Cartography M.Sc.

Using Information Chunking for Spatial Learning based on Augmented Reality

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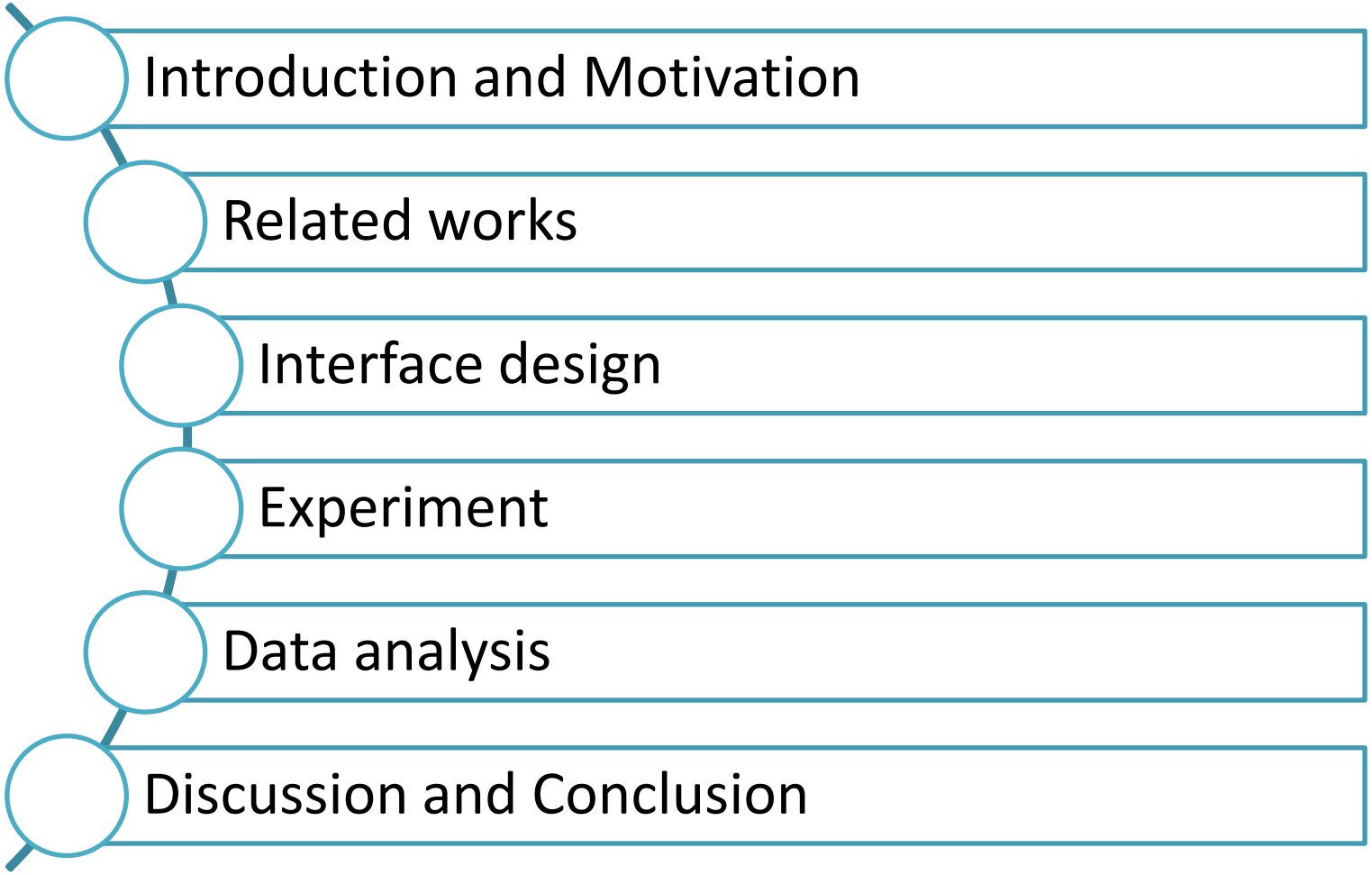
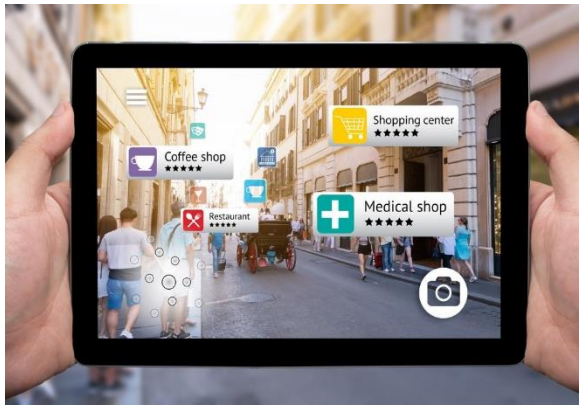
25.09.2023

Outline

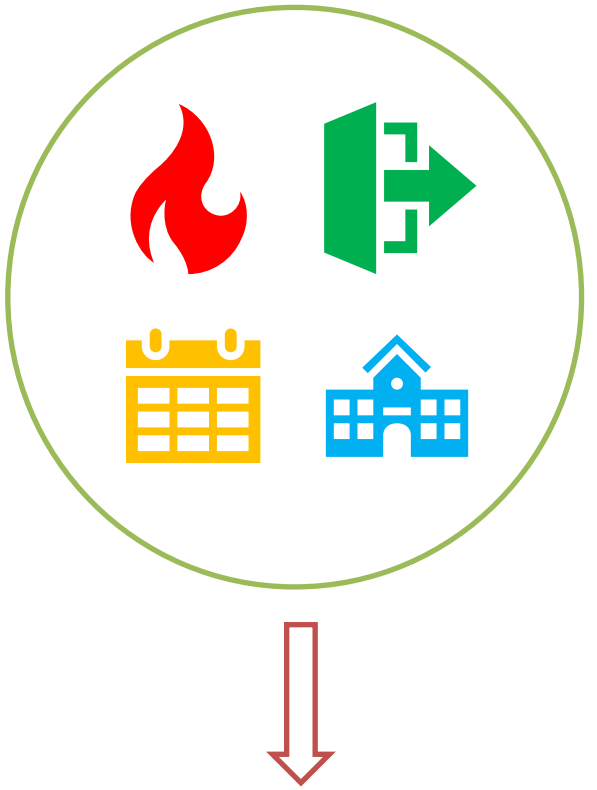

Introduction and Motivation
Related works
Interface design
Experiment
Data analysis
Discussion and Conclusion

Introduction and Motivation



Augmented Reality (AR) can carry virtual landmarks, which draws people's attention and guide people.

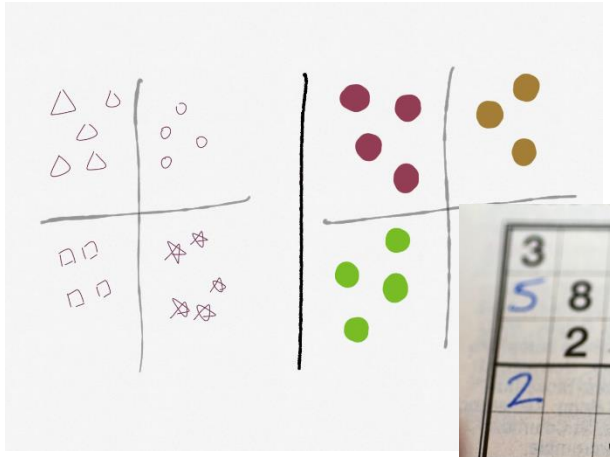
However, too many landmarks lead to information overload, decreasing learning efficiency – especially in the indoor environment.

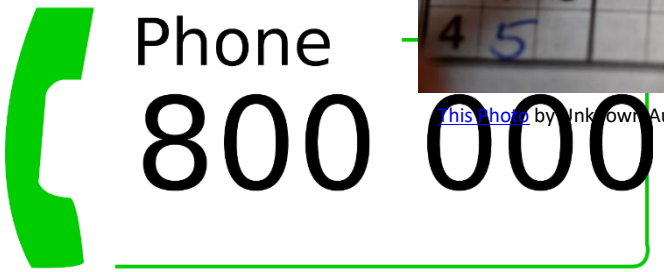


Necessity to do indoors spatial learning – when facing daily and emergent situation.

How to solve this problem?

How to solve: *Chunking*?





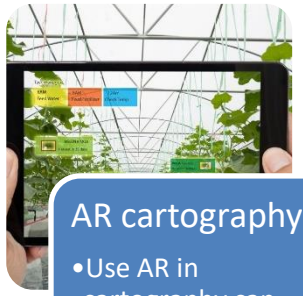
Divide items by some certain rules: colors, shapes, textures…

Apply to indoors environment: Reflect the internal relationship of indoor space structure

Our goals

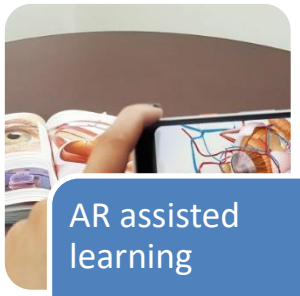
- Create a kind of chunking method to balance the information
- Designing a kind of visual guidance to assist spatial learning
- Carrying out the control experiment to analyze the effect: we anticipate that our chunking system will be better than the one without chunking.

Related works



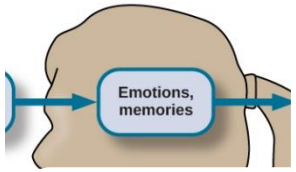
AR cartography

- Use AR in cartography can increase user experience.



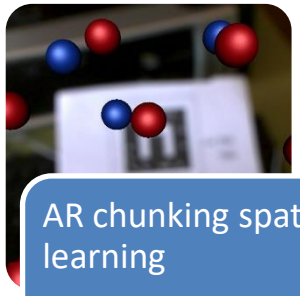
AR assisted learning

- AR can improve users' learning efficiency.



Chunking assisted learning

- Chunking method can balance users' work memory.



