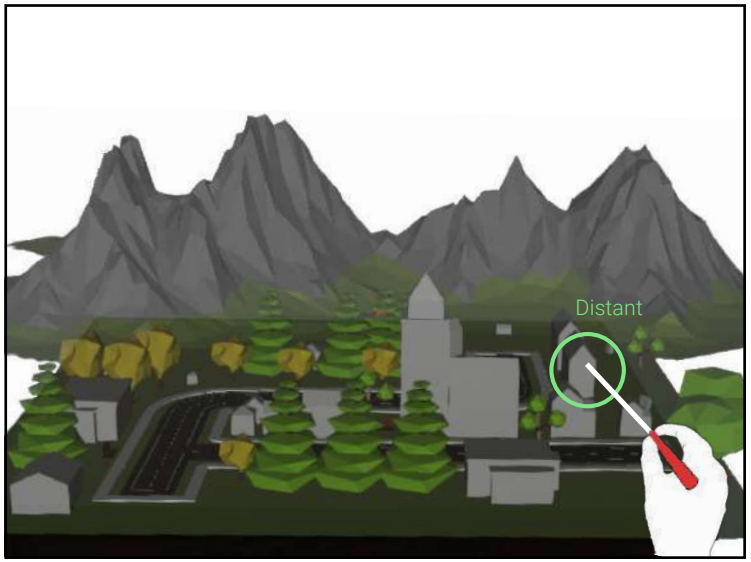
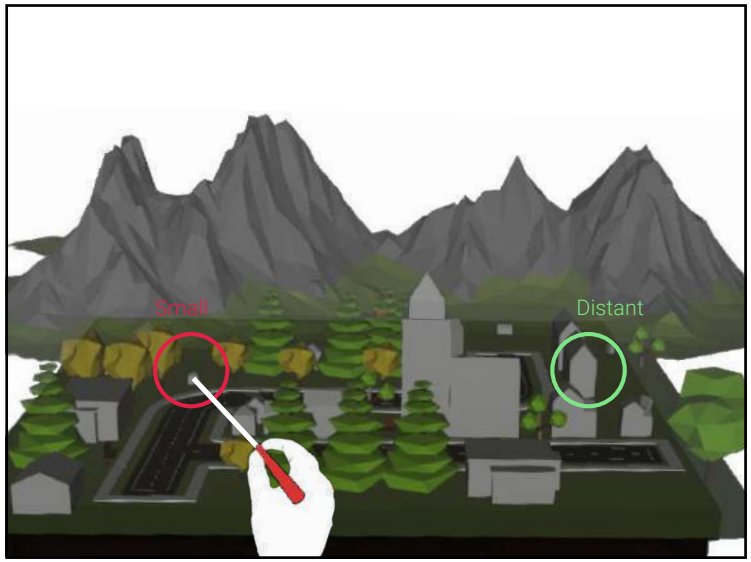
- Definitions
- Handheld AR/AV
  - Pointing at physical targets
  - Pointing at virtual targets
- **HMD-based AR/AV**
  - **3D pointing**

Augmented Reality/Virtuality (AR/AV)

- Challenges
  - Tracking
  - Rendering
  - Interaction





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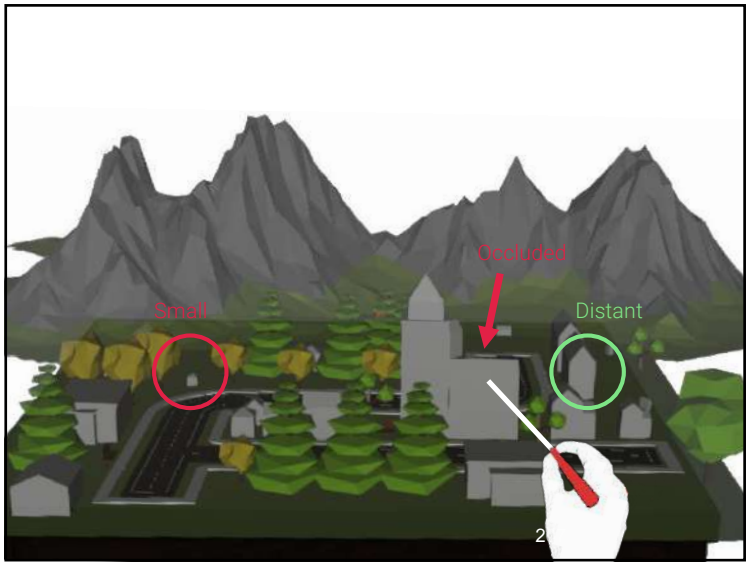
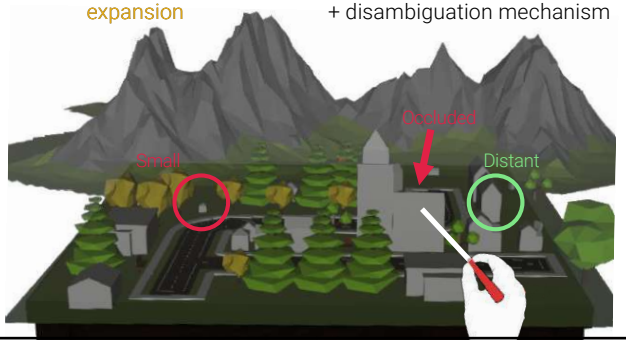


