



ICC 2019 in Tokyo

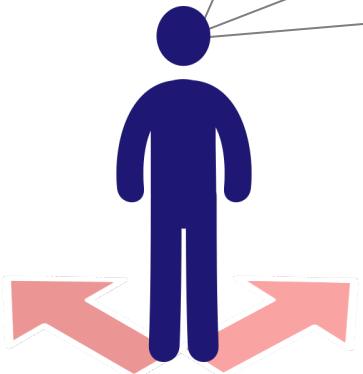
# Understanding the Process of Geospatial Reasoning: Evidences from an Eye-tracking Experiment



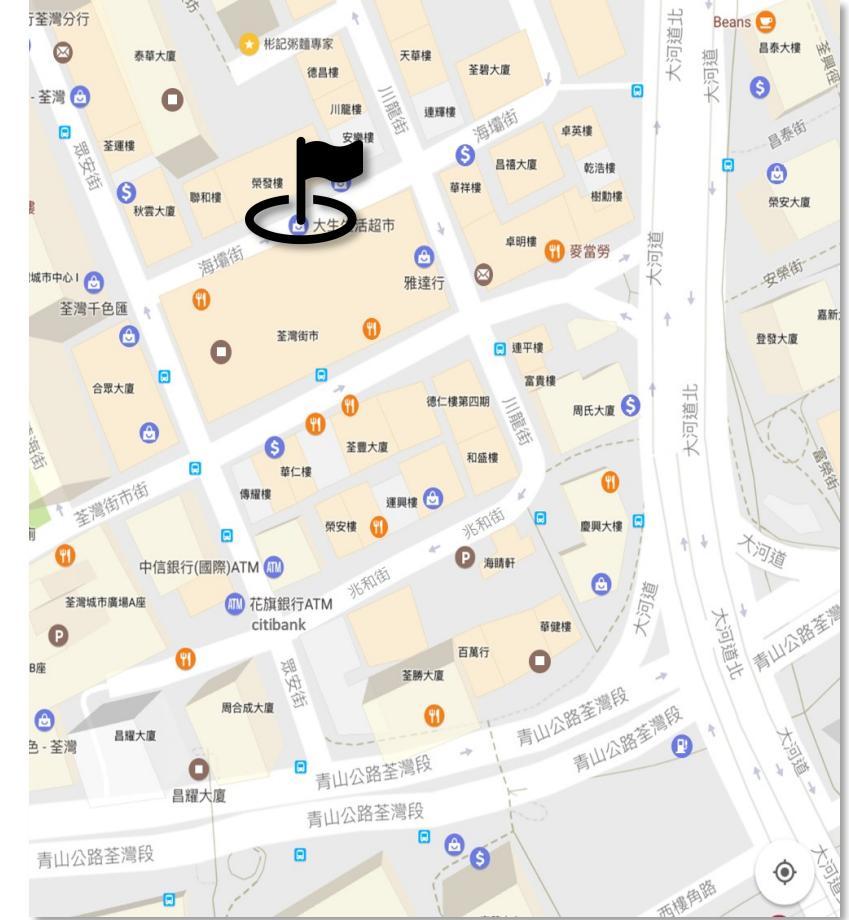
國立台灣大學 地理環境資源學系  
地理計算科學研究室  
Laboratory for Geospatial Computational Science  
**NTU Geography**

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Department of Geography, National Taiwan University

# Imagine a scenario...



- Where am I?
- Which direction am I facing?
- Should I walk forward or turn around?





# Imagine a scenario...

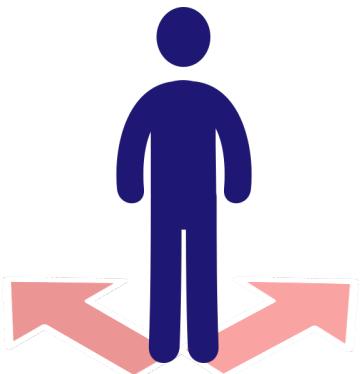


+



Environment

Map

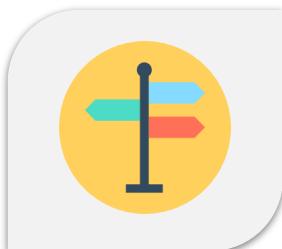


In this scenario,  
We are trying to integrate **the map** and **the environment**  
to build our sense of direction.



# Map alignment

People maintain the perspective adopted during first learning... (*Levine et al 1982*)



- When we are reading the map in our hand,  
**we need to match the map with the environment.**



- Alignment effects are **the extra time and effort** required to  
**rotate** the mental representation of physical maps.

(*Shephard & Metzler 1971; Shephard & Hurvitz 1984; Finke 1990; Golledge 1999*)



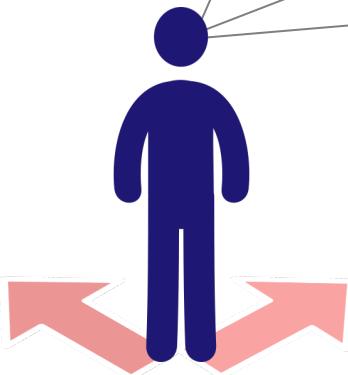
## Relationship between alignment effect and mental rotation

- People with higher **mental rotation ability** are more likely to get free from alignment effect (Pazzaglia & De Beni 2004)
- Mental rotation also affects a person's cognitive styles (Pazzaglia & De Beni 2001)

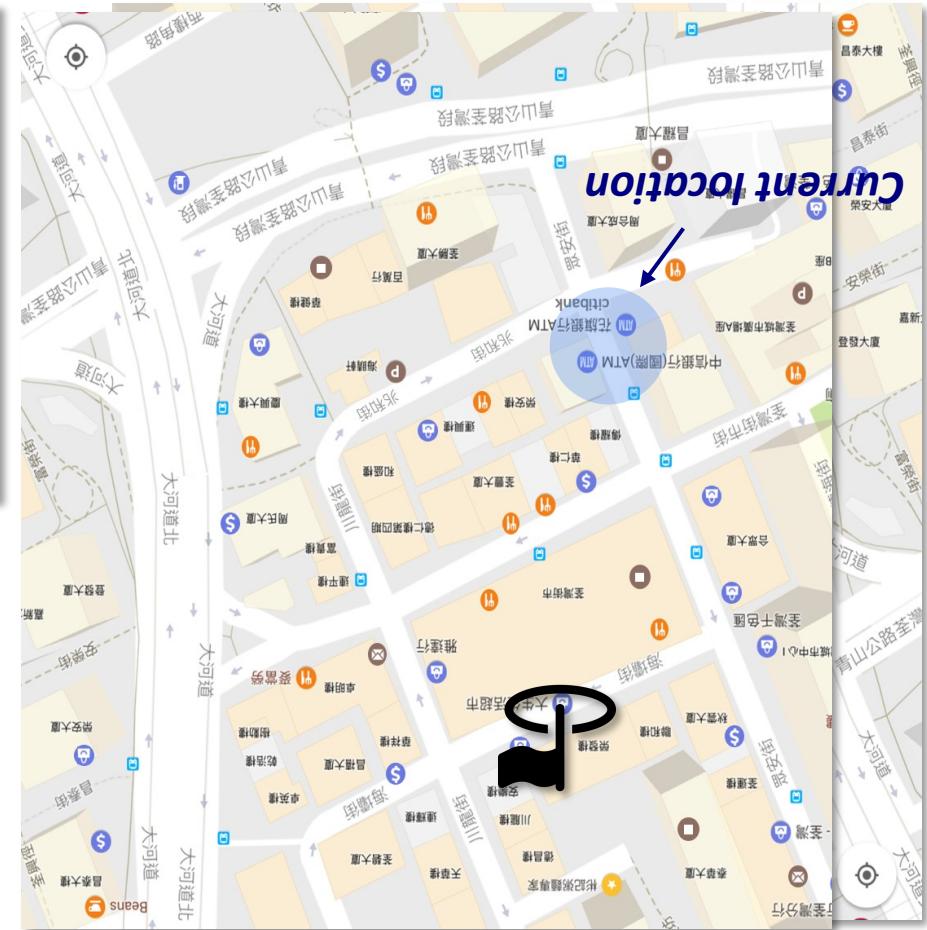
**Alignment effect is strongly related to mental rotation ability.**

- High mental rotation ability → Map aligning performance 
- Low mental rotation ability → Map aligning performance 

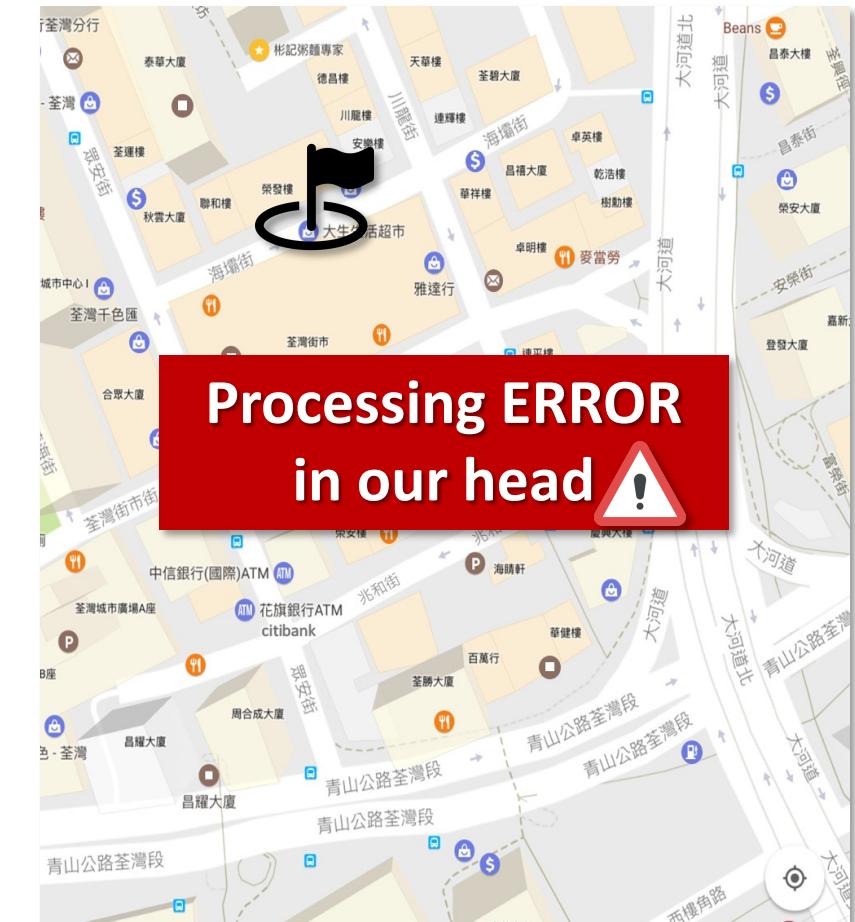
# Let's go back to the scenario, Align the map to the environment



- Where am I?
- Which direction am I facing?
- Should I walk forward or turn around?