AR chunking spatial learning

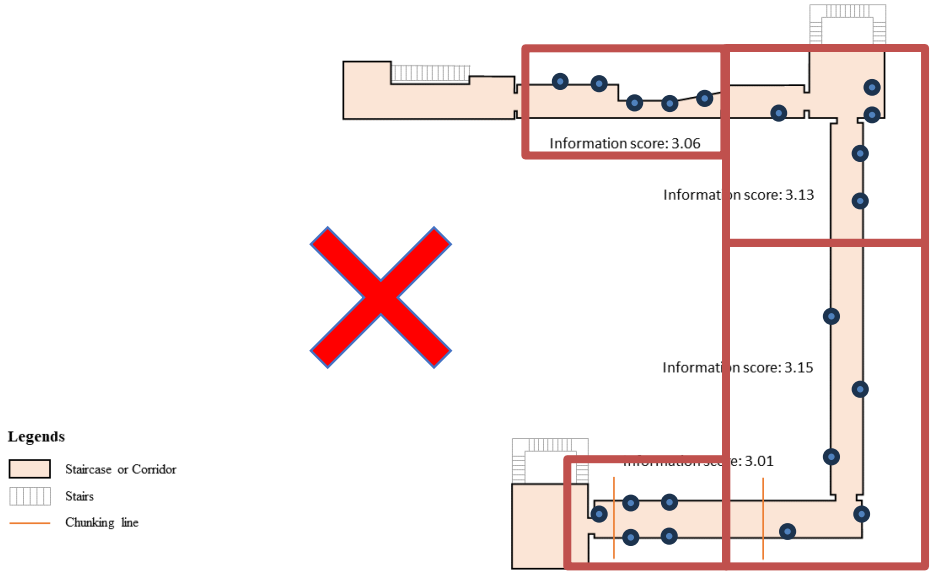
- Combining AR and chunking: Quantitative Vs. Qualitative

Sketch map analysis

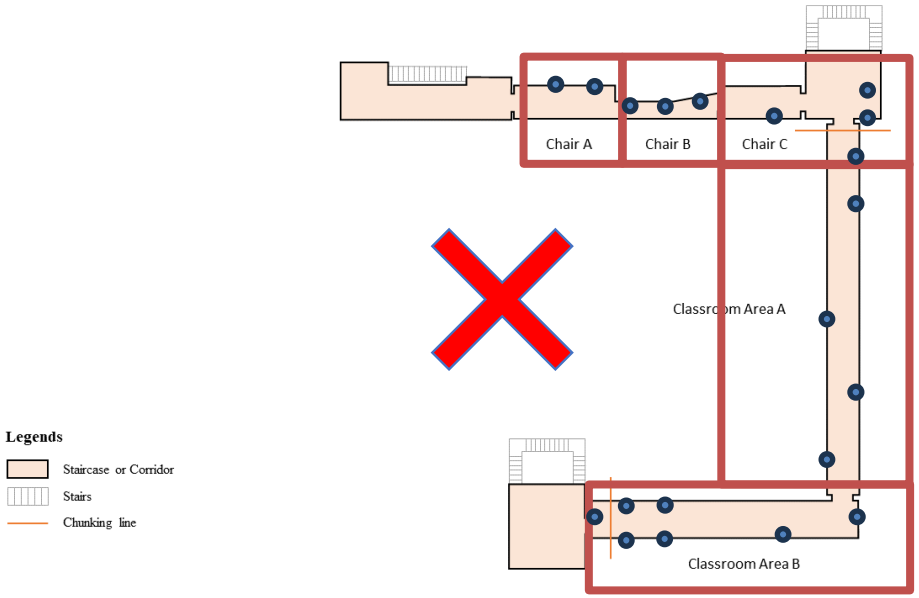
- Set a pivot to adjust the whole map structure to digitalize the sketch.

Images:
https://www.completebusinessnews.com/agricultural-drones-is-it-worth-getting-one/
https://edtech4beginnerscom.files.wordpress.com/2020/03/2.png?w=1140
https://s3-us-west-2.amazonaws.com/courses-images-archive-read-only/wp-content/uploads/sites/902/2015/02/23224821/CNX_Psych_07_01_Concepts.jpg
https://claretscience5.weebly.com/uploads/1/2/3/7/123740240/gas_9_orig.jpg
https://cdn.pixabay.com/photo/2016/07/14/00/27/hand-1515895_960_720.png

Design principle: chunking methods



Information volume chunking: Split the inherent structure of space



Semantics chunking: Spatial semantics not continuous

Try to find a better and more flexible solution

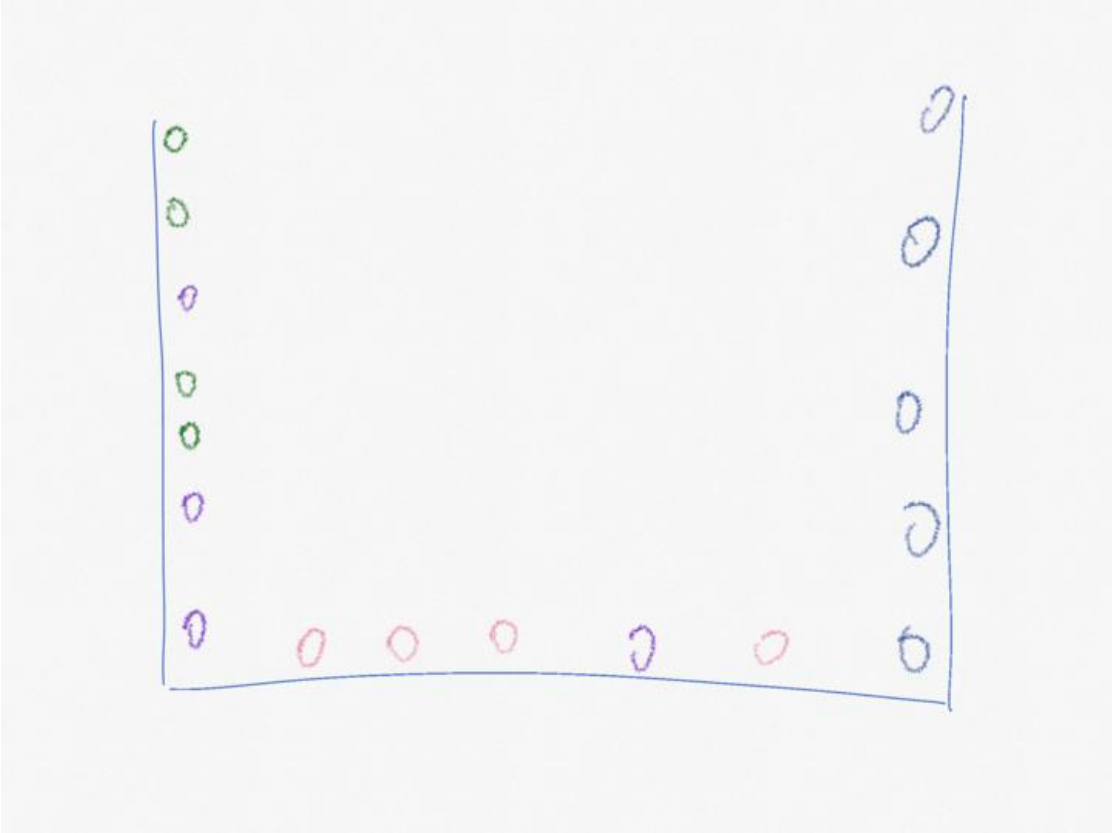
Design principle: how to chunk

Use classification and hierarchy visualization to chunk:

👉 Indoors spatial design has certain connection and we need to visualize the potential relationship.

- Classification: classify indoors objects into several types.
- Hierarchy: highlight most important objects to reduce information overload.
- No rigid segmentation – more flexible.

Design principle: classification

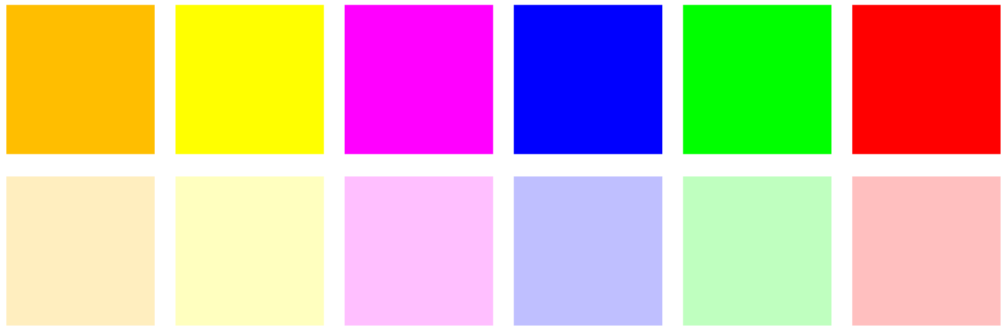


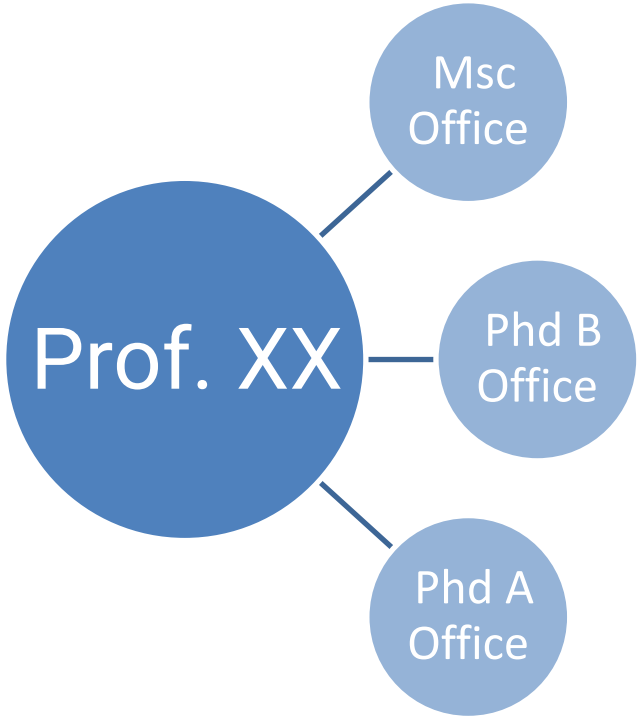
Using different colors to represent different kinds of targets:

Category	RGB	Color
Cartography Dept	(0.13f , 0.54f , 0.13f , 1.0 f)	
Photogrammetry Dept	(0.8 f , 0.55f , 0.22f , 1.0 f)	
Traffic Eng.	(0.0 f , 0.54f , 0.54f , 1.0 f)	
Transportation Cons.	(0.62f , 0.16f , 0.94f , 1.0 f)	
OpenLab	(0.7 f , 0.13f , 0.13f , 1.0 f)	
Restrooms	(1.0 f , 1.0 f , 0.0 f , 1.0 f)	
Fire Hydrants	(1.0 f , 0.5 f , 0.5 f , 0.5 f)	
Trash Bins	(1.0 f , 0.5 f , 0.0 f , 0.5 f)	
Stereoscopes	(0.0 f , 1.0 f , 0.0 f , 0.5 f)	
Show boards	(0.0 f , 0.5 f , 1.0 f , 0.5 f)	
Independent Objects	(0.8 f , 0.7 f , 0.0 f , 0.54f)	
Highlight Color	(1.0 f , 0.0 f , 0.0 f , 1.0 f)	
Transparent Color	(0.0 f , 0.0 f , 0.0 f , 0.0 f)	

Design principle: hierarchy

Highlight the key points: hierarchy of primary and secondary landmarks, using the HSV color channel to control color prominence and guide visual attention.





Platform and devices

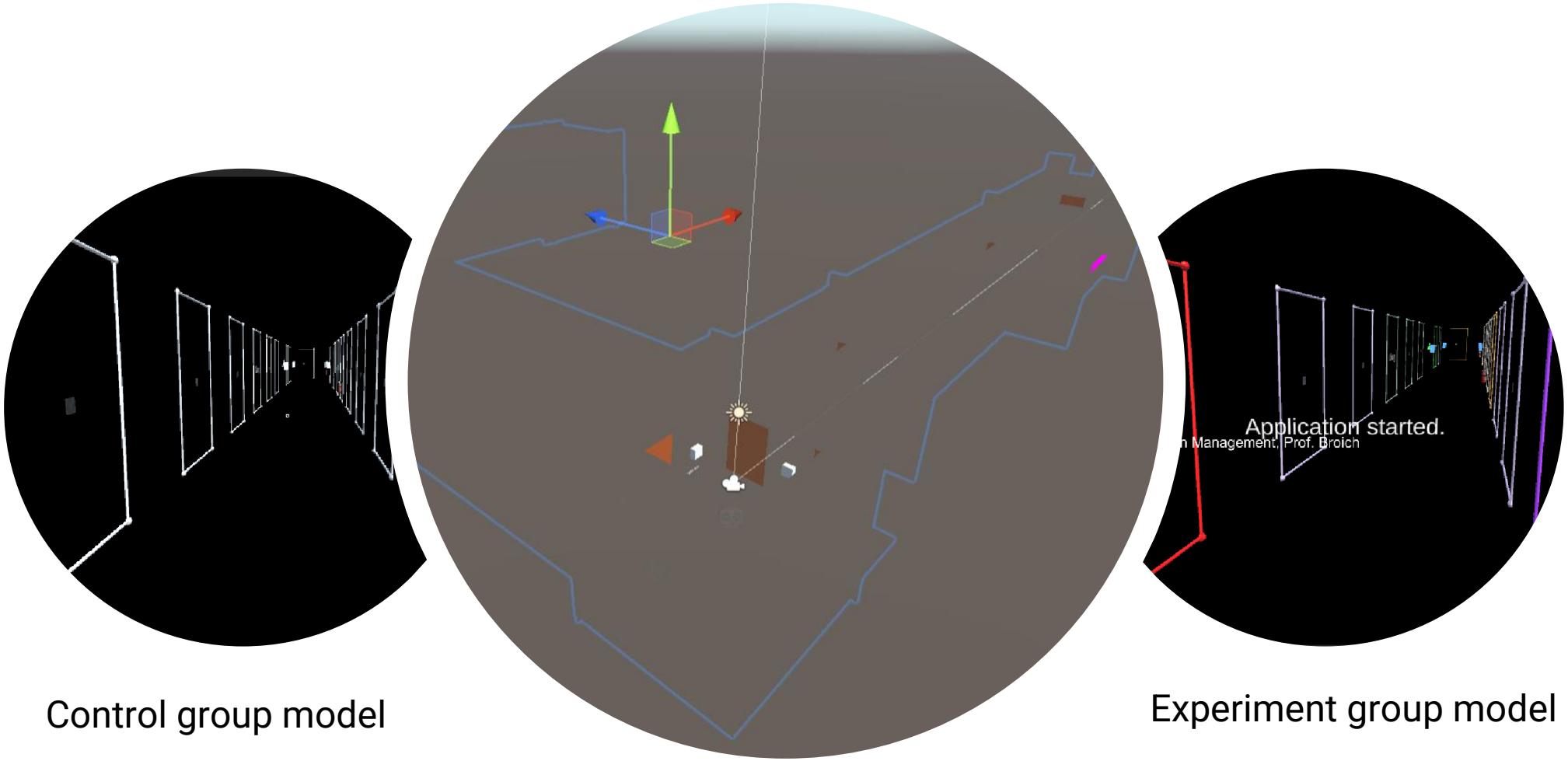
Unity serves as a cross-platform game engine and development environment. (Version 2020.3.15f2, education license)

MRTK is a Mixed Reality Toolkit that constitutes interoperability across a diverse spectrum of software and hardware platforms. (MRTK 3, MIT license)

HoloLens 2, a product of Microsoft, is a mixed reality head-mounted. (Hololens 2, , Microsoft license)

Design visualization - simulator

Motivation
Related Works
Design
Experiment
Analysis
Discussion



Control group model

Unity model

Experiment group model

Design visualization - realword

Motivation
Related Works
Design
Experiment
Analysis
Discussion

Control group real scene

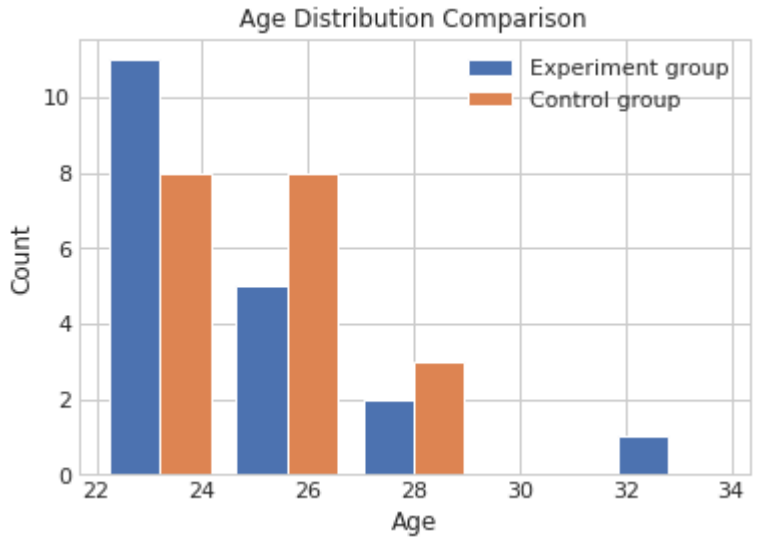
Experiment group real scene

Participants

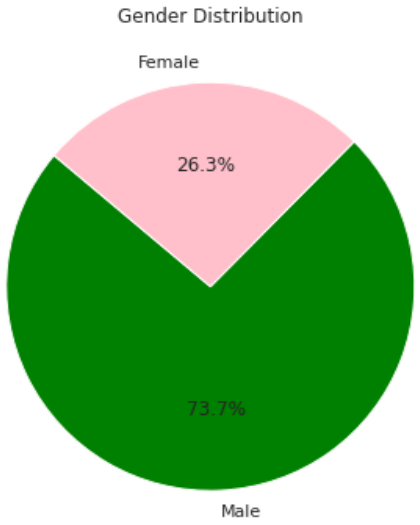
Experimental group: 19 volunteers.

Control group: 19 volunteers.