Extensions of raycasting

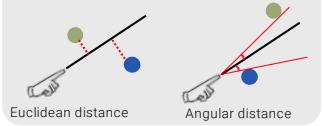
Target expansion

Selection of a subset of objects + disambiguation mechanism

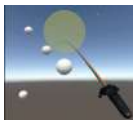


Extensions of raycasting with target expansion

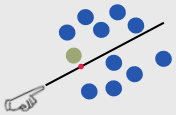
Ray only



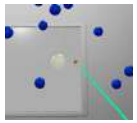
Bubble Ray
Lu et al. 2020



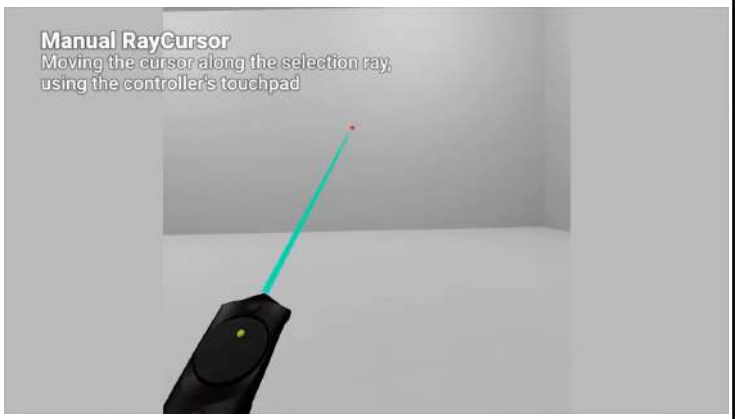
Cursor on the ray



RayCursor
Baloup et al. 2019



RayCursor



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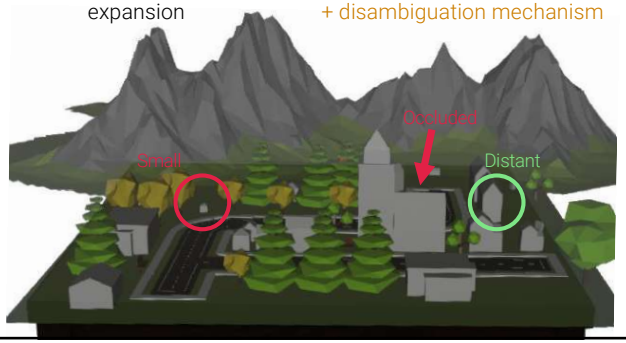
Extensions of raycasting

Target expansion

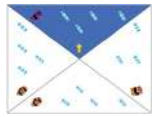
Selection of a subset of objects + disambiguation mechanism



Techniques with desambiguation of selectable objects

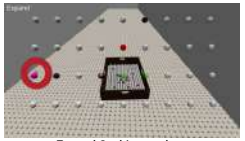
Zoom standard

Quad menu + progressive refinement



SQUAD *Kopper et al. 2011*

Spatial rearrangement



Expand Cashion et al. 2012

Extensions of raycasting

	Small targets	Occluded targets
Target expansion	✔	✔
Quad menu + progressive refinement	✔	✔
Zoom	✔	✖
Spatial rearrangement	✔	✔

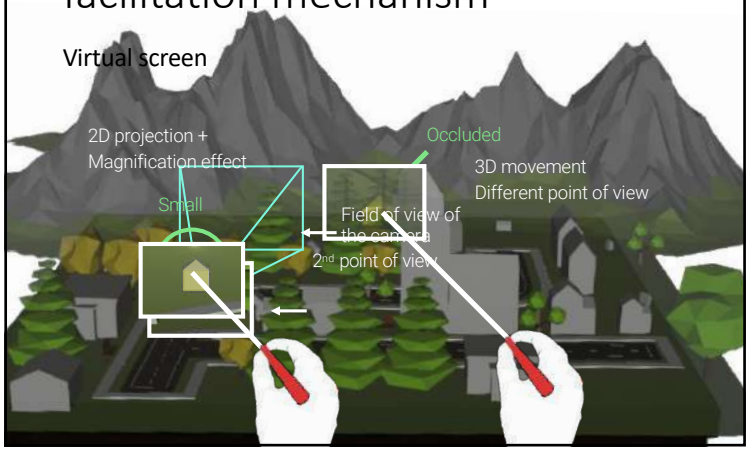
Limitation of existing works

	Small targets	Occluded targets	⚠
Target expansion	✔	✔	Density
Quad menu + progressive refinement	✔	✔	Density Loss of context Loss of links between objects
Zoom	✔	✖	Loss of context
Spatial rearrangement	✔	✔	Loss of links between objects

What about magnification lenses?

