale and interview

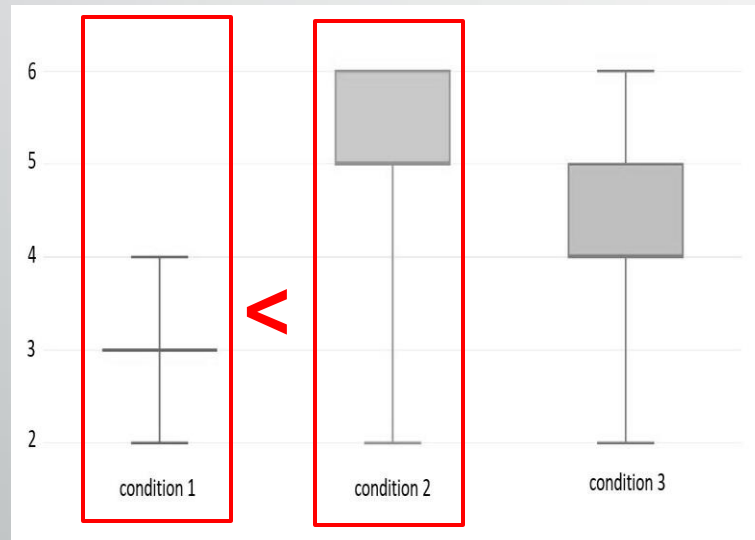
# Quantitative Results from Friedman's test

	2D grid	3D grid	Appt hall	$\chi^2_E(2)$	p-value
Point coordinate – acc (m)	<b>0.79</b> $\pm$ 0.55	<b>0.83</b> $\pm$ 1.08	<b>0.83</b> $\pm$ 0.97	3.62	0.164
Delta coordinate – acc (m)	<b>1.07</b> $\pm$ 0.69	<b>0.8</b> $\pm$ 0.84	<b>0.99</b> $\pm$ 0.67	3.73	0.155
Point coordinate – time (s)	<b>31.9</b> $\pm$ 14.1	<b>37.7</b> $\pm$ 15.2	<b>32.6</b> $\pm$ 11.5	9.45	<b>0.009*</b>
Delta coordinate – time (s)	<b>48.2</b> $\pm$ 22.8	<b>52.6</b> $\pm$ 19.7	<b>48.8</b> $\pm$ 18.6	3.9	0.142



# Qualitative Results – 7-point Likert Scale

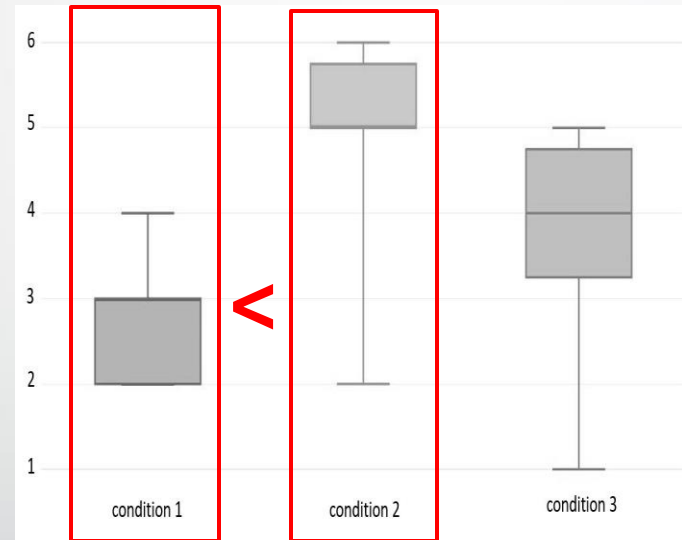
Easiness to determine  
coordinate of one point



$p - value = 0.001^*$

$$\chi^2_E(2) = 13.64$$

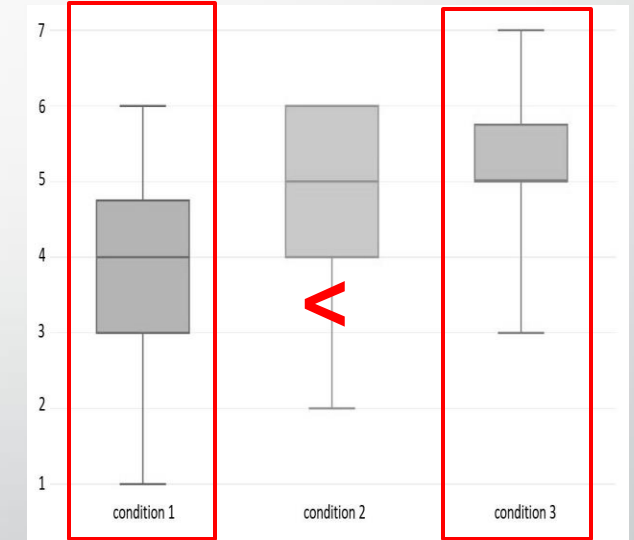
Easiness to determine  
delta coordinate of two  
points



$p - value = 0.005^*$

$$\chi^2_E(2) = 10.71$$

Appreciation of the  
environnement



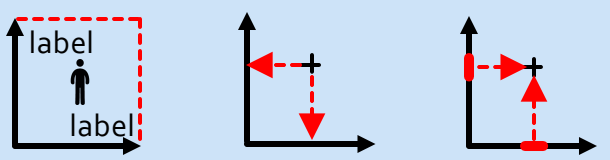
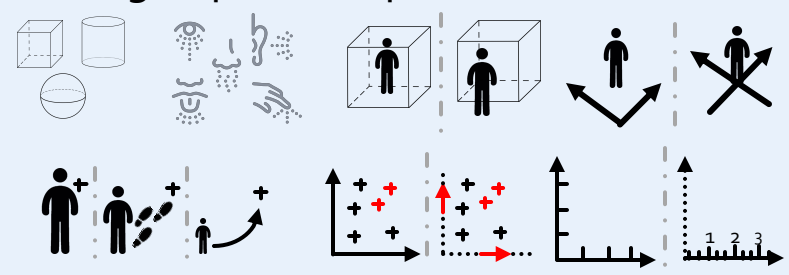
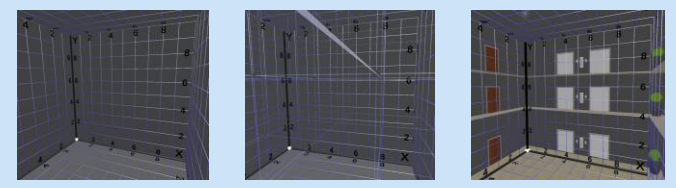
$p - value = 0.024^*$

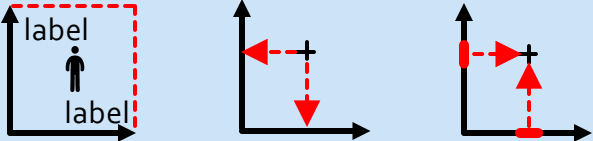
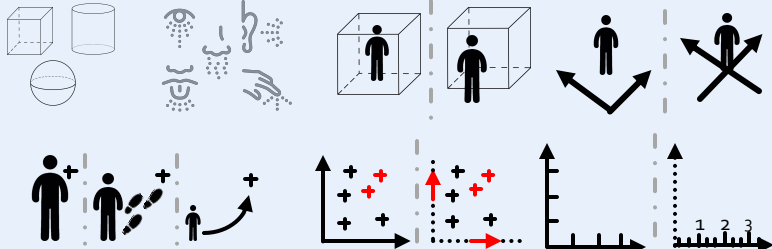
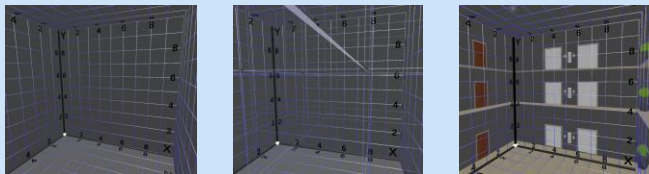
$$\chi^2_E(2) = 7.48$$

# Discussion

- No significant effect on accuracy
- However impact on behaviour and strategy of user
  - 3D grid allowed user to compute delta directly
  - Multiple users used proprioception to help them in the apartment hall
- Moreover qualitative feedback shows positive result
  - 3D grid is considered better to give accurate answer
  - Apartment hall improved user enjoyment

# Conclusion & Future Works

Contribution	Importance	Limitation
<p>Task-Based Definition of CSR for IA</p> 	Allows to consider immersive coordinate system representations	
<p>Design Space Proposal of CSR for IA</p> 	Supports the reflexion for future immersive analytics systems	A first version that should be refined and solidified
<p>Exploratory Study</p> 	Interesting user behaviours have been observed	Small number of users

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Questions?