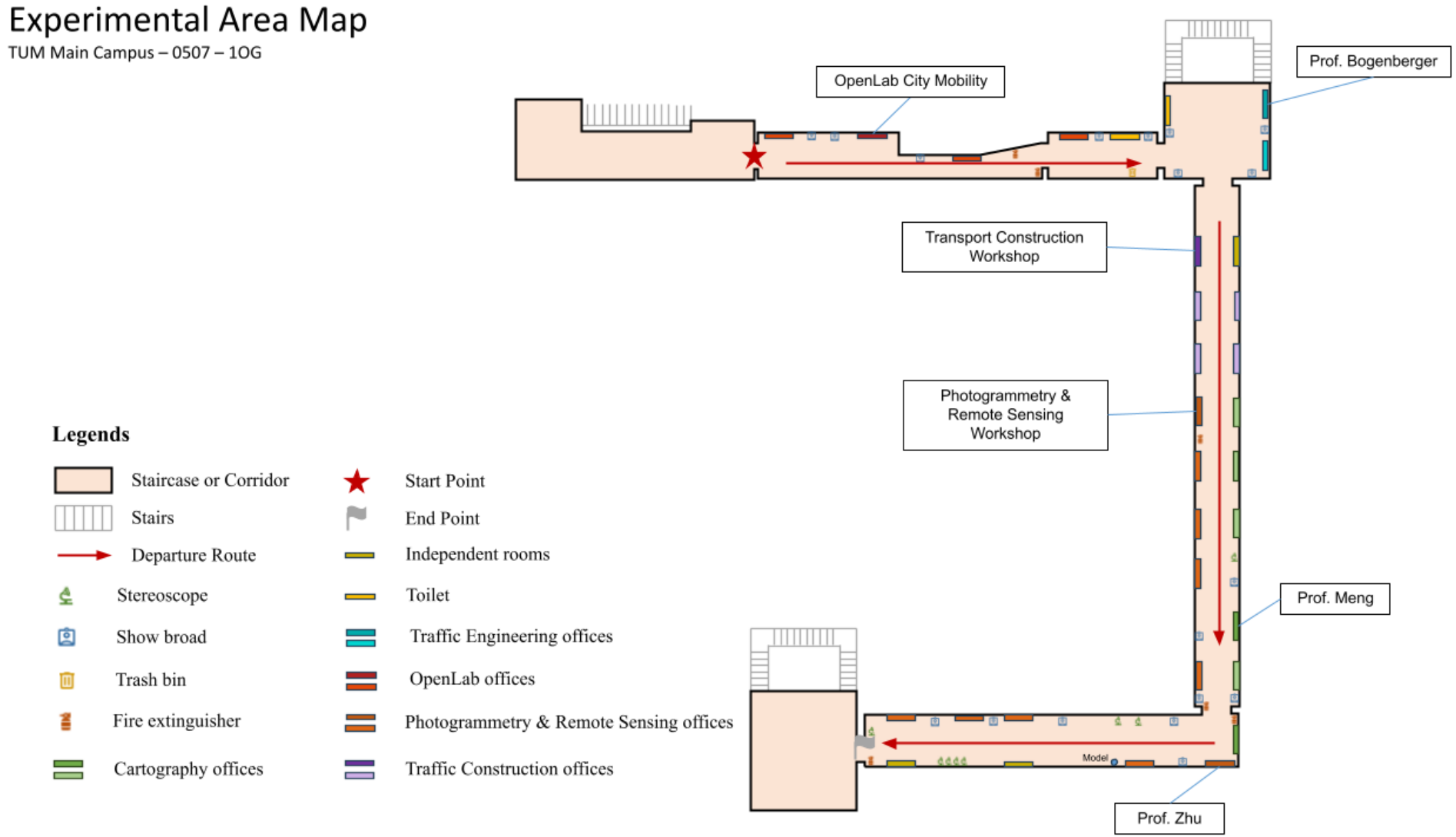
Age mainly from 24 ~ 28:



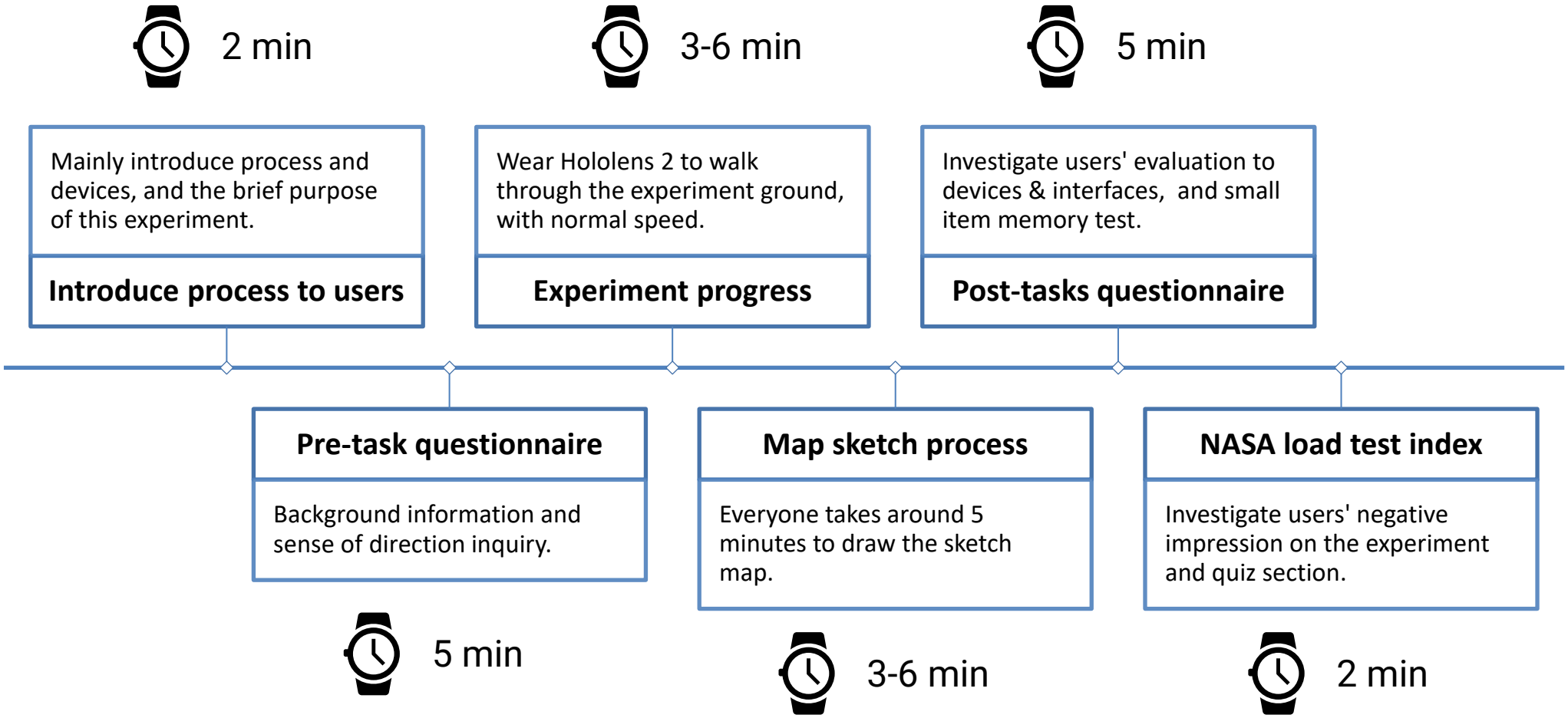
Participants are mainly male:



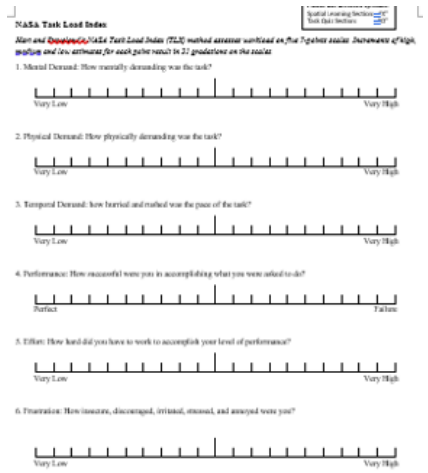
Study area


Experimental Area Map
TUM Main Campus – 0507 – 1OG
OpenLab City Mobility
Prof. Bogenberger
Transport Construction Workshop
Photogrammetry & Remote Sensing Workshop
Prof. Meng
Prof. Zhu
Model
Legends
Staircase or Corridor
Stairs
Departure Route
Stereoscope
Show broad
Trash bin
Fire extinguisher
Cartography offices
Start Point
End Point
Independent rooms
Toilet
Traffic Engineering offices
OpenLab offices
Photogrammetry & Remote Sensing offices
Traffic Construction offices

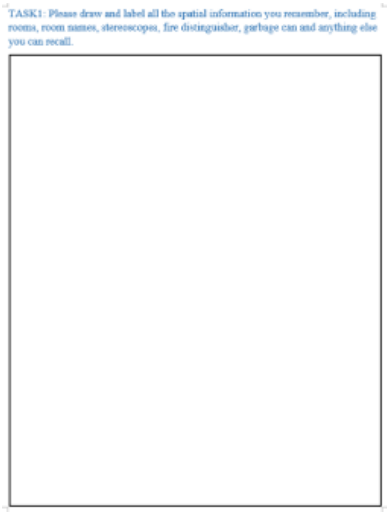
Experiment process



Questionnaire structure



NASA load test



Map Sketch

Small item memory

Post-task questions

Pre-task questionnaire

Gender: □Male □Female □Other Nationality: Age:

Field you are working/studying in:

This questionnaire consists of several statements about your spatial and navigational abilities, preferences, and experiences. After each statement, you should circle a number to indicate your level of agreement with the statement. Circle "1" if you strongly agree that the statement applies to you, "7" if you strongly disagree, or some number in between if your agreement is intermediate. Circle "4" if you neither agree nor disagree.

1= strongly agree / none, 7 = strongly disagree / a lot of

1	I am very good at giving directions.	strongly agree	1	2	3	4	5	6	7	strongly disagree
2	I have a poor memory for where I left things.	strongly agree	1	2	3	4	5	6	7	strongly disagree
3	I am very good at judging distances.	strongly agree	1	2	3	4	5	6	7	strongly disagree
4	My "sense of direction" is very good.	strongly agree	1	2	3	4	5	6	7	strongly disagree
5	I tend to think of my environment in terms of cardinal directions(N, S, E, W).	strongly agree	1	2	3	4	5	6	7	strongly disagree
6	I very easily get lost in a new city.	strongly agree	1	2	3	4	5	6	7	strongly disagree
7	I enjoy reading maps.	strongly agree	1	2	3	4	5	6	7	strongly disagree
8	I have trouble understanding directions.	strongly agree	1	2	3	4	5	6	7	strongly disagree
9	I am very good at reading maps.	strongly agree	1	2	3	4	5	6	7	strongly disagree
10	I don't remember routes very well while riding as a passenger in a car.	strongly agree	1	2	3	4	5	6	7	strongly disagree
11	I don't enjoy giving directions.	strongly agree	1	2	3	4	5	6	7	strongly disagree
12	It's not important to me to know where I am.	strongly agree	1	2	3	4	5	6	7	strongly disagree
13	I usually let someone else do the navigational planning for long trips.	strongly agree	1	2	3	4	5	6	7	strongly disagree
14	I can usually remember a new route after I have traveled it only once.	strongly agree	1	2	3	4	5	6	7	strongly disagree
15	I don't have a very good "mental map" of my environment.	strongly agree	1	2	3	4	5	6	7	strongly disagree
16	I usually get lost indoors.	strongly agree	1	2	3	4	5	6	7	strongly disagree
17	I usually get lost outdoors.	strongly agree	1	2	3	4	5	6	7	strongly disagree
18	I have__ experience with Augmented Reality.	none	1	2	3	4	5	6	7	a lot of
19	I have__ experience with Virtual Reality.	none	1	2	3	4	5	6	7	a lot of