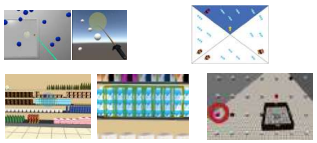
Magnification lenses in AR/VR

Magnification lens: pointing facilitation mechanism



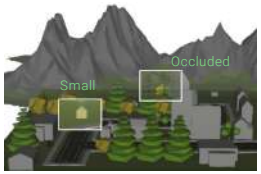
Magnification lenses: advantages

Previous works



Impact of the density
Loss of link between objects
Loss of context

Magnification lens



Independent of the density
Maintains links between objects
Maintains the context

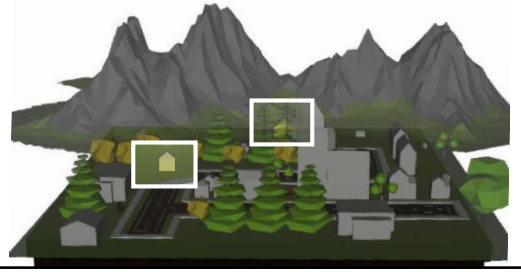
Experimental study

Performant?

Speed
Accuracy

3D movement of the lens?

Ease
Fatigue



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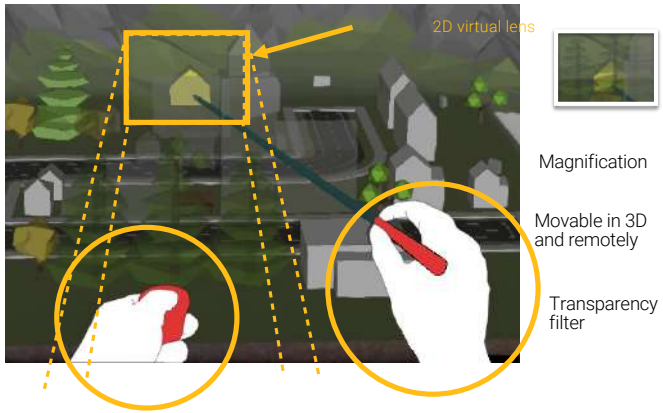
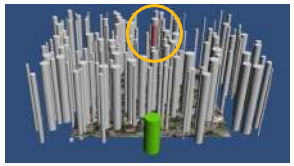
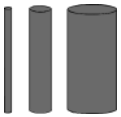
RayLens



RayLens

Evaluation of RayLens performance Task

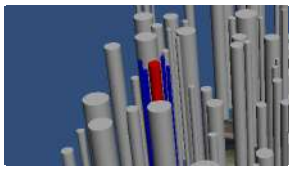




3 target sizes

2 density spacing

Evaluation of RayLens performance Task



3 target sizes

2 density spacing

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Evaluation of RayLens performance Techniques

RayLens

RayCasting

RaySlider

Evaluation of RayLens performance Techniques

RayLens

Evaluation of RayLens performance Techniques

RayLens

RayCasting

RaySlider

Evaluation of RayLens performance Techniques

RayCasting

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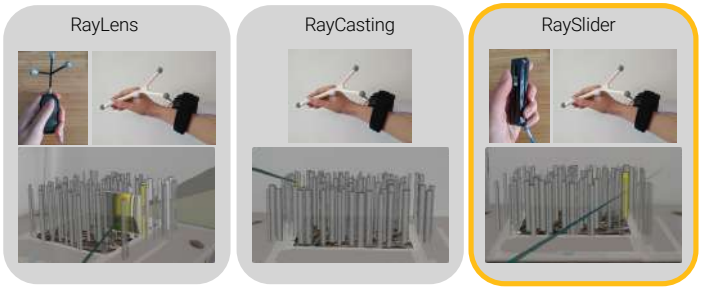
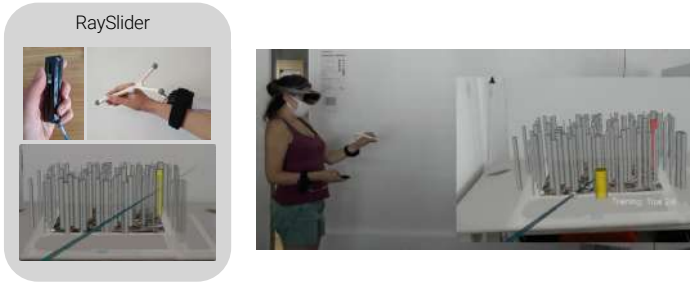
Evaluation of RayLens performance Techniques