# Let's go back to the scenario, Align the map to the environment

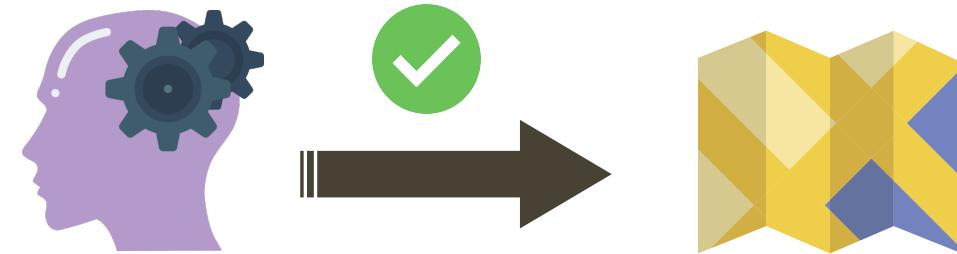




# What affect our mental rotation ability?

## Factors of mental rotation:

- *Biological factors, human evolutions* (Buss 1999; Geary 1998)
- *Spatial tasks* (Cherney & Neff 2004)
- *Spatial sport activities* (Ginn and Pickens 2005)
- *Educational experiences* (Burnett & Lane 1980; Casey, Colon & Goris 1992; Quaiser-Pohl & Lehmann 2002)
- *Social gender roles* (Eagly & Wood 2002; Lippa et al. 2010)
- *Travel experiences* (Mondschein et al. 2010)



**Mental rotation**

**Map alignment**

- *The relationship* (Pazzaglia & De Beni 2004)
- *Factors of mental rotation*



However, if we want to improve the rotation and map aligning skills,

**Not only about knowing what causes the alignment effect,  
But also how we process spatial information when we are  
reading maps and rotating different spaces.**



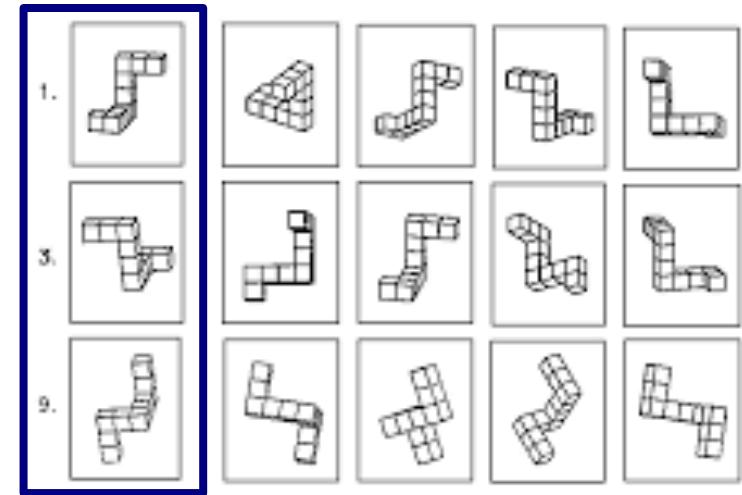
# How to quantify mental rotation ability?

- Mental rotation test (*Shepard and Metzler 1971*)

**Psychological field for understanding:**

- Human cognition (*Just, M. A., & Carpenter, P. A. 1985*)
- Internal representation (*Cooper, L. A. 1976*)
- Imagery processing (*Marmor, G. S., & Zaback, L. A. 1976*)  
etc...

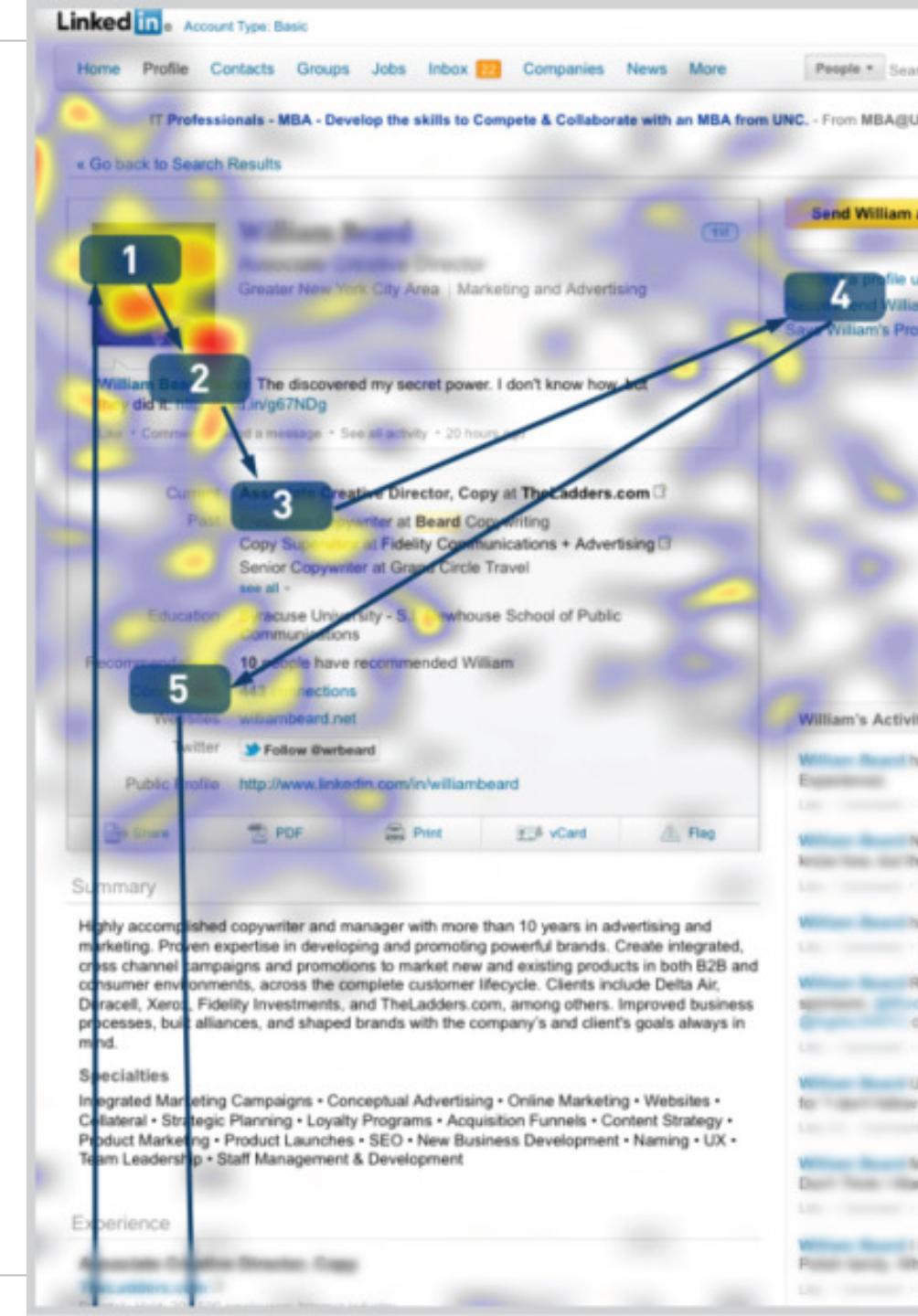
**Test score → Mental rotation ability**



However,  
we only know the **performance**, but the **reasoning process** is unclear.

# Eye tracking technique

- Visualize **where** people see
- Understand **how** people read things
- Provide insights into people's **ways of reasoning** and **problem solving**
- Applications:
  - Human-computer interactions, e.g. web-pages, mobile phones, computer video games, and etc.





# RESEARCH OBJECTIVES

From an **eye tracking approach**,  
explore the process of **spatial reasoning** and **building senses**  
**of direction** from map aligning tasks.

# METHODOLOGY

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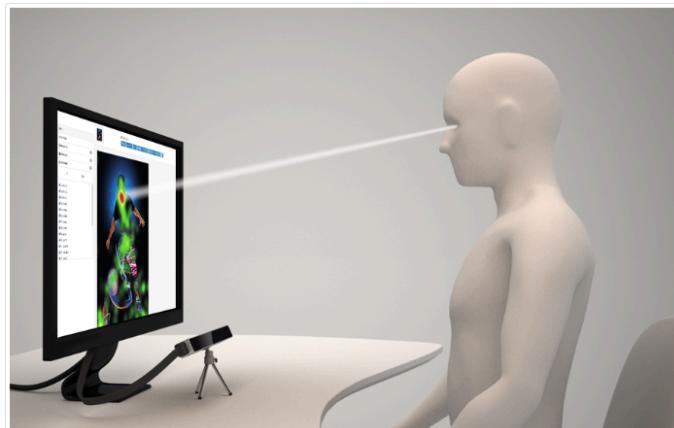