Pre-task questions

Data preparation: structured data

Make each question's score into a vector:

1= strongly agree / none, 7 = strongly disagree / a lot of

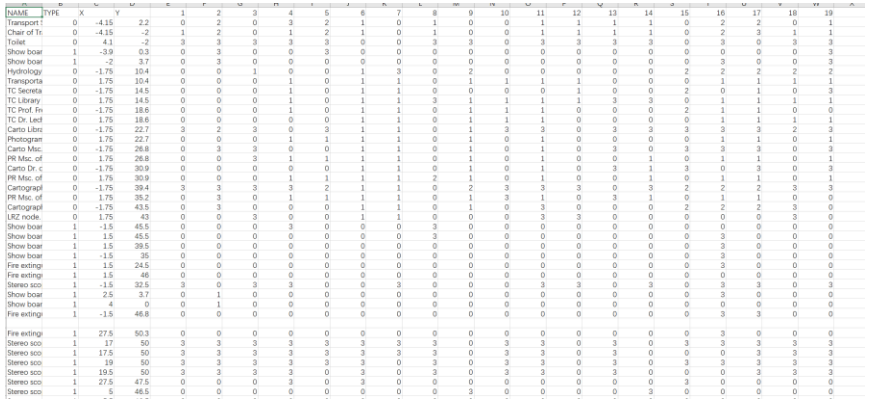
1	I am very good at giving directions.	strongly agree	1 2 3 4 5 6 7 strongly disagree
2	I have a poor memory for where I left things.	strongly agree	1 2 3 4 5 6 7 strongly disagree
3	I am very good at judging distances.	strongly agree	1 2 3 4 5 6 7 strongly disagree
4	My "sense of direction" is very good.	strongly agree	1 2 3 4 5 6 7 strongly disagree
5	I tend to think of my environment in terms of cardinal directions(N, S, E, W).	strongly agree	1 2 3 4 5 6 7 strongly disagree
6	I very easily get lost in a new city.	strongly agree	1 2 3 4 5 6 7 strongly disagree
7	I enjoy reading maps.	strongly agree	1 2 3 4 5 6 7 strongly disagree
8	I have trouble understanding directions.	strongly agree	1 2 3 4 5 6 7 strongly disagree

raduteThesis_Master > EXP_DATA > CO > 1 > {} data.json > ...

```
{
    "direction": [3, 5, 3, 4, 5, 6, 1, 7, 1, 6, 6, 7, 3, 5, 5, 2, 6, 1, 1],
    "post": [5, 3, 3, 6, 6, 6, 6, 6, 6, 5, 5, 5, 7, 7, 7, 5, 4, 3, 5, 4, 6, 4, 6, 4],
    "nasa_1": [1, 1, 1, 1, 1, 1],
    "nasa_2": [11, 1, 1, 17, 17, 1]
}
```

Data preparation: un-structured data

→ Sketch map

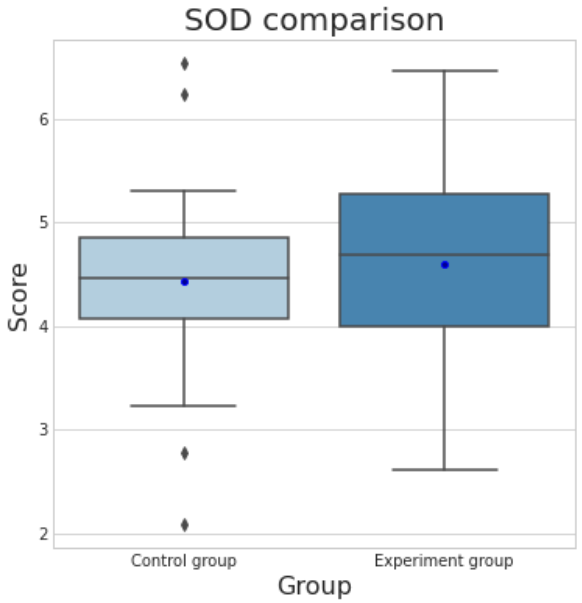


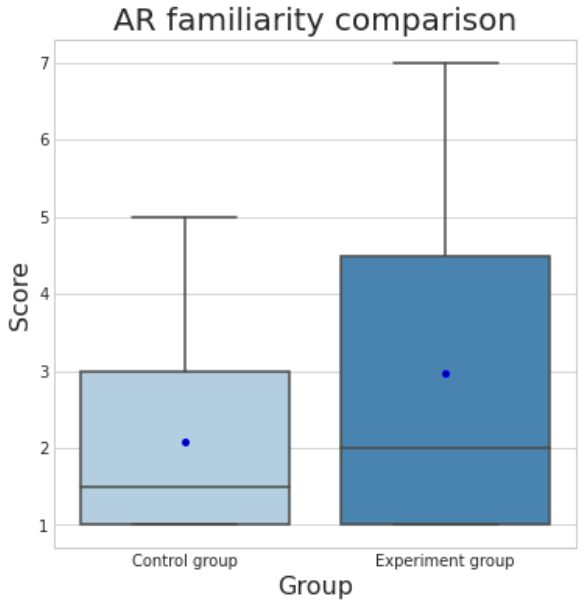
Quantitative Evaluation: Assign scores for each spatial object.

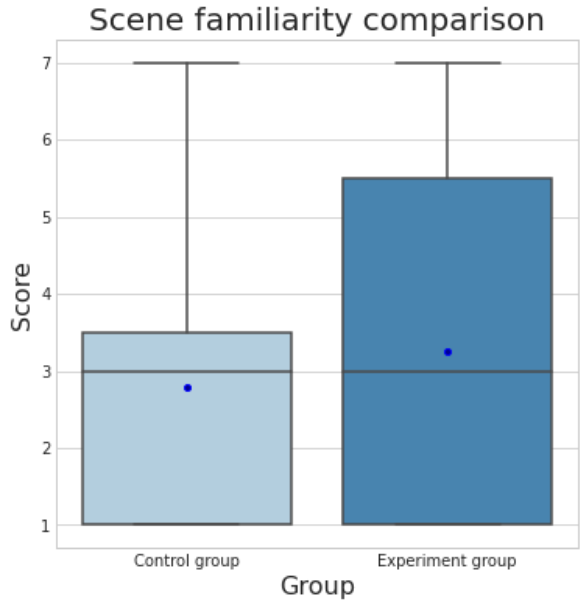
Spatial Evaluation: Using edit distance.

Important objects: rooms
Un-important objects: affiliated objects

Background research



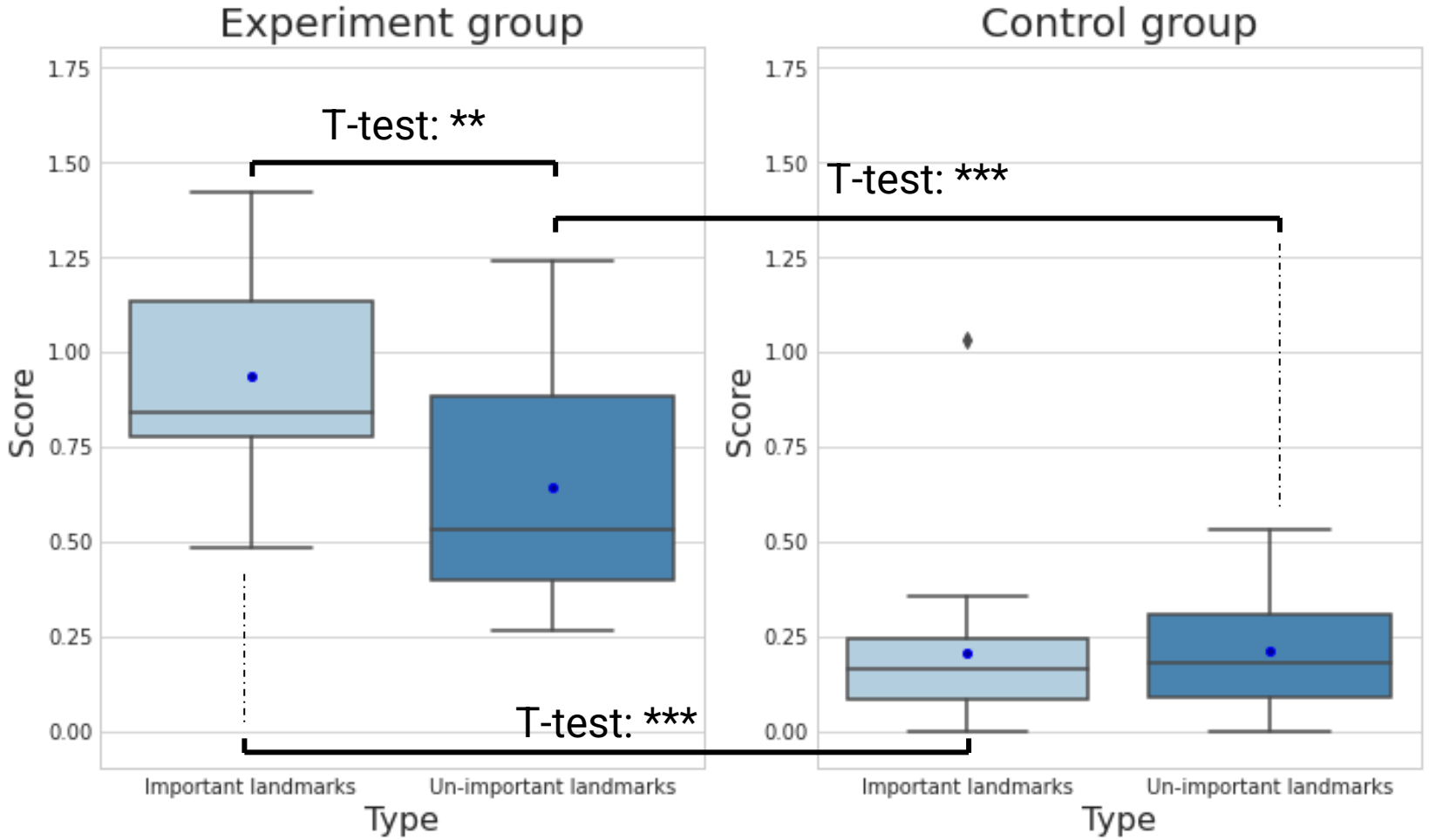




Aspect	Levene P-Value	Diff P-Value
SOD	0.796	0.632
Scene Familiarity	0.173	0.480
MR Familiarity	0.187	0.112