Evaluation of RayLens performance Techniques



Evaluation of RayLens performance Experiment & Measures

Quantitative evaluation

Speed

Accuracy

Qualitative evaluation

Workload

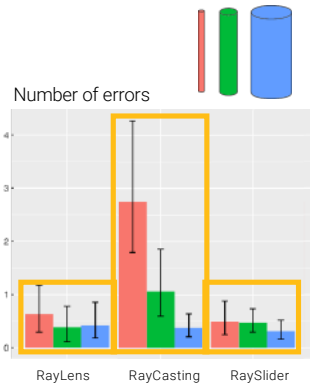
Users preferences

Results: accuracy

The 3 techniques are equivalents on average

RayCasting impacted by the target size

RayLens and **RaySlider** more accurate



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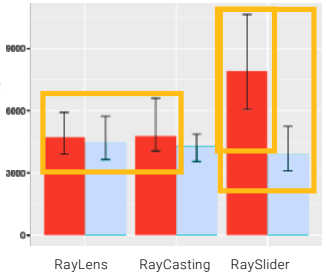
Results: speed

RaySlider impacted by the density

3 techniques equivalents in time

RayLens 1.6x faster than **RaySlider**

Completion times

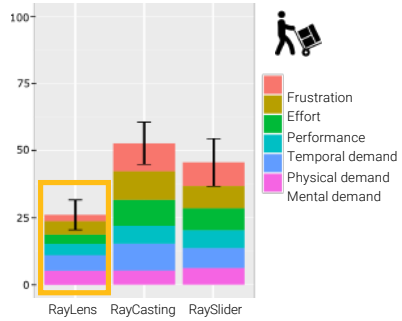


Qualitative results

The lowest workload with **RayLens**

RayLens is easy-to-learn and easy-to-use

RayLens is preferred by all participants

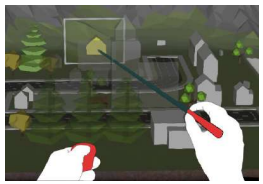


RayLens: extension of raycasting

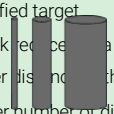
Performant?

Speed

Accuracy



- Magnified target
- 3D task reduced to a 2D task
- Shorter distance to the target
- Smaller number of distractors


Target size

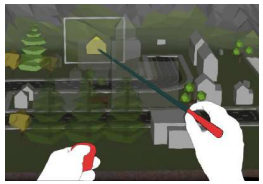

Density of the environment

RayLens: extension of raycasting

3D movement of the lens?

Ease

Fatigue



- Simple, intuitive
- The lowest workload
- The least physically and mentally tiring
- Preferred

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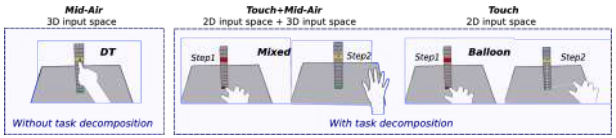
Augmented Reality/Virtuality (AR/AV)

- Challenges
  - Tracking
  - Rendering
  - Interaction

3D object selection in Tabletop AR

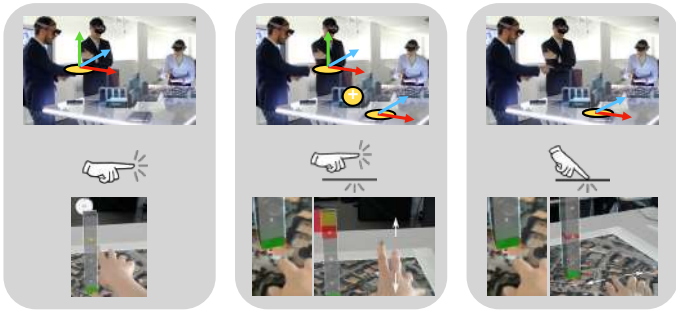
Experimental study



- Comparison of 3 interaction techniques

Experimental study

- Comparison of 3 interaction techniques



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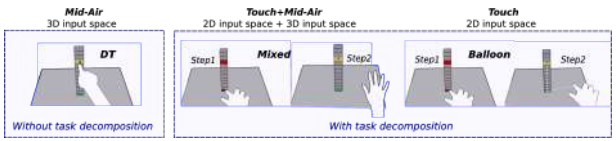
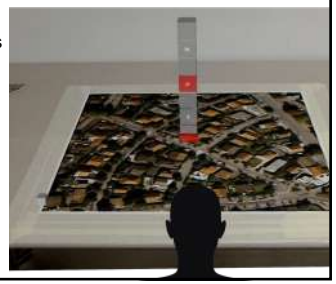
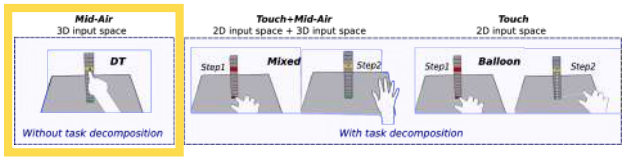
Experimental study