## METHOD

# An eye tracking approach to understand geospatial reasoning

- The process of recording and measuring gaze positions of eye movements

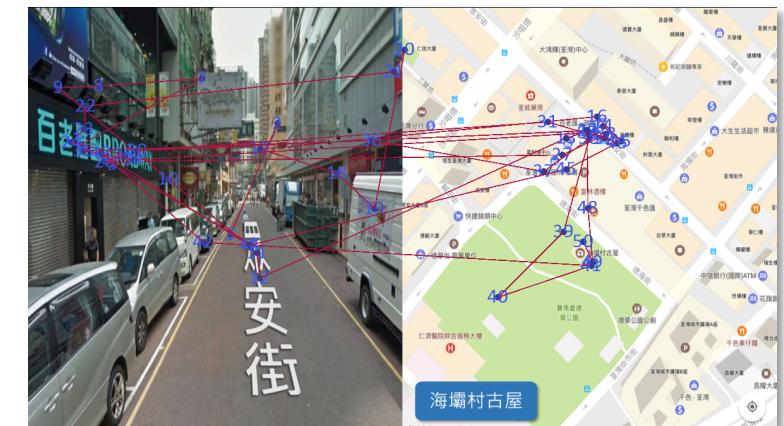
## An Eye tracker



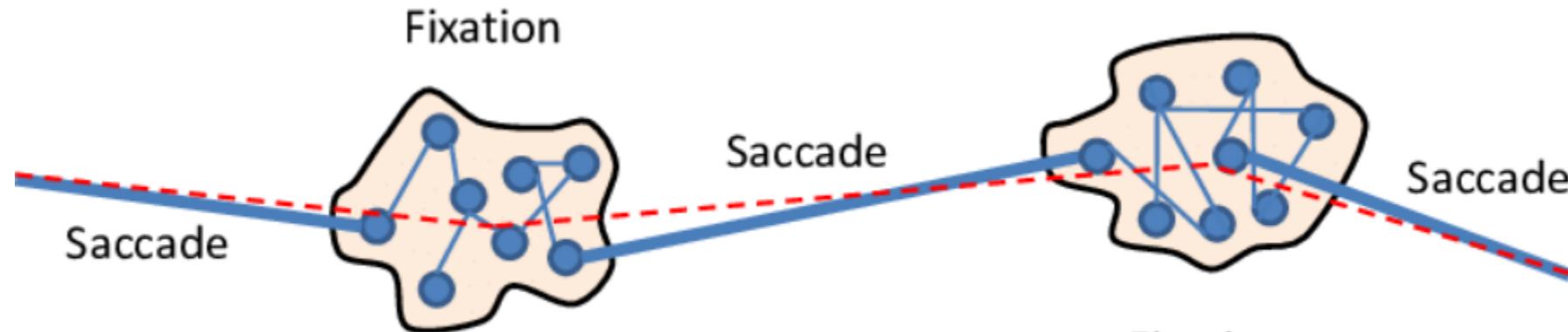
## Map aligning tasks



## Recordings of eye movement



# Elements of eye tracking

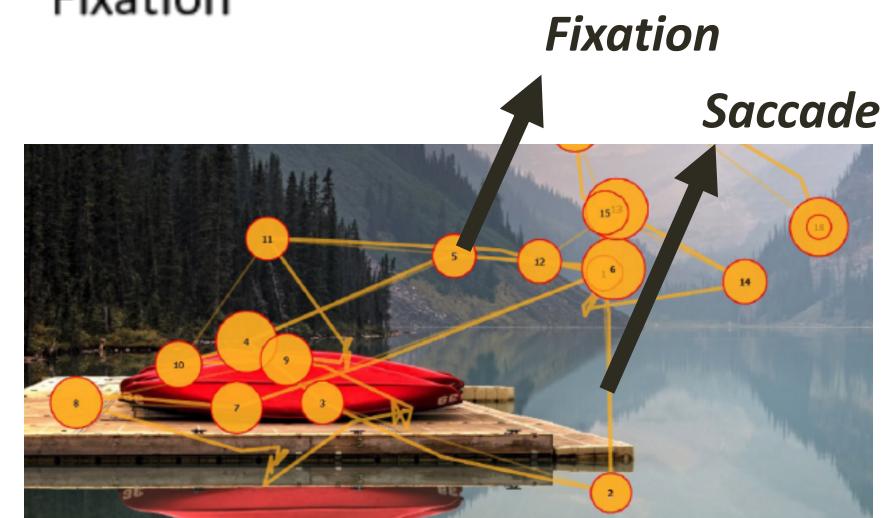


## Fixation

- The pause of the eye movement on a specific area of the visual field
- Optical gazes that are close in time and space

## Saccades

- The rapid movement from one fixation to another





# Elements of eye tracking

## Area of interest (AOI)

- Regions of a display that researchers define and classify by shape.
- Quantify fixations and saccades in and between the AOI regions.





# **METHOD** Developing an eye tracking experiment...

## Experiment description

## Map aligning task

- Apparatus: The Eye Tribe (eye tracker)
- Software: Ogama for designing experiments and recording eye movements
- Time: Feb. 21 – Mar. 3, 2017 (about 2 weeks)
- Participants
  - 12 subjects: 6 males and 6 females
  - Age: 18 – 30
  - Students from National Taiwan University



# METHOD Developing an eye tracking experiment...

Experiment description

Map aligning task

In **each** task,

Be informed of their current location and destination by words...

① Task:

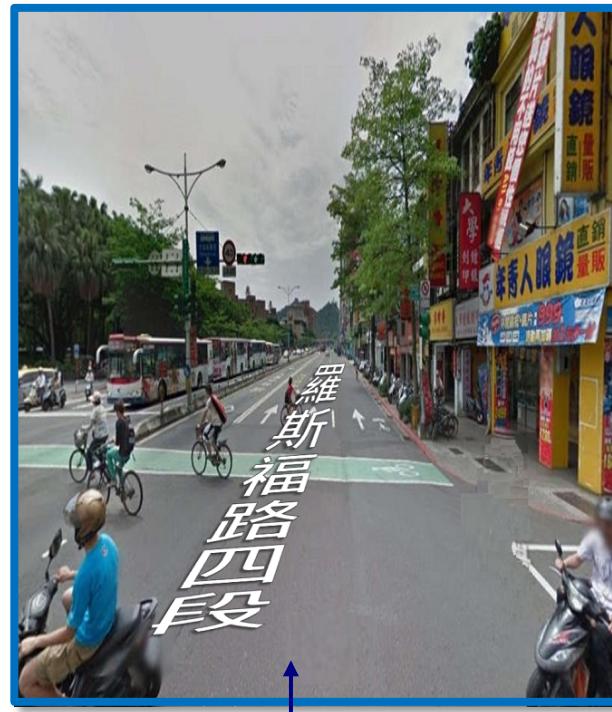
- Figure out the direction of destination by aligning the map to the environment

② Time limit:

- 15 seconds at most

③ Answer:

- The direction of the destination from current location and facing



*Current facing*

*Destination*



*黃蜂體育用品*

*Current location*

\* Current location and destination are NOT on the map in the experiment.



# METHOD Developing an eye tracking experiment...

Experiment description

Map aligning task

*6 tasks in total.*

- Task 1, Task 2 and Task 3: Degree of rotation



0° rotation Easy



< 45° rotation Medium



> 45° rotation Hard

Easy task  
to  
Hard task

- Task 4, Task 5 and Task 6: Quantity of key element



2 elements



3 elements

More landmarks



4 elements

More landmarks and street names

Landmark  
or  
Street names



# Grouping the subjects based on their map aligning scores...

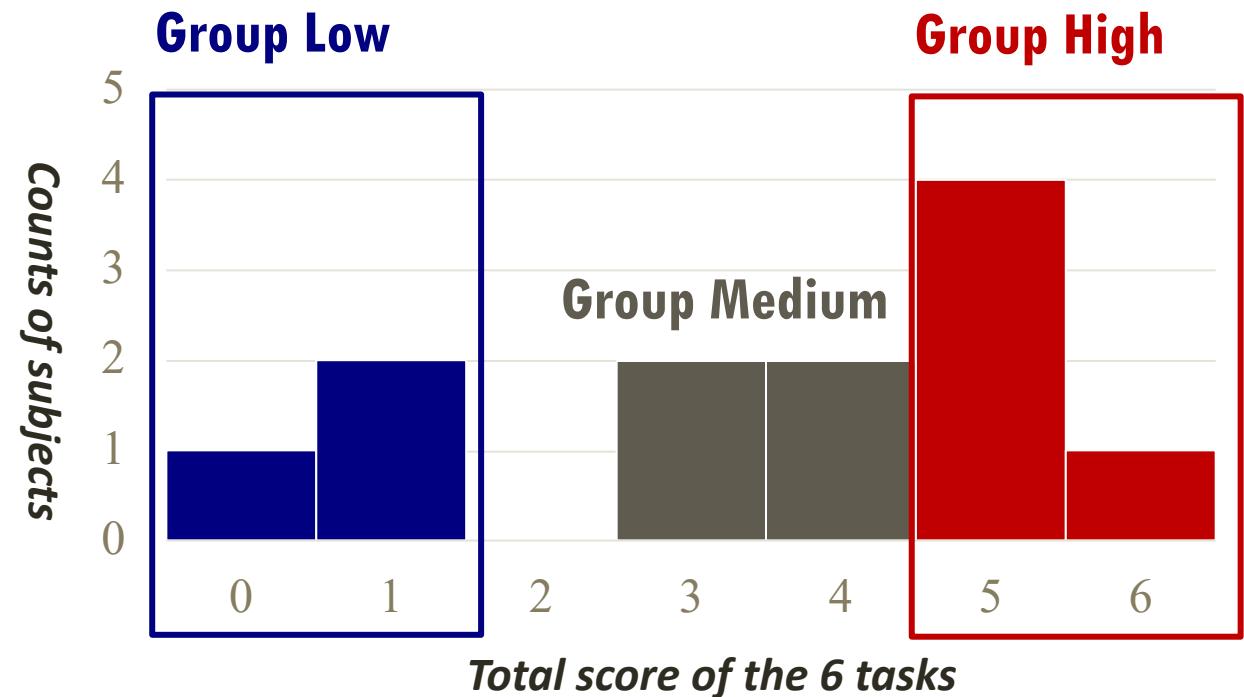
In **each** task,

- If correct → **1** point
- If incorrect → **0** point



**6** tasks in total.

- Total score: **0 ~ 6** points



# RESULTS

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**Before the Results,  
Let's take a look at the subjects' eye movement!**



# Eye movement of map aligning: Case of a High score subject



# Eye movement of map aligning: Case of a Low score subject



*Analysis framework*

***“Explore the differences between  
Group High’s and Group Low’s spatial reasoning  
process.”***

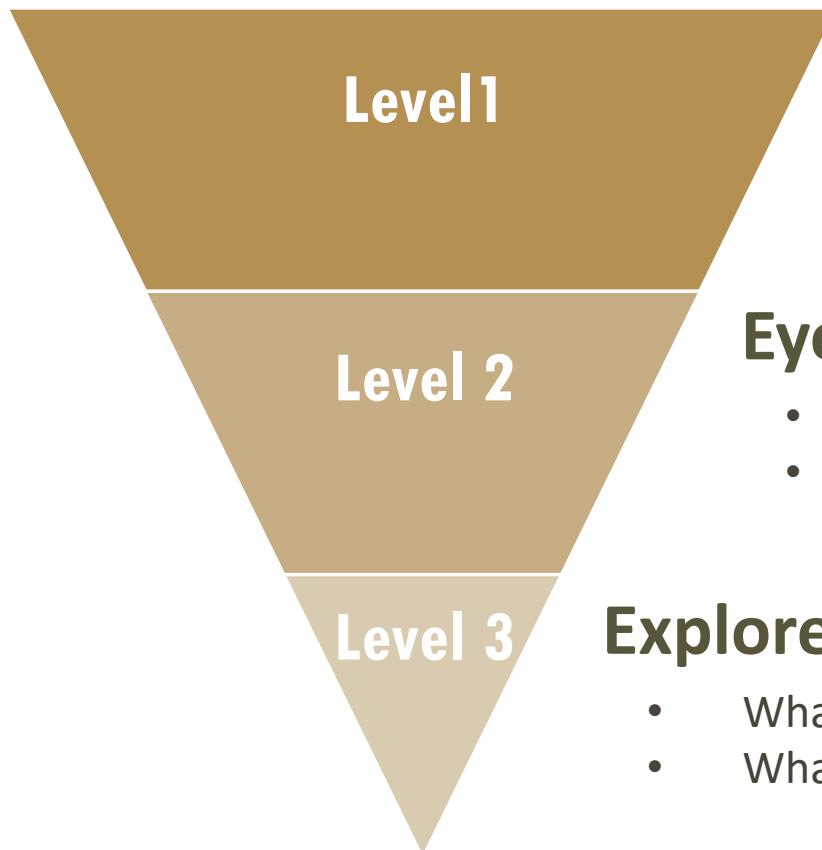
**From eye movement patterns, learn the experiences / rules from Group High,**

- Identify important map aligning strategies
- Establish guidelines to map design





# Explore spatial reasoning of **Group High** and **Group Low**



## Similarity of eye movement patterns

- Do the Group High have similar patterns of eye movement?