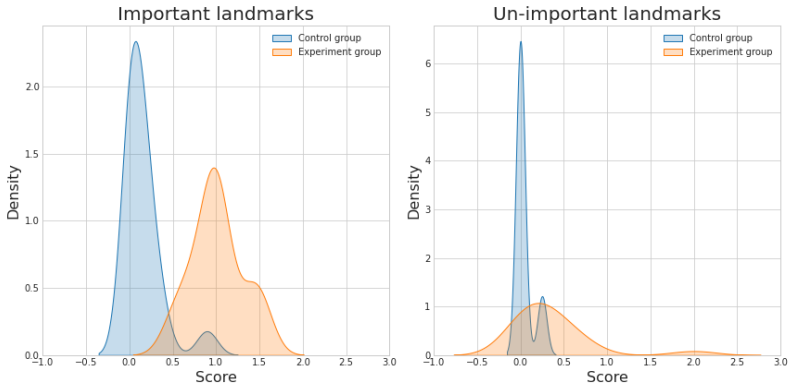
No significant difference about main background factors.

Sketch map research: quantitative view - Overall

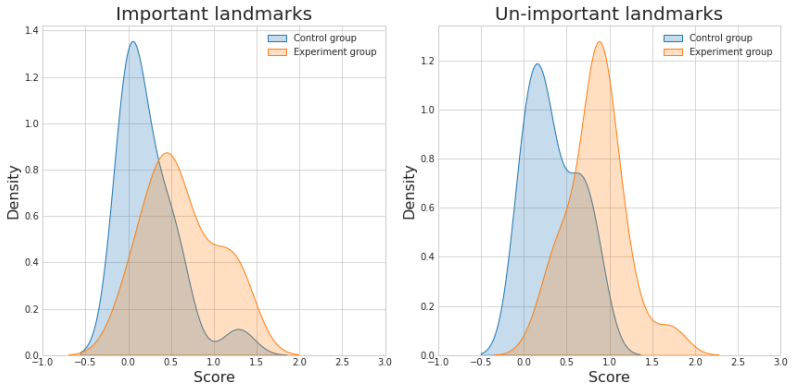


Experimental group acts better than Control group.
No significant difference between important landmarks and un-important landmarks recall in Control group.

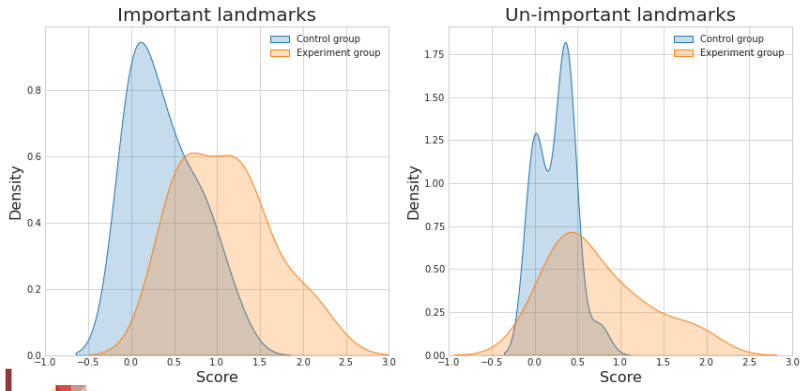
Sketch map research: quantitative view - Blocks



BLOCK 1



BLOCK 2

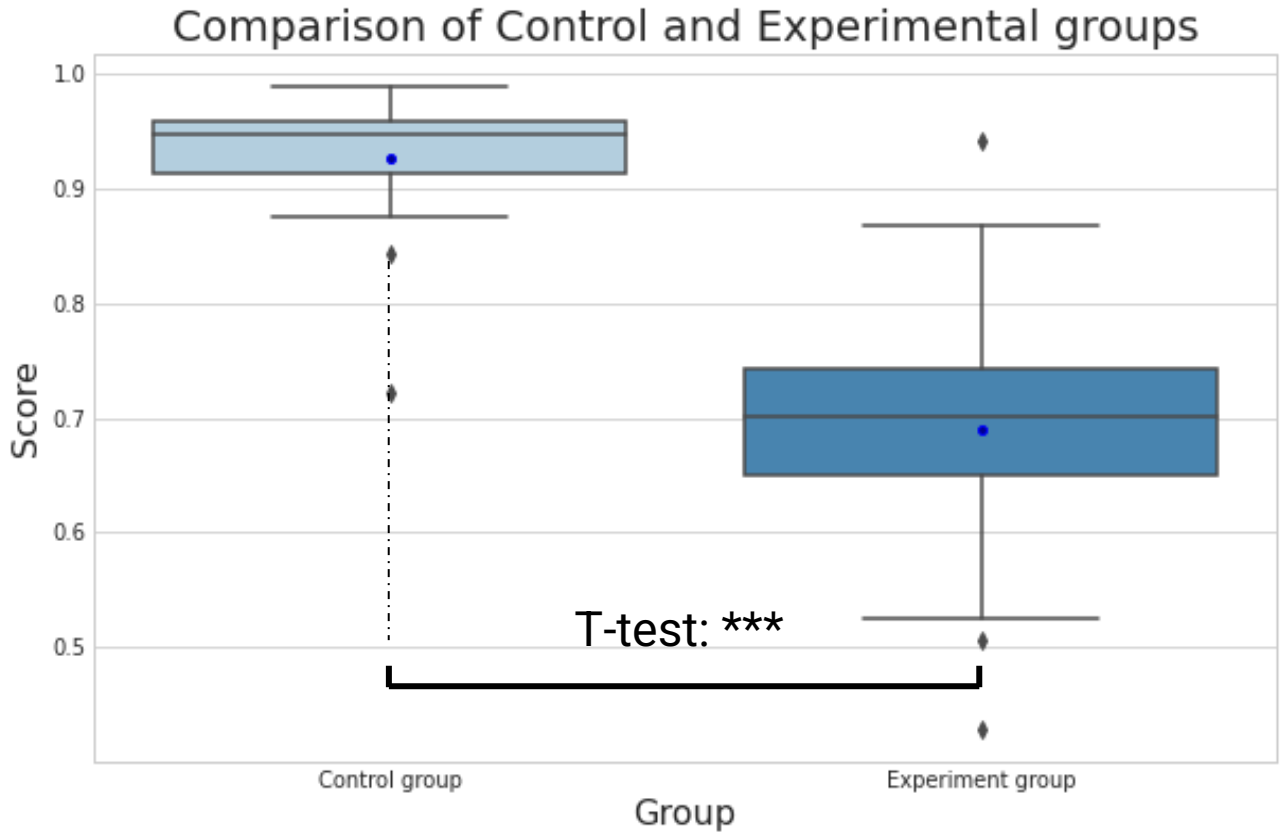


BLOCK 3

In any block, the experiment group acts better than the control group:

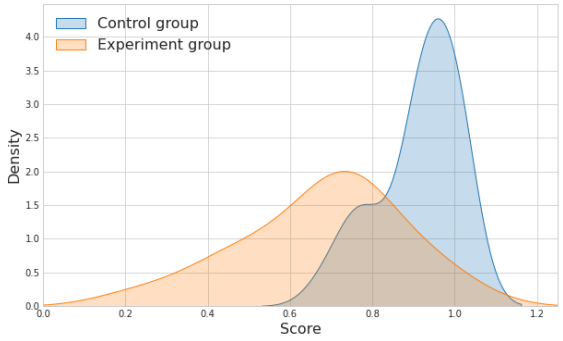
- Important landmarks: Exp. Group acts worse in Block 2; Con. Group acts worse in Block 1.
- Un-important landmarks: Exp. Group acts better in Block 2; Con. Group acts worse in Block 1.

Sketch map research: spatial view - Overall

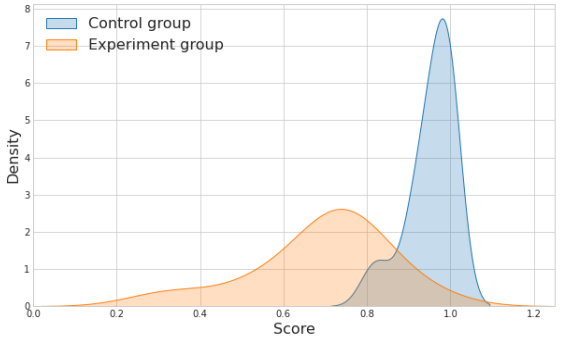


Experiment group shows better performance than Control group in the spatial relationship aspect, with significant difference.