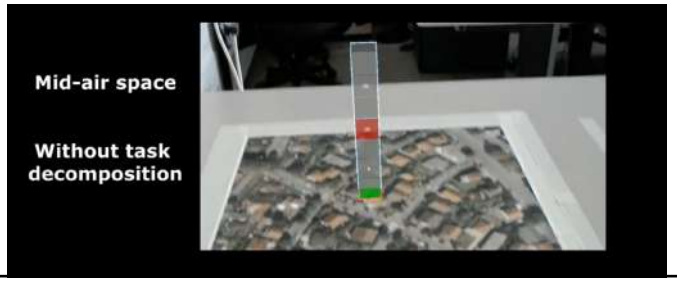


- Comparison of 3 interaction techniques
- Selection of a 3D box in a stack of 3D boxes placed on the table

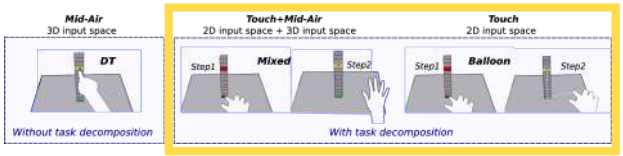


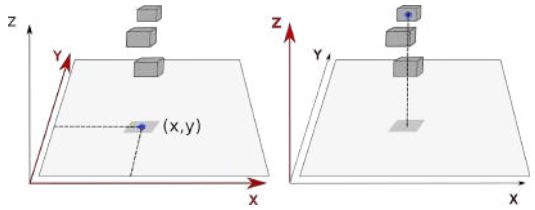
The 3 compared techniques



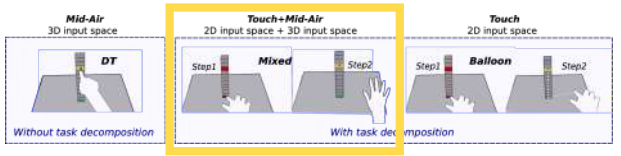


The 3 compared techniques





The 3 compared techniques



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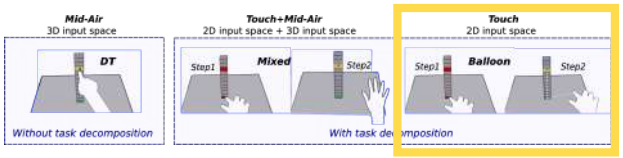
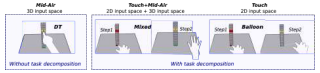
The 3 compared techniques



Design

- Quantitative Evaluation: completion time & accuracy

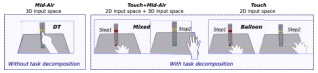
TECHNIQUE



Design

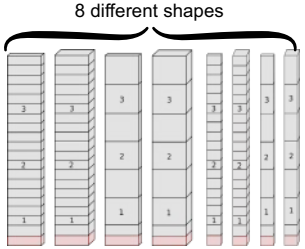
- Quantitative Evaluation: completion time & accuracy

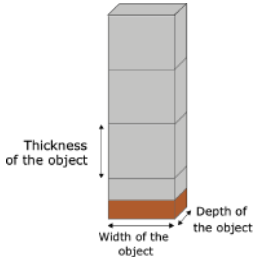
TECHNIQUE



SHAPE

8 different shapes

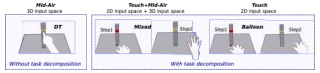




Design

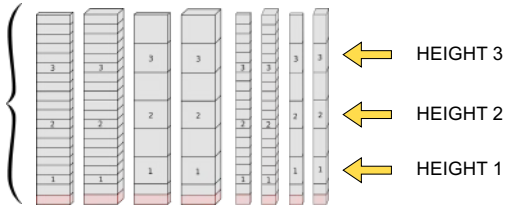
- Quantitative Evaluation: completion time & accuracy

TECHNIQUE



SHAPE

HEIGHT



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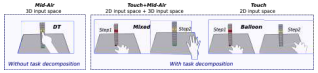
Design

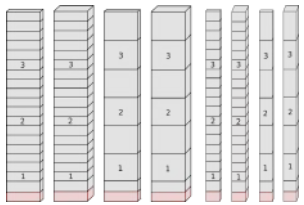
• Quantitative Evaluation: completion time & accuracy