## Eye movement difference in space and time

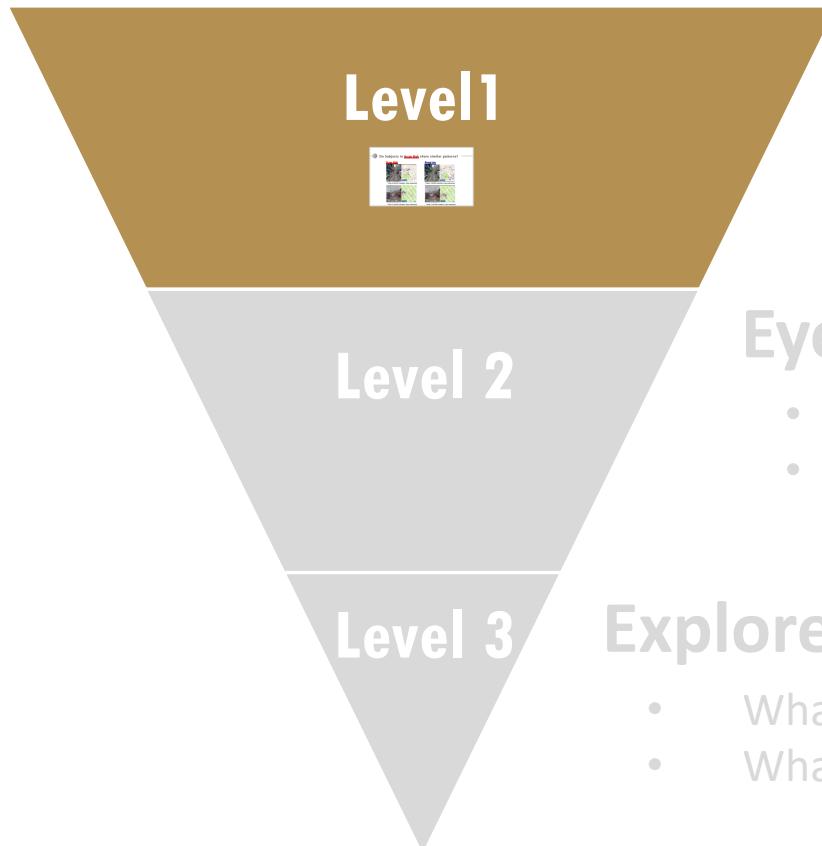
- Where do they look?
- How much time do they spent on specific elements?

## Explore in details: the matching strategies

- What do they look next?
- What is the key reading patterns to shape the sense of direction?



# Explore spatial reasoning of **Group High** and **Group Low**



## Similarity of eye movement patterns

- Do the two groups have similar patterns of eye movement?

## Eye movement difference in space and time

- Where do they look?
- How much time do they spent on reading key elements?

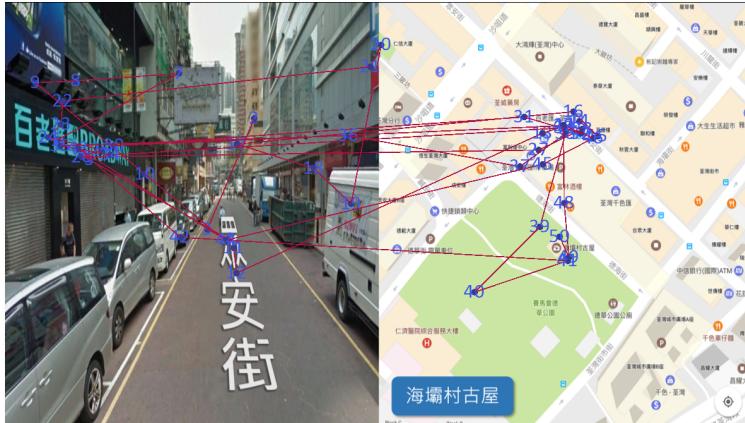
## Explore in details: the matching strategies

- What do they look next?
- What is the key reading sequence to shape the sense of direction?



# Do Subjects in Group High share similar patterns?

## Group High



\* Task 4. (45-90° rotation; 2 key elements).

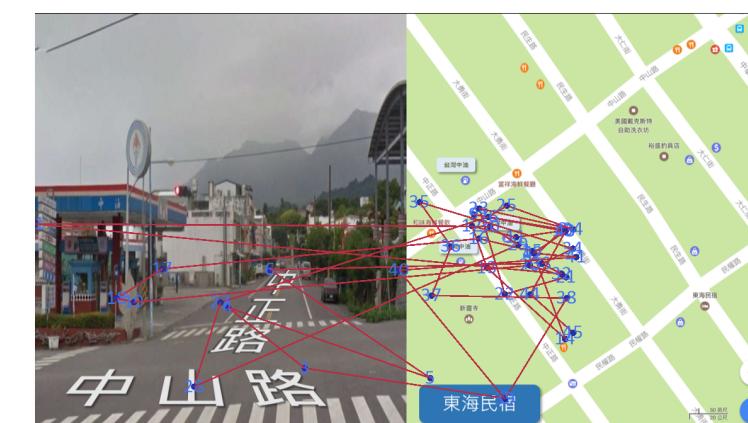


\* Task 3. (45-90° rotation; 3 key elements).

## Group Low

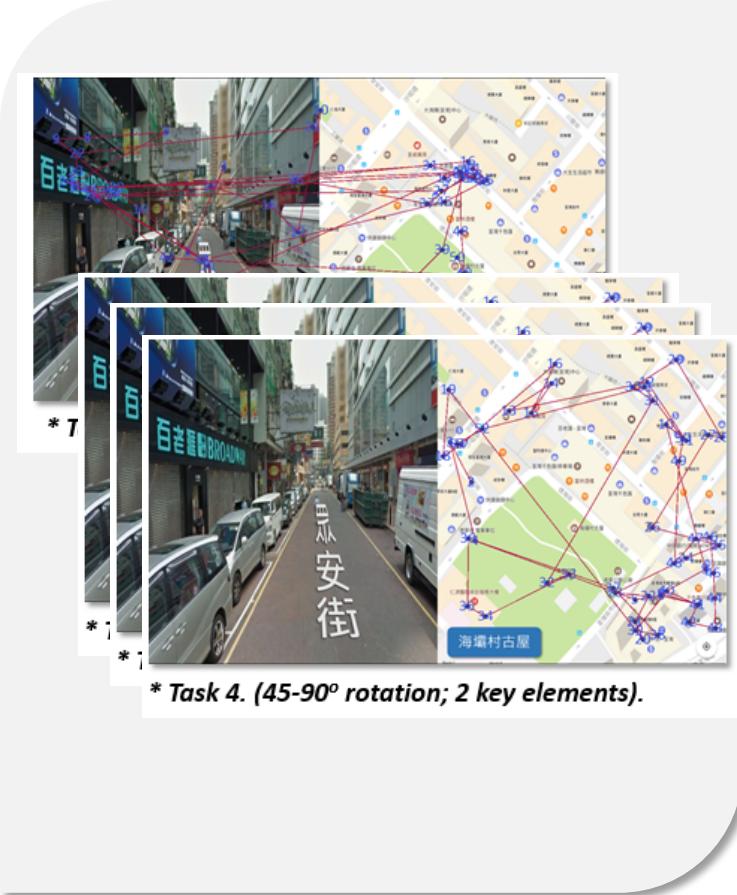


\* Task 4. (45-90° rotation; 2 key elements).



\* Task 3. (45-90° rotation; 3 key elements).

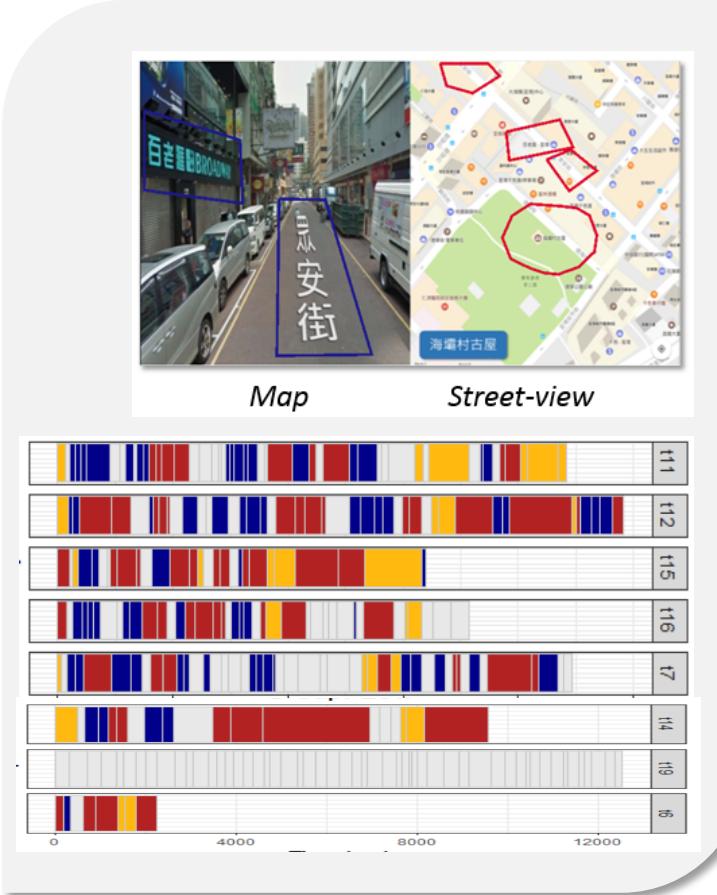
# “ How to explore the sequence similarity among groups? ”