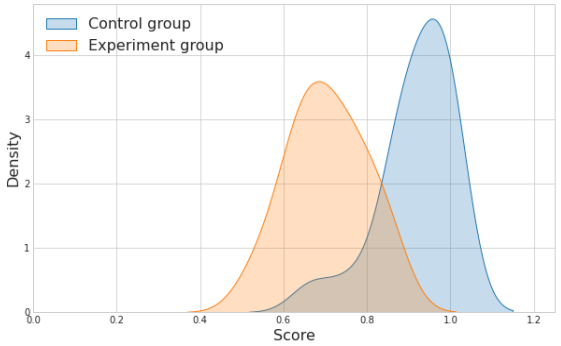
Sketch map research: spatial view - Blocks



BLOCK 1



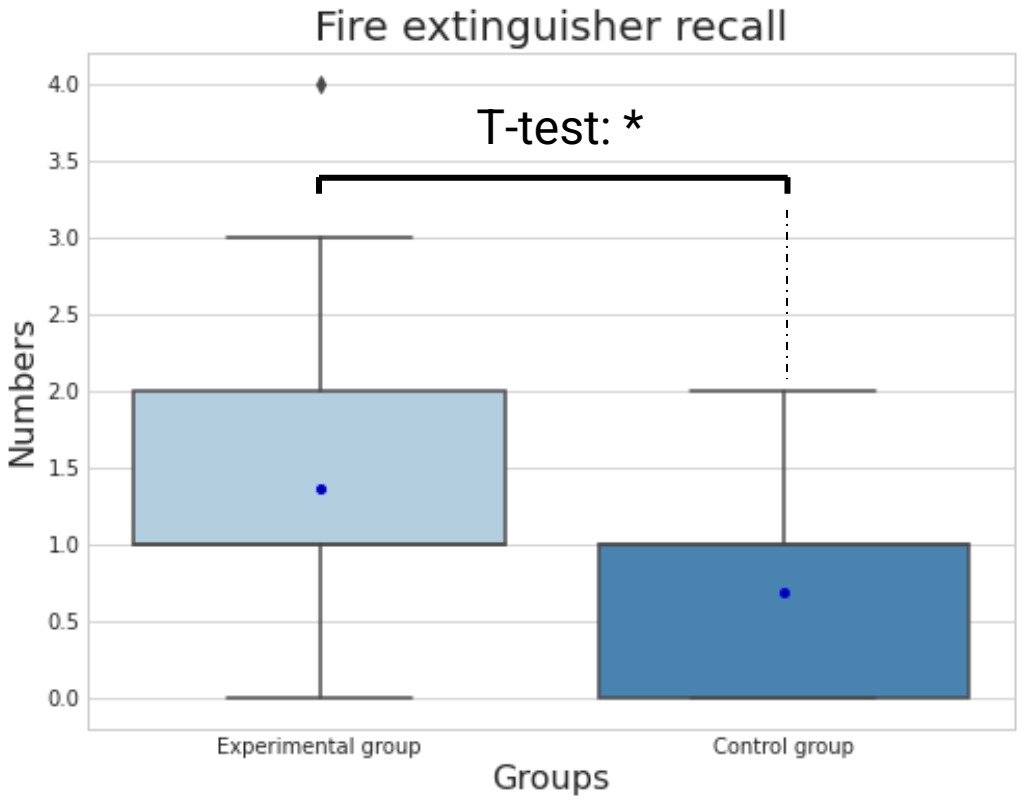
BLOCK 2



BLOCK 3

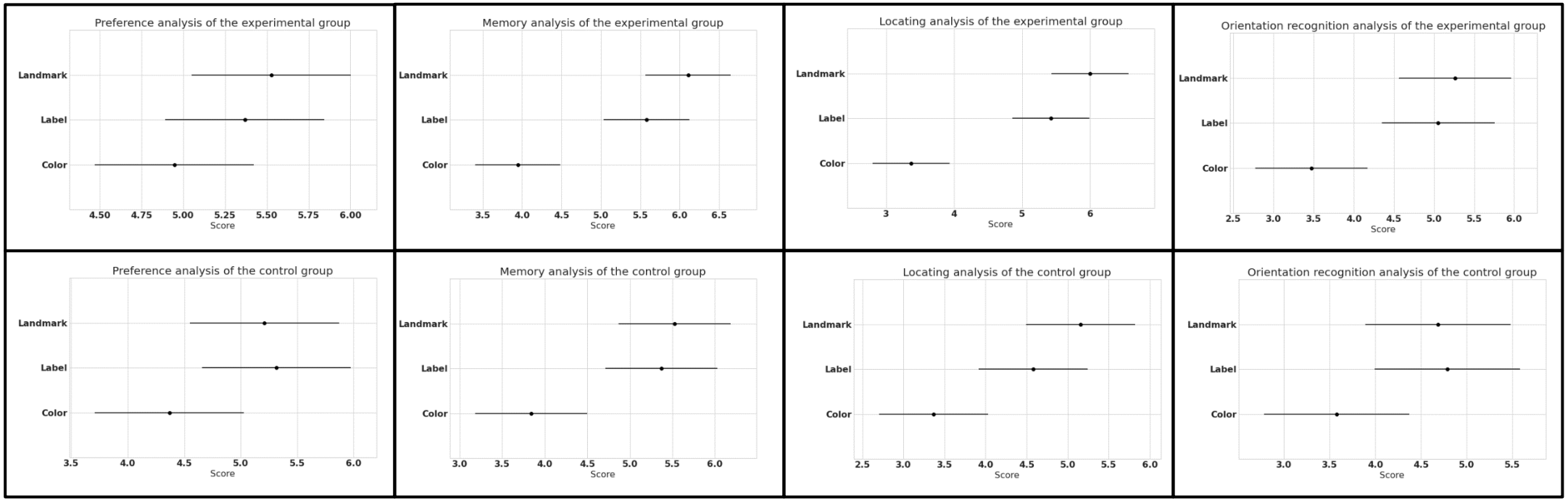
1. Experiment group has better performance in each block;
2. Each block has comparable edit distance scores within Experiment group or Control group.

Small items memory test



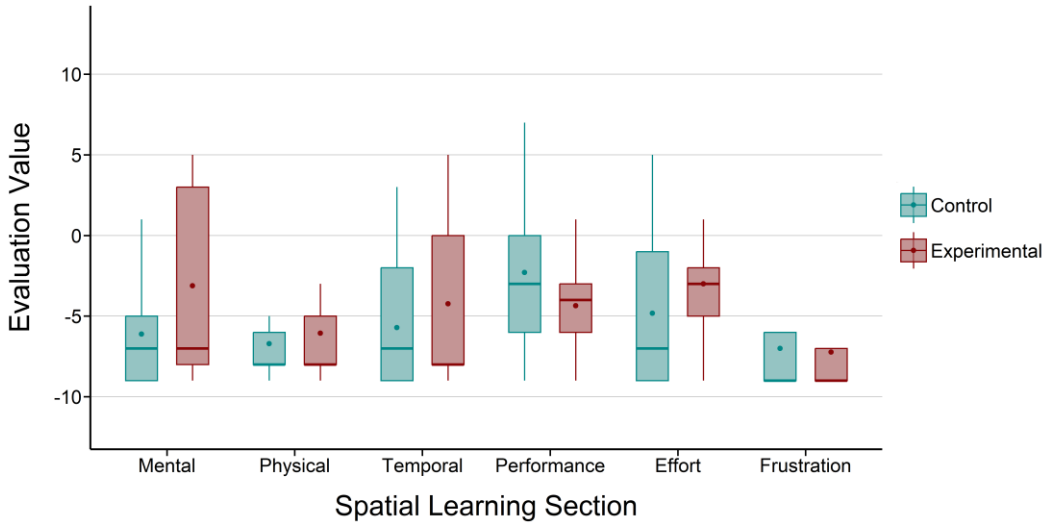
Experiment group acts better than Control group. However, in the absolute aspect, both groups don't achieve a high score in this part.

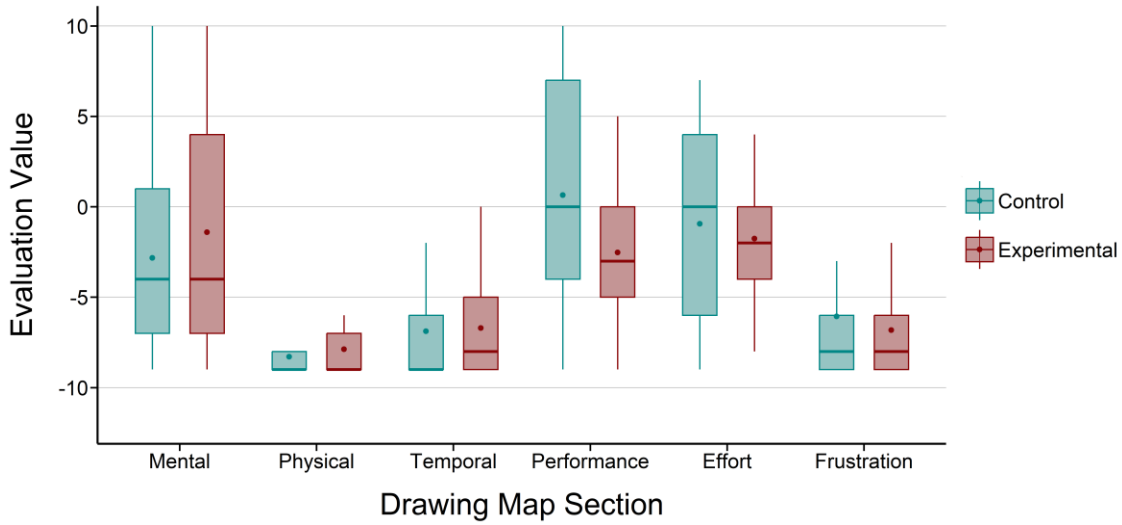
Post-task question analysis



We examine landmarks, labels and colors effects in four aspects: preference, memory, locating assistance and orientation assistance. Colors seem a relatively urgent part for further improvement (by Tukey HSD Test). It is caused by interference from natural light, device limitation, etc.