TECHNIQUE



SHAPE

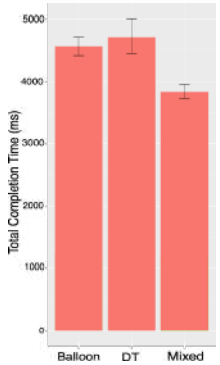
HEIGHT



• Qualitative Evaluation: NASA-TLX & users' preferences

Results: speed

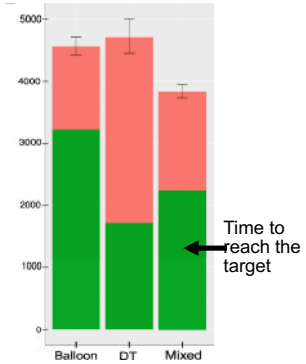
1. *Mixed, a* fast selection technique on average



Results: speed

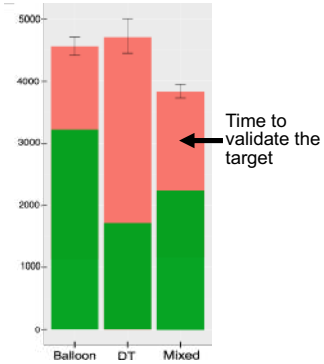
1. *Mixed* a fast selection technique on average

2. Similar completion times to reach the targets for the first time with *DirectTouch* and *Mixed*



Results: accuracy

DirectTouch less accurate than others



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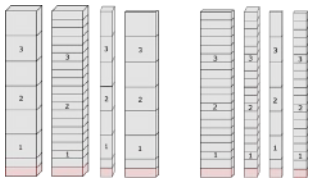
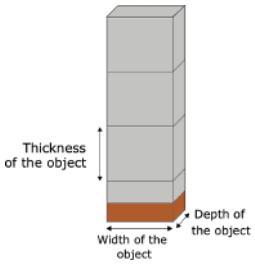
Results: SHAPE effect

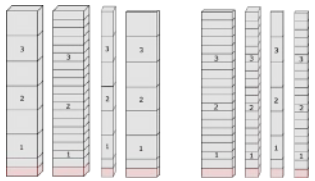
Grouping the shapes according to the numbers of small dimensions

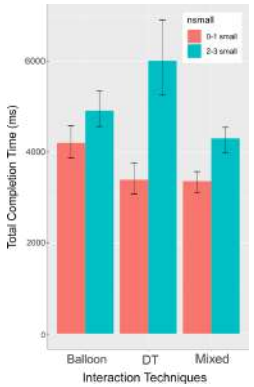




Results: SHAPE effect

Grouping the shapes according to the numbers of small dimensions

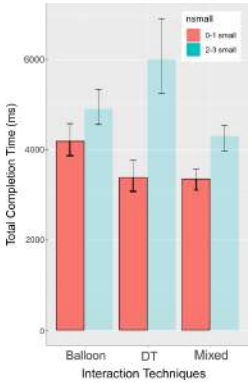




Results: SHAPE effect

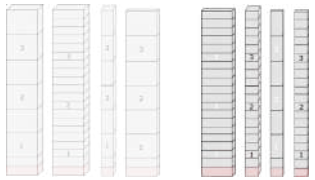
- For shapes with at most 1 small dimension:

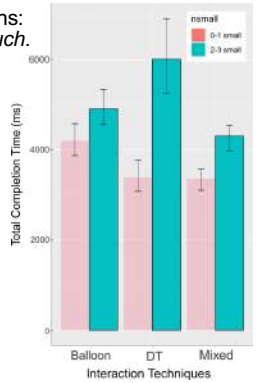
Mixed and *DirectTouch* are faster than *Balloon*



Results: SHAPE effect

- For shapes with at least 2 small dimensions:
Mixed and *Balloon* outperformed *DirectTouch*.





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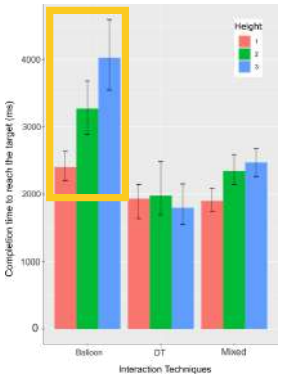
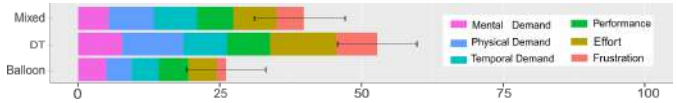
Results: HEIGHT effect

Time to reach the target with *Balloon* strongly impacted by the height of the target in the stack



Results: Qualitative evaluation

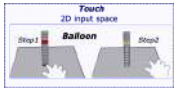
- *Mixed* and especially *Balloon* are largely preferred over *DirectTouch*
- They also required a lower workload than *DirectTouch*



Lessons learned

	• Intuitive • Fast to reach the target regardless of its height	• Least accurate • Frustration • Fatigue