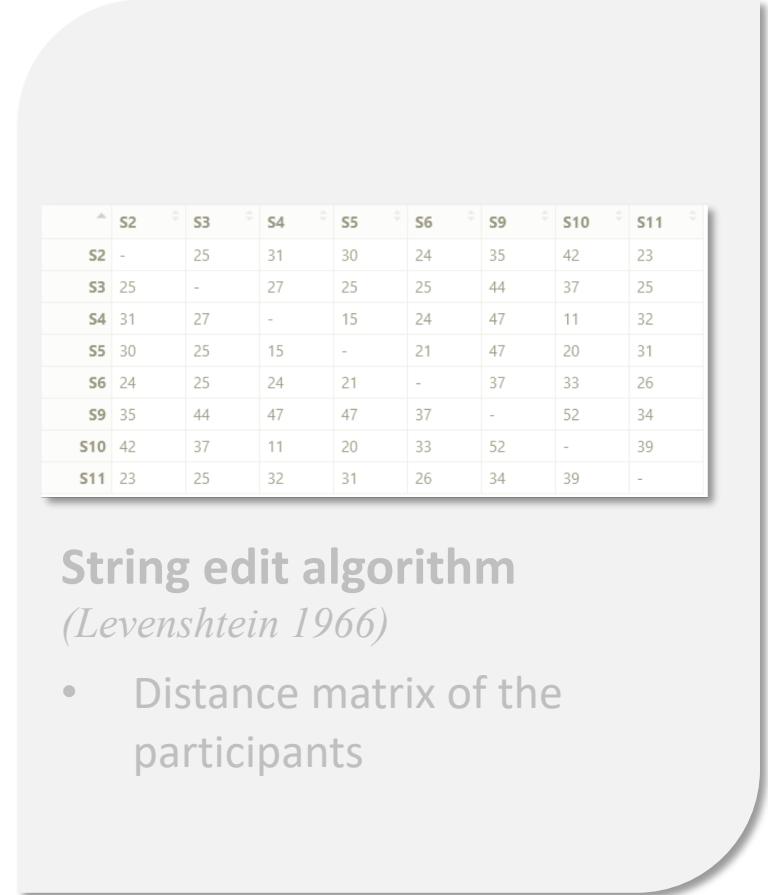
**Eye movement data**



**Sequence of AOIs**



**Sequence of AOIs**

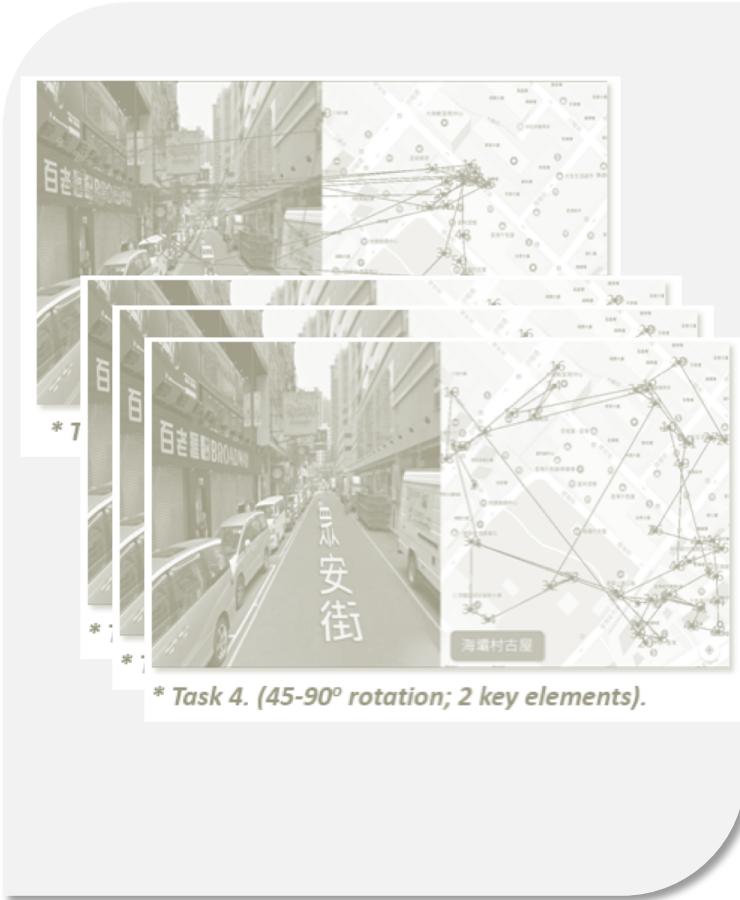


**String edit algorithm**  
(Levenshtein 1966)

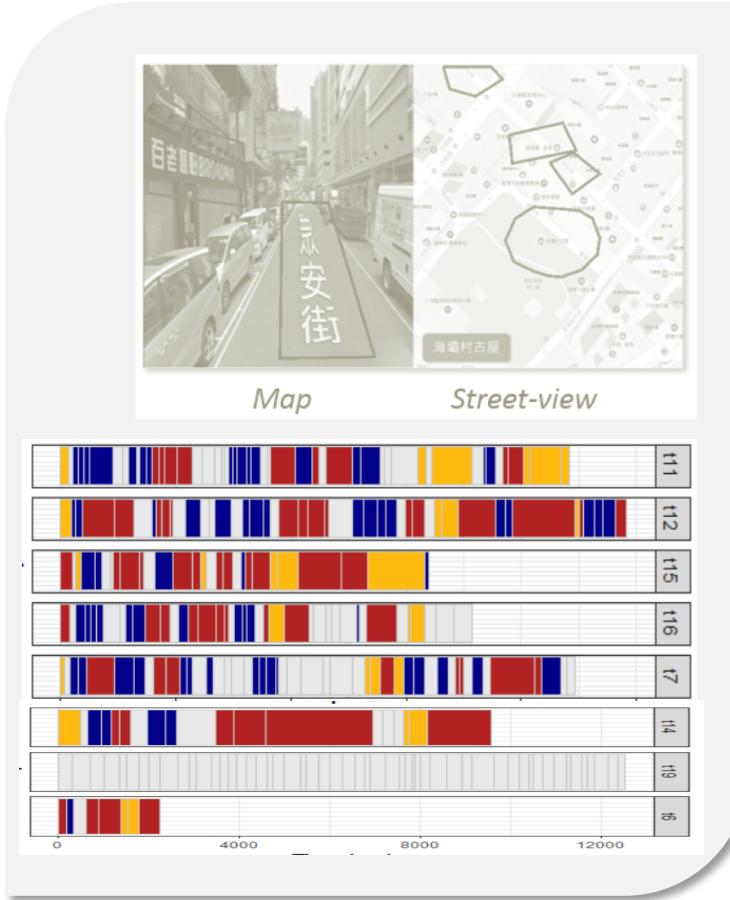
- Distance matrix of the participants

**Multidimensional scaling**  
**(MDS)** (Kruskal & Wish 1978)

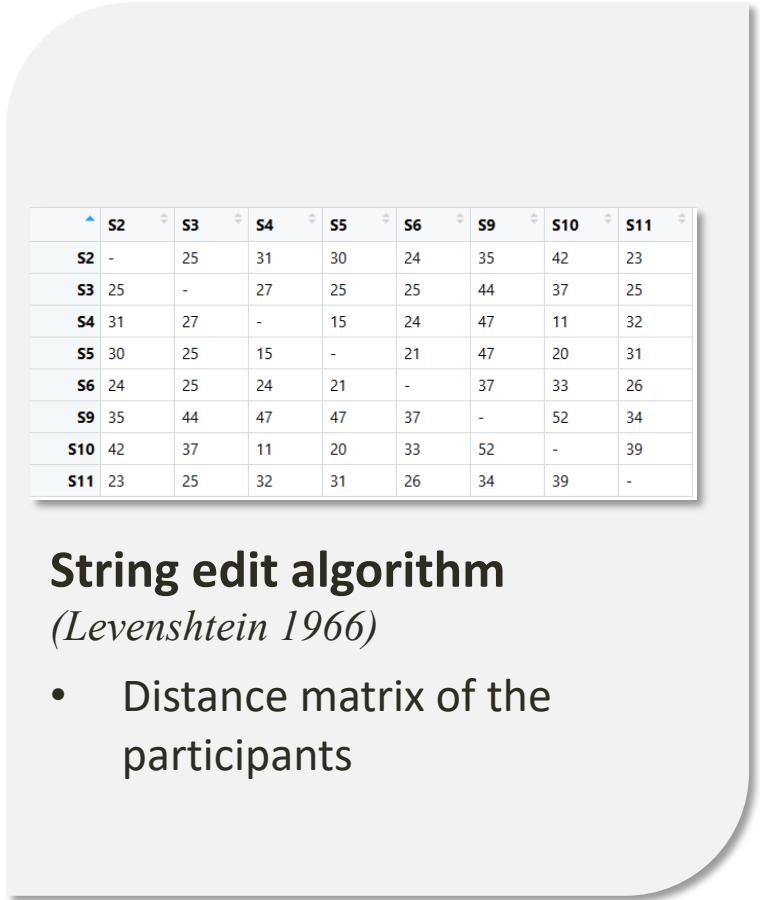
# “ How to explore the sequence similarity among groups? ”



Eye movement data



Sequence of AOIs



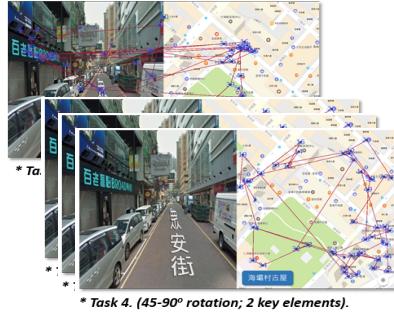
**String edit algorithm**

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- Distance matrix of the participants