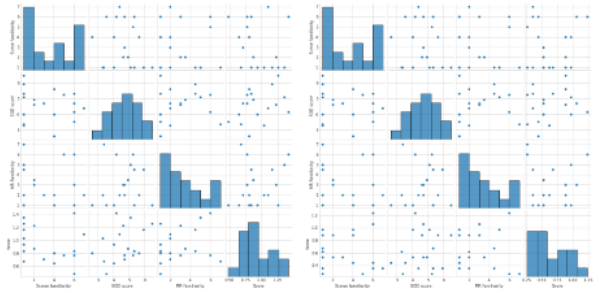
NASA Task Load Index



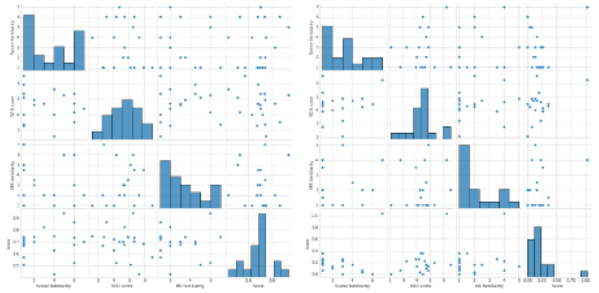


Generally, Experiment group shows greater pressure than Control group, but feels better performance, which is corresponding to the analysis result (Dunning-Kruger effect).

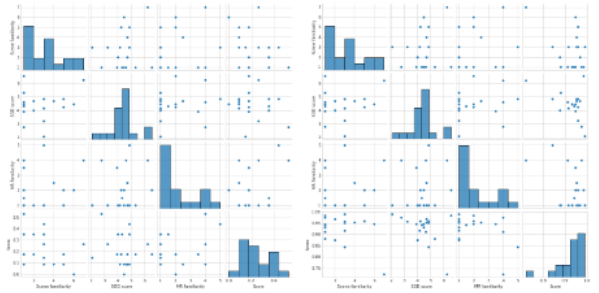
Correlation analysis: collinearity diagnosis



(a) Experiment group: Important landmark (b) Experiment group: Un-important landmark

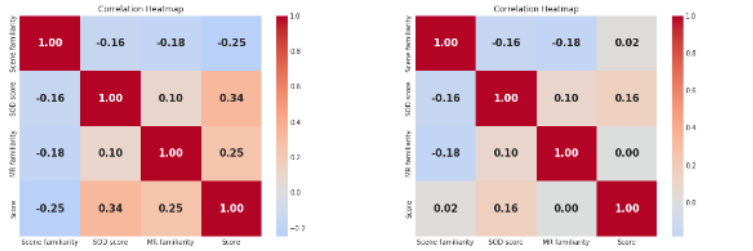


(c) Experiment group: Edit distance (d) Control group: Important landmark

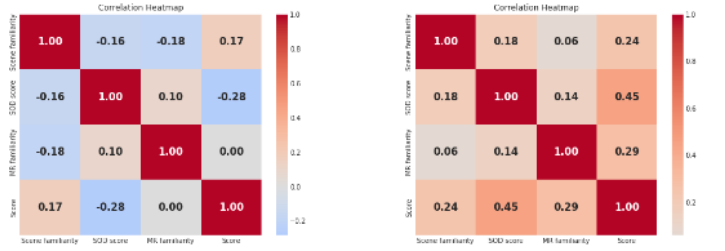


(e) Control group: Un-important landmark (f) Control group: Edit distance

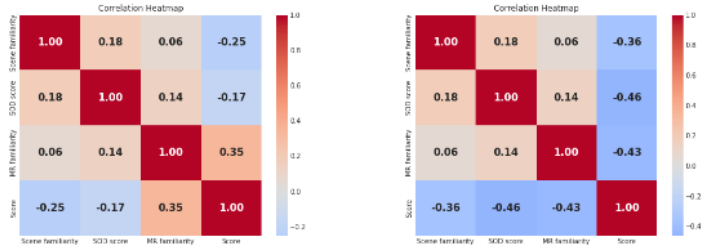
Scatter plot of variables



(a) Experiment group: Important landmark (b) Experiment group: Un-important landmar



(c) Experiment group: Edit distance (d) Control group: Important landmark



(e) Control group: Un-important landmark (f) Control group: Edit distance

Heatmap of variables

Correlation analysis: classical models – EXP.

Model	MSE	R^2
Linear	0.199	-3.508
Polynomial	1.039	-22.509
Ridge	0.188	-3.264
Lasso	0.112	-1.542
DT	0.134	-2.026

Experimental Group: important landmarks

Model	MSE	R^2
Linear	0.205	-2.582
Polynomial	0.456	-6.963
Ridge	0.184	-2.212
Lasso	0.069	-0.207
DT	0.235	-3.110

Experimental Group: un-important landmarks

Model	MSE	R^2
Linear	0.030	-0.779
Polynomial	0.170	-9.233
Ridge	0.028	-0.699
Lasso	0.018	-0.106
DT	0.029	-0.429

Experimental Group: edit distance

The classical regression model shows no relationship between dependent and independent variables during the experimental group test.

Correlation analysis: classical models – CON.

Model	MSE	R^2
Linear	0.019	-3.170
Polynomial	0.017	-2.582
Ridge	0.019	-3.003
Lasso	0.011	-1.262
DT	0.031	-5.671

Control Group: important landmarks

Model	MSE	R^2
Linear	0.040	-7.722
Polynomial	0.075	-15.491
Ridge	0.038	-7.296
Lasso	0.018	-2.999
DT	0.079	-16.429

Control Group: un-important landmarks

Model	MSE	R^2
Linear	0.001	-2.274
Polynomial	0.002	-5.187
Ridge	0.001	-2.207
Lasso	0.001	-1.050
DT	0.001	-2.738

Control Group: edit distance

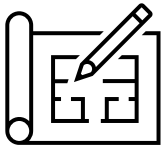
The classical regression model shows no relationship between dependent and independent variables during the control group test.

Correlation analysis: Spearman correlation

Group & Dependent Variable	Scene familiarity	SOD	MR familiarity
Experimental & Important	0.240	0.213	0.384
Experimental & Un-important	0.895	0.767	0.936
Experimental & Edit distance	0.486	0.248	0.830
Experimental & Edit distance	0.146	0.491	0.715
Control & Un-important	0.362	0.810	0.422
Control & Edit distance	0.935	0.262	0.411

Spearman correlation p-values: as all the p-values > 0.05, therefore, it is not considered that there is a relatively significant monotonic correlation between independent variables and dependent variables.

Discussion to the result



Design a kind of chunking method: classification and hierarchy visualization.

Use virtual guidance to help learning:

- The performance of Experiment group is better than Control group in many aspects.

- Why better?
  - NASA Task Load Index
    - Control group with lower pressure: feel confusion and no motivation to remember things.
    - Experiment group with higher pressure: get touch with organized information, with a motivation to remember things.
- Blockwise analysis: No great difference in edit distance, low score in Block 2.
- Small and un-important items: Experiment group is better than control group, however, the memory for un-important items still needs to be improved.
- Correlation analysis: Our system suits users from different backgrounds.

Scene transferability

- Museum of Art and History
  - What → guide visitors through exhibitions
  - How → using virtual landmarks and color coding to categorize art and historical periods
- Conference Center
  - What → locate meetings or meeting rooms
  - How → with virtual signposts and color-coded schedules
- Library
  - What → find books and study areas
  - How → using virtual landmarks and interactive sub-maps
- Shopping Mall…
- University Campus…

Limitations

1.Limited participant pool: Future research should involve a more diverse set of participants.

2.Narrow experimental environment: diverse architectural contexts are needed.

3.Color design challenges: take care of actual visualization effect in the device.

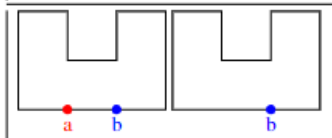
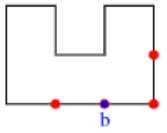
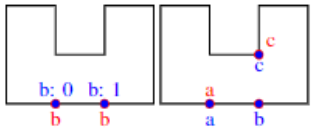
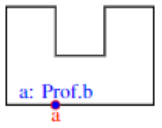
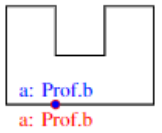
4.Questionnaire refinement: improving the questionnaire design by incorporating a broader range of assessment methods.

5.Memory retention for inconspicuous landmarks.

Thanks for your participation and listening!

Feel free to raise any questions!

Appendix: Quantify sketch map

Situation	Score
	0: Completely erroneous labeling or omission of labeling will both be recorded as a score of zero.
	0: Users may randomly label numerous unnamed landmarks in a certain area based on their impression that it contains numerous elements. However, if they cannot accurately indicate the corresponding landmark locations and content, nor provide meaningful spatial reference information, their score is also considered as zero in such cases.
	1: Users fall into two categories: In the first scenario, a user can label a landmark but cannot recall its specific content; however, they are aware of the category to which the landmark belongs, which warrants a score of 1. Alternatively, users who cannot recall the specific content or category of a landmark, yet provide sufficiently accurate surrounding annotations, demonstrating their comprehension of the spatial distribution within that area, also receive a score of 1.
	2: Users are capable of accurately placing marks and providing corresponding labels, although lacking in providing more detailed information. Such annotations can demonstrate the users' remembrance of the marked object and its relative spatial location, serving as global anchors for evaluating the spatial and semantic accuracy of other landmarks with less informational content.
	3: Users not only demonstrate accurate recall of the respective landmark's location but also provide detailed information, thereby ensuring semantic clarity as well.

Quantitative score assignment

		L	e	v	e	n	s	h	t	e	i	n
	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5	5.5
L	0.5	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5	5
e	1	0.5	0	0.5	1	1.5	2	2.5	3	3.5	4	4.5
v	1.5	1	0.5	0	0.5	1	1.5	2	2.5	3	3.5	4
e	2	1.5	1	0.5	0	0.5	1	1.5	2	2.5	3	3.5
n	2.5	2	1.5	1	0.5	0	0.5	1	1.5	2	2.5	3
s	3	2.5	2	1.5	1	0.5	0	0.5	1	1.5	2	2.5
h	3.5	3	2.5	2	1.5	1	0.5	0	0.5	1	1.5	2
t	4	3.5	3	2.5	2	1.5	1	0.5	0	0.5	1	1.5
e	4.5	4	3.5	3	2.5	2	1.5	1	0.5	0	0.5	1
i	5	4.5	4	3.5	3	2.5	2	1.5	1	0.5	0	0.5
n	5.5	5	4.5	4	3.5	3	2.5	2	1.5	1	0.5	0

Edit distance

Appendix: Difference Testing