Lessons learned



	• Intuitive • Fast to reach the target regardless of its height	• Least accurate • Frustration • Fatigue
	• Most accurate • Low fatigue • Most preferred • Feeling of control	• Slowest to reach the target • Slower for high targets

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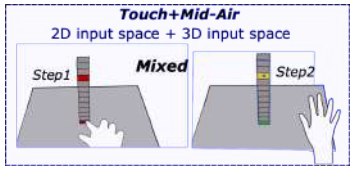
Lessons learned



- The fastest technique on average
- Efficiency of the task decomposition with a fast height adjustment in mid-air, little impacted by the height of the target
- Unifying 2D and 3D spaces:
  good compromise for fast and accurate selections

Augmented Reality/Virtuality (AR/AV)

- Challenges
  - Tracking
  - Rendering
  - Interaction

- Definitions
- Handheld AR/AV
  - Pointing at physical targets
  - Pointing at virtual targets
- HMD-based AR/AV
  - 3D pointing

Perspective

+ Unlimited viewing space
- Interaction techniques : fatigue and precision

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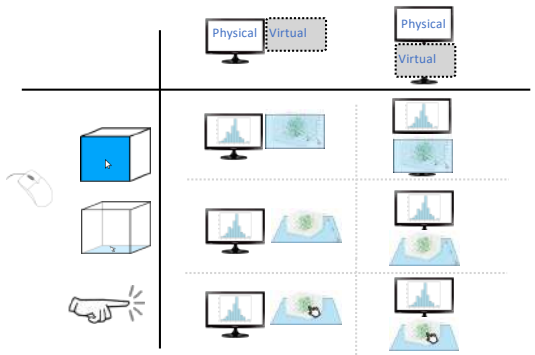
Perspective

+ Unlimited viewing space
+ 3D stereoscopic view
- Interaction techniques : unifying 2D and 3D desktop

Selection techniques for extended workstation

Mouse-based interaction

Design space



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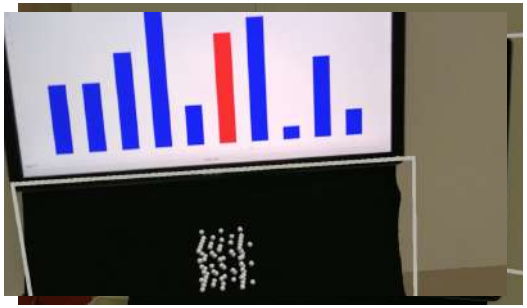
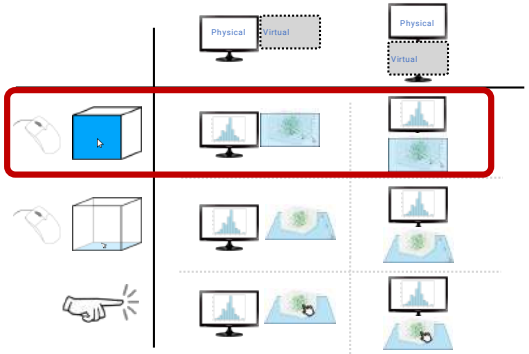
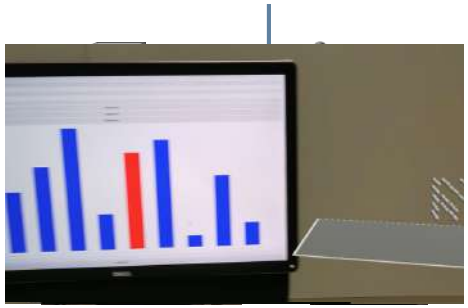
Mouse: Vertical plane



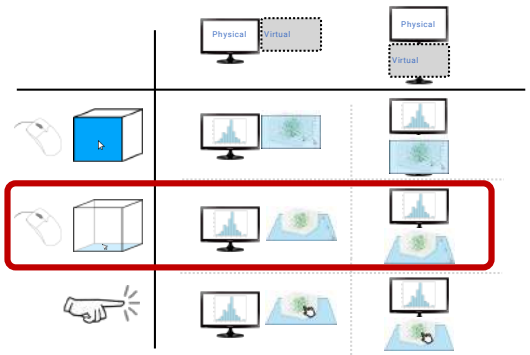
Mouse: Horizontal plane



Mouse: Horizontal plane



Mid-air interaction



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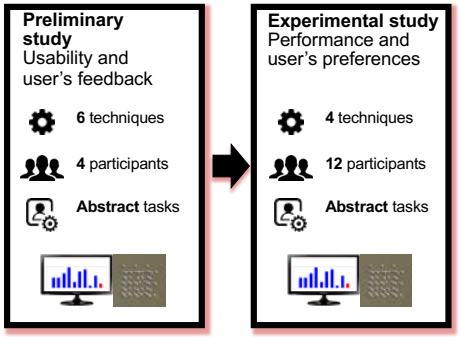
Mid-air interaction