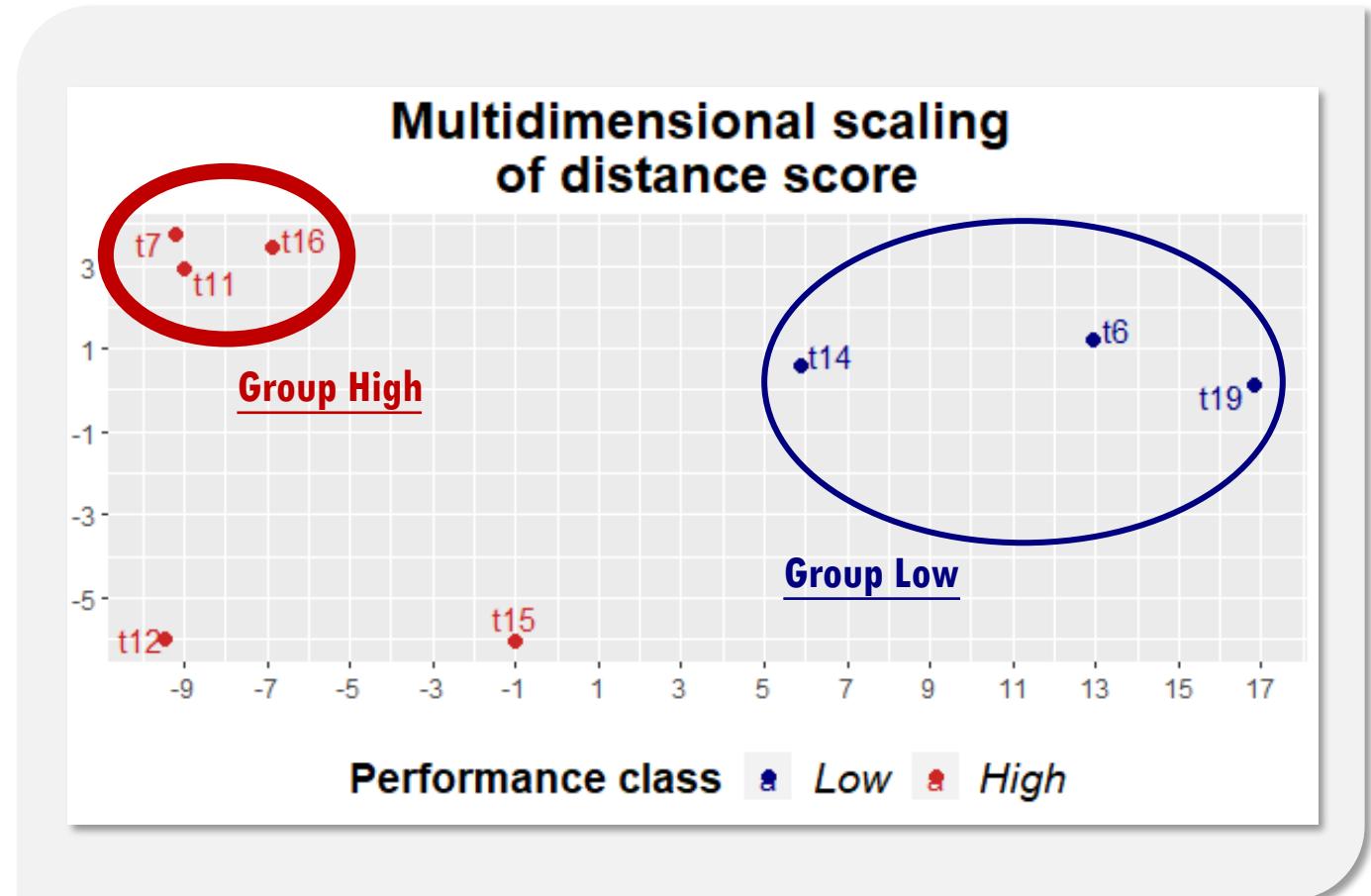
**Multidimensional scaling  
(MDS)** (Kruskal & Wish 1978)

# Sequence similarity between Group High and Group Low



Eye movement → Sequence of AOIs

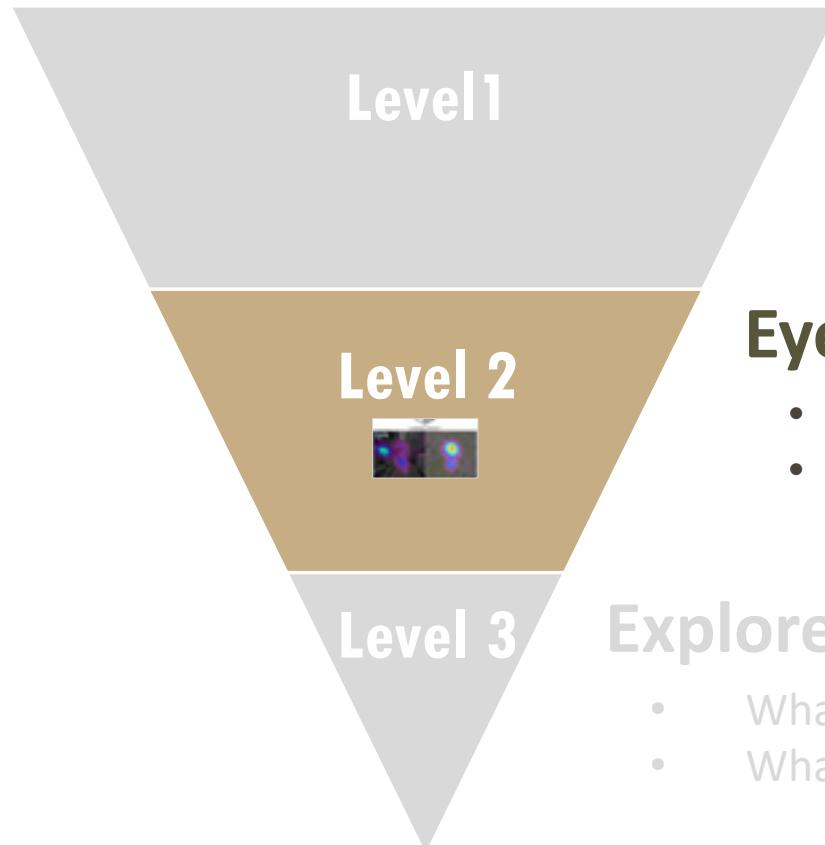
Aligning task 4. Collapsed sequence.  
Sequence by *street name AOI & landmark AOI*.



Multidimensional scaling (MDS)  
(Kruskal & Wish 1978)



# Explore spatial reasoning of **Group High** and **Group Low**



## Similarity of eye movement patterns

- Do the two groups have similar patterns of eye movement?

## Eye movement difference in space and time

- Where do they look?
- How much time do they spent on specific elements?

## Explore in details: the matching strategies

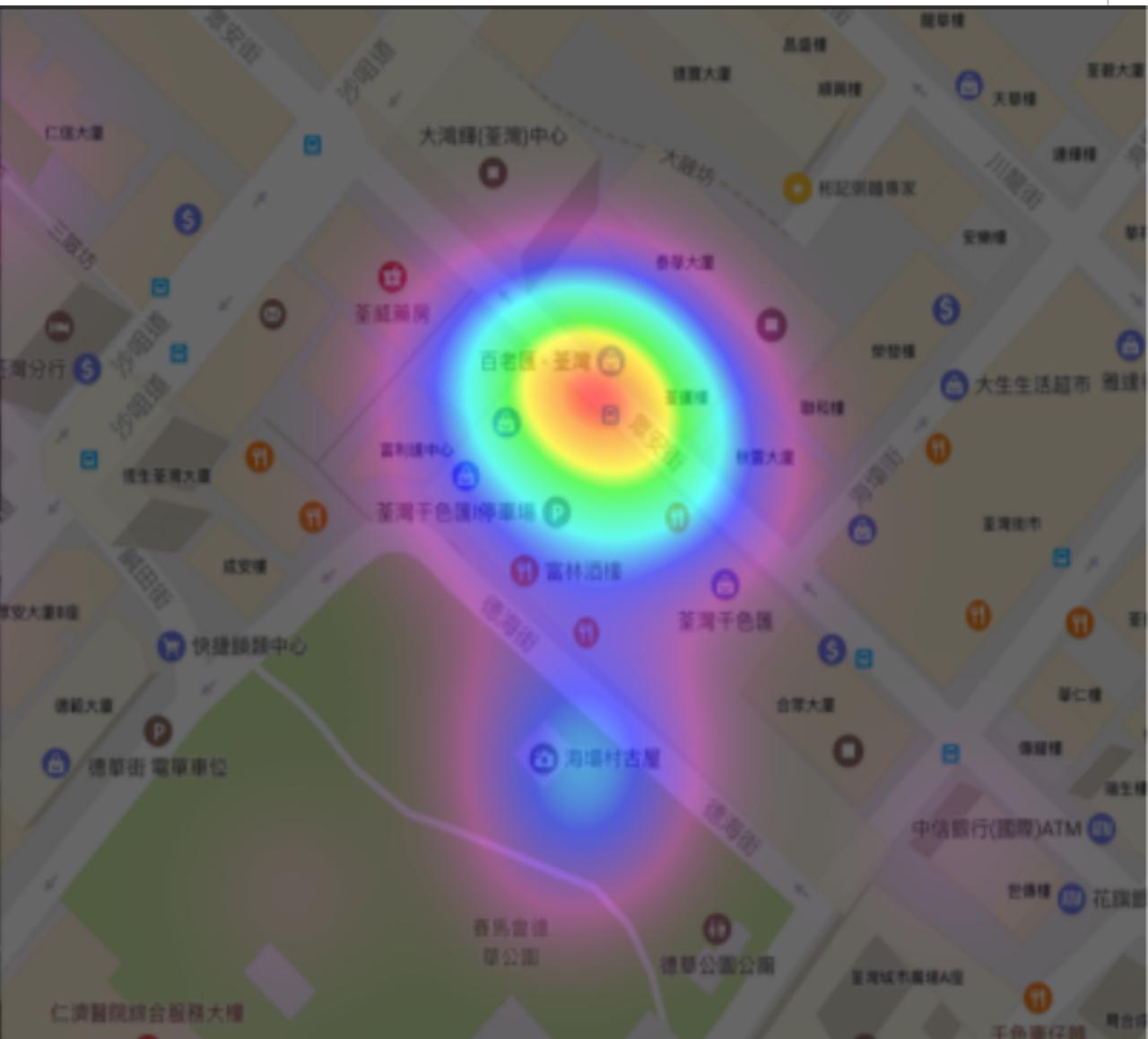
- What do they look next?
- What is the key reading sequence to shape the sense of direction?



# “ Looking where? ”

## Group High

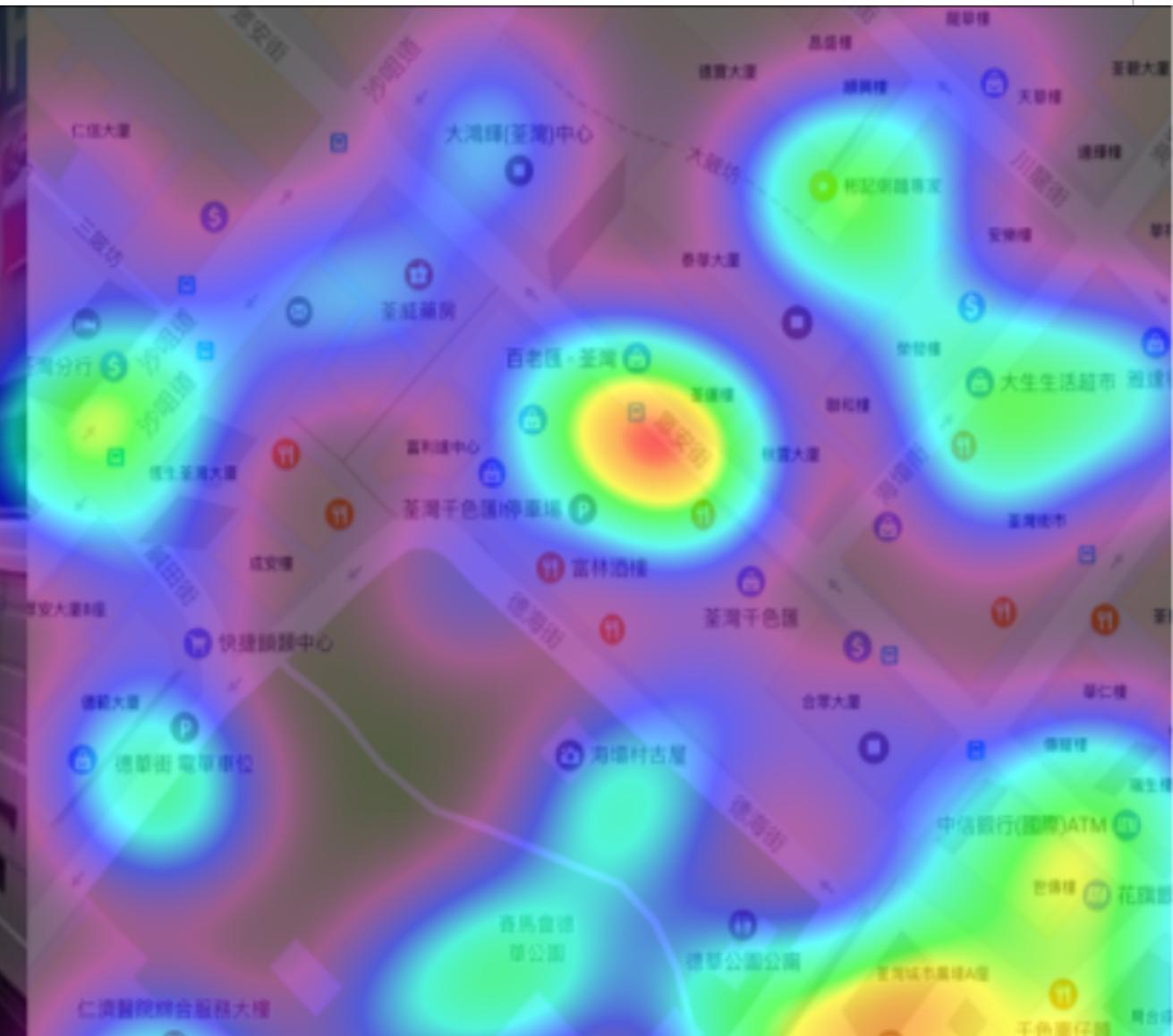
Task 4.



# “ Looking where? ”

**Group Low**

**Task 4.**

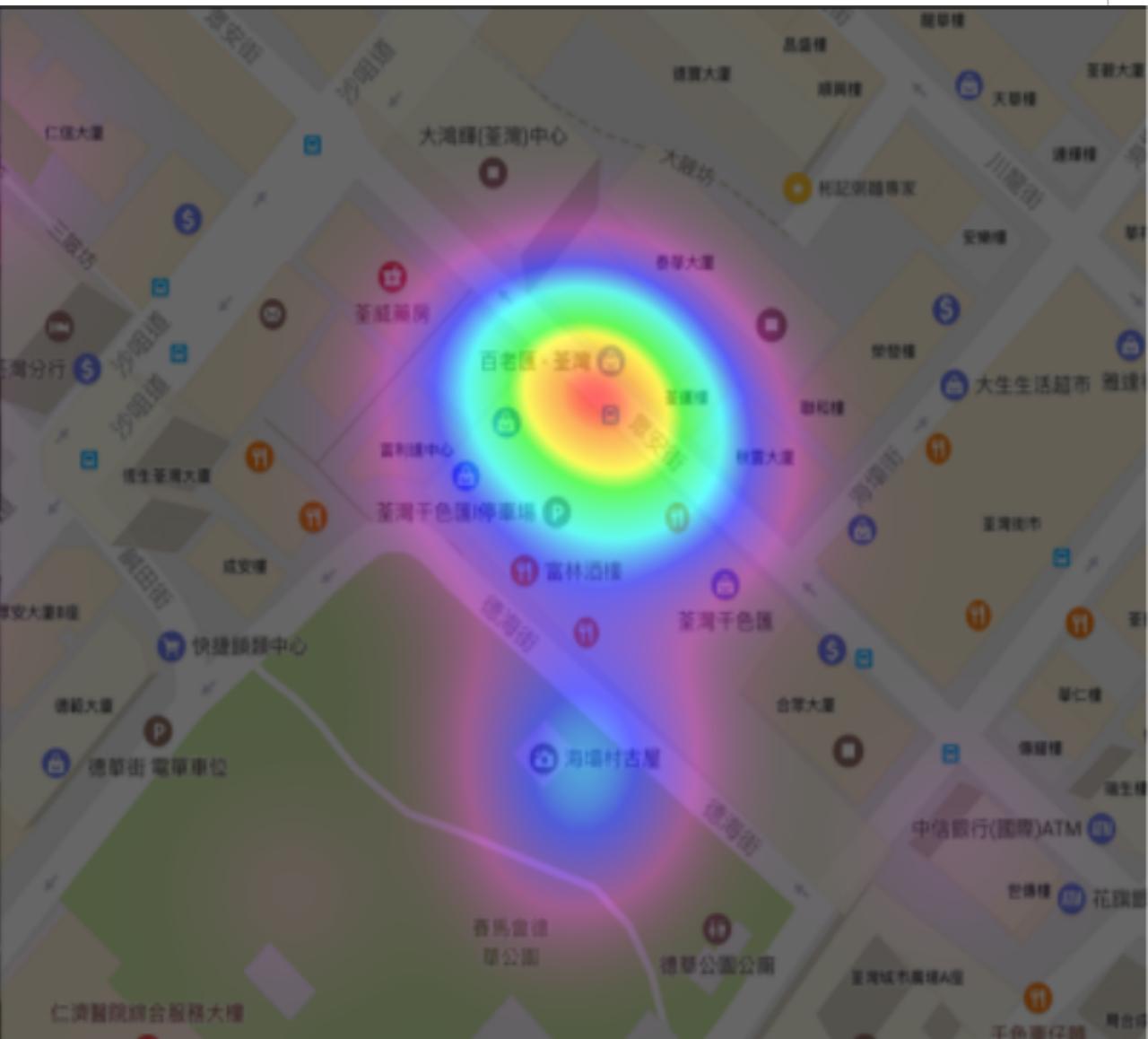




# “ Looking where? ”

## Group High

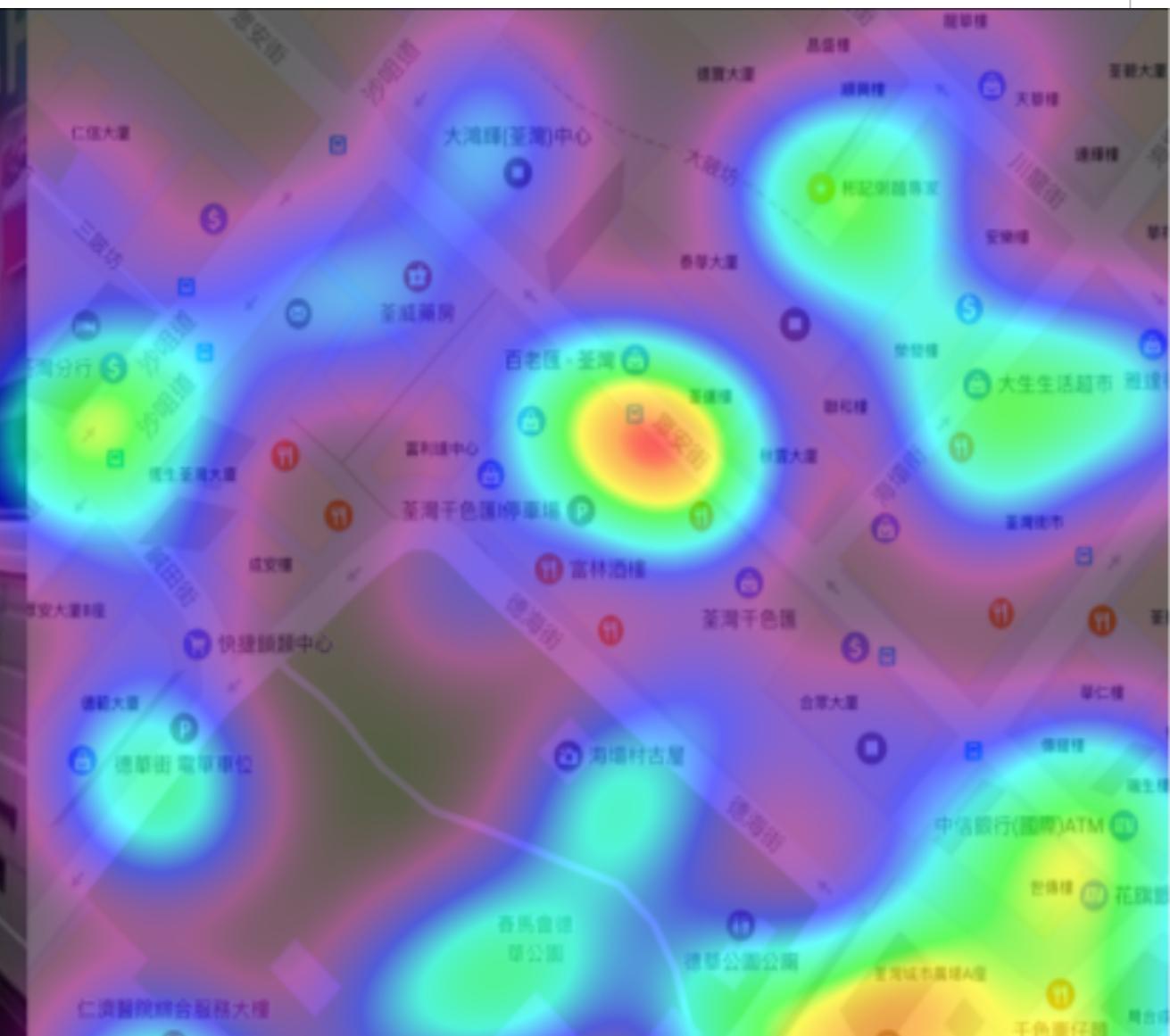
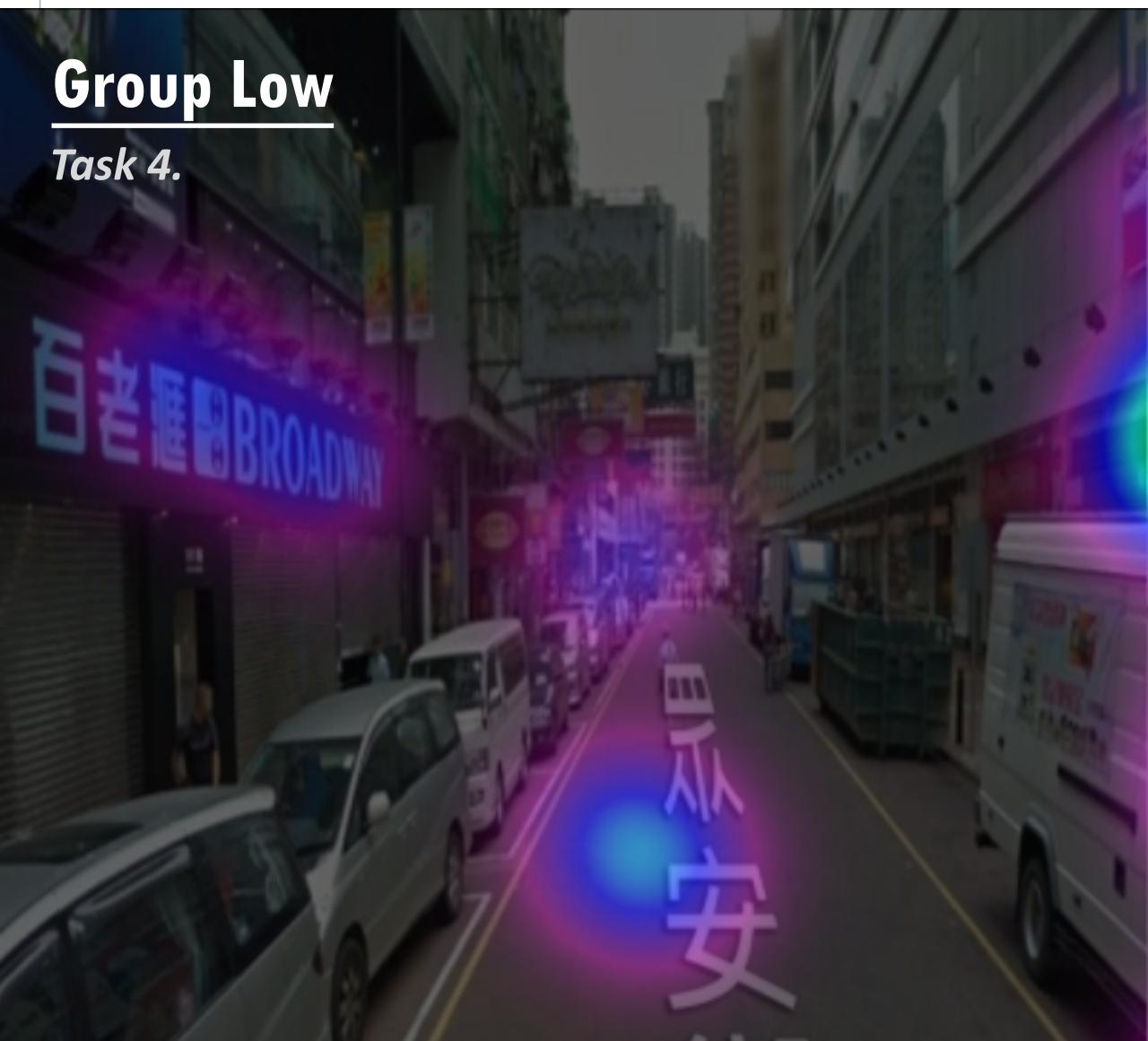
Task 4.



# “ Looking where? ”

Group Low

Task 4.



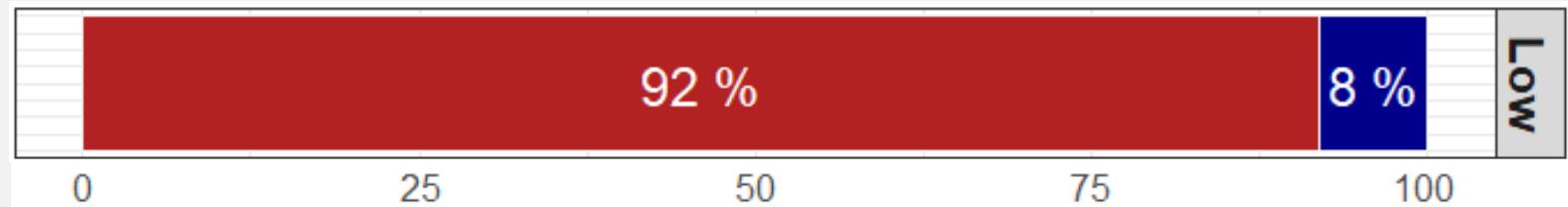


# Time investment between Group Low and Group High

*Percentage of time spent on :*  
**Map & Street-view**



## Group Low



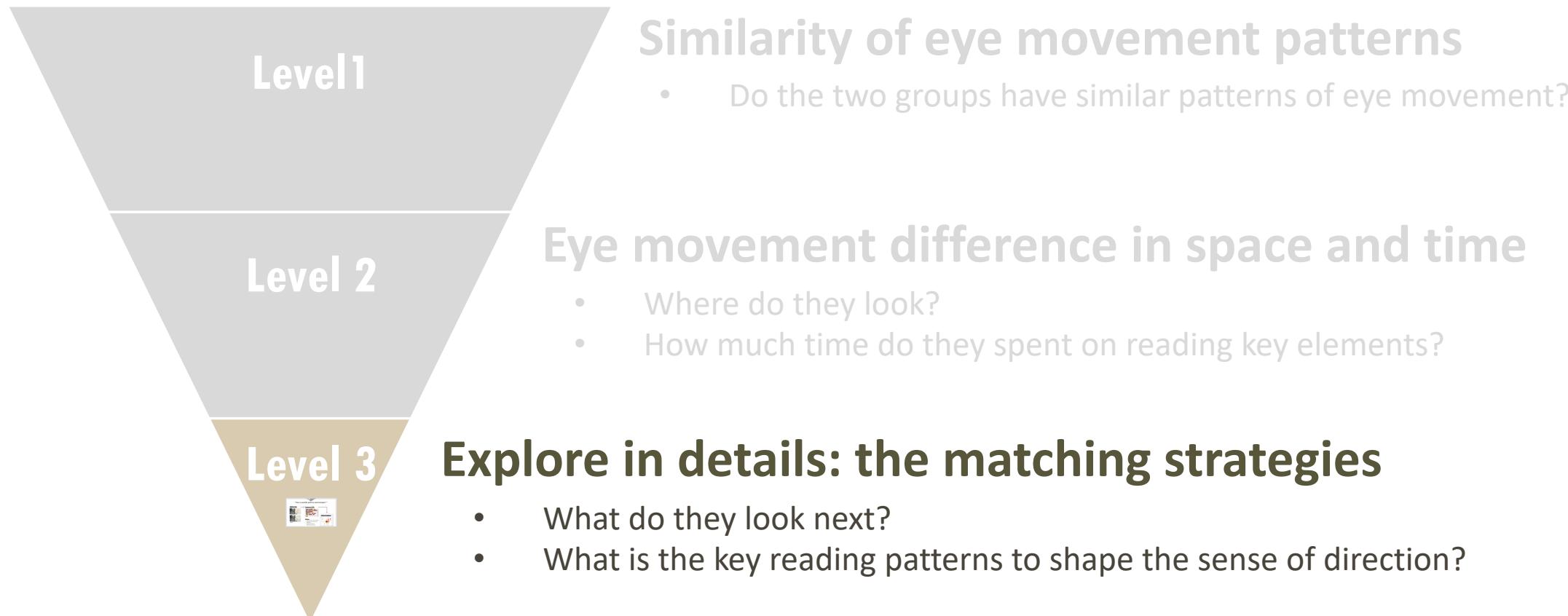
## Group High



map view



# Explore spatial reasoning of **Group High** and **Group Low**



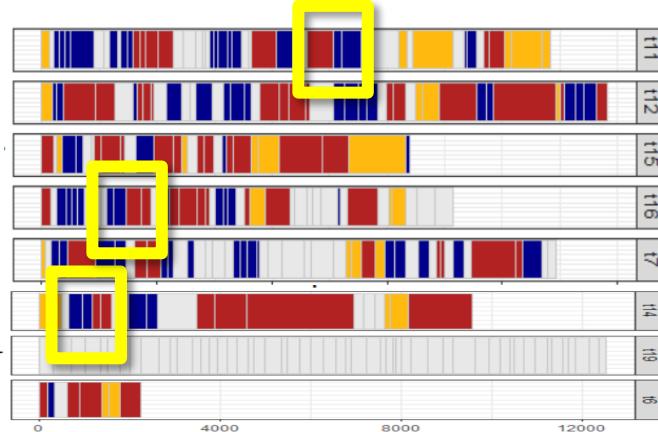
# “ How to quantify patterns and strategies? ”

## Aligning task



\* Task 4.

## Sequence of AOIs



### Patterns:

- Map and street view transitions
- Landmarks and street-name integration
- Matching landmarks
- Matching street-names

## Counts of patterns





# Map & Street-view transitions

1.

*Searching pattern:*

**Map AOIs**



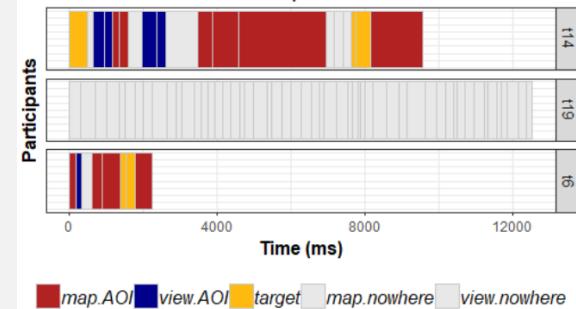
**Street-view AOIs**