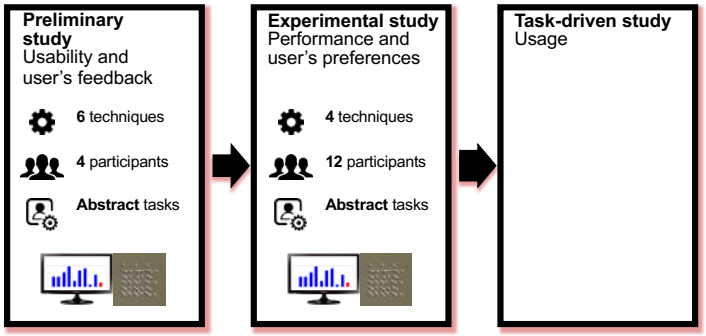
Conducted experimental studies



Key insights

- **Usefulness of the mouse and mid-air interaction techniques**
- **Mouse interaction: double screen setup**
- **Flexible position of the 3D scene**

Conducted experimental studies



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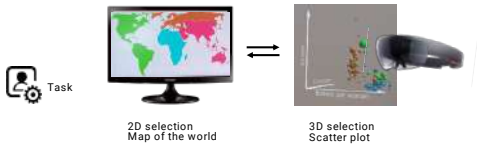
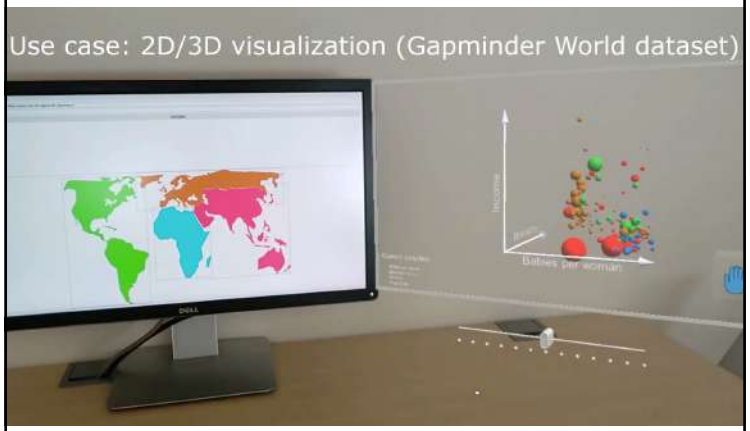
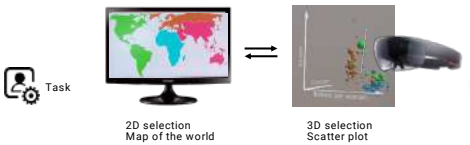
Task-driven study





Task-driven study



14 participants

Questions about the usage of the system
e.g. Do they have a favorite position of the 3D scene?

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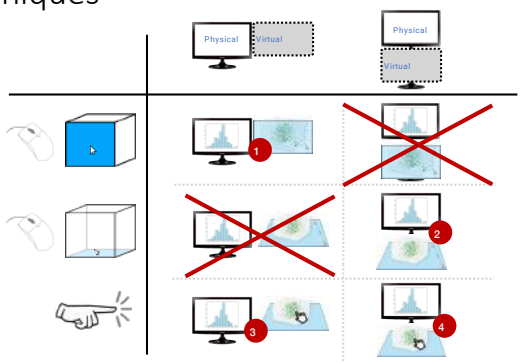
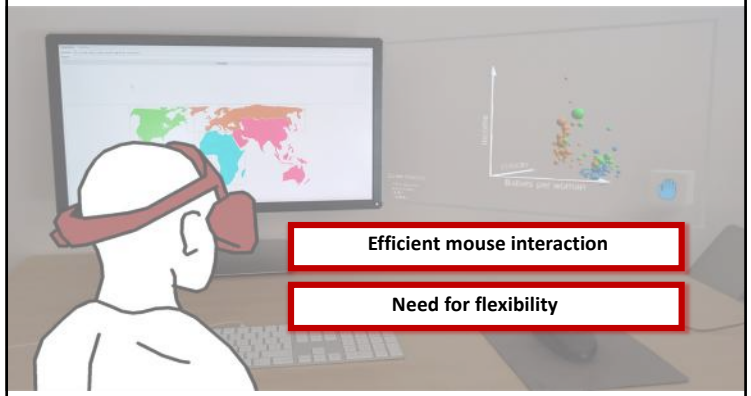
Task-driven study: implemented techniques



Task-driven study: key insights

- **Usefulness of the mouse and mid-air interaction techniques**
- **Flexible position of the 3D scene**
- **Mouse interaction easy to use**

Takeaways



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Perspective

+ Unlimited viewing space + 3D stereoscopic view

Interaction techniques :

- unifying 2D and 3D desktop
- managing the views
- beyond hand gesture
- collaboration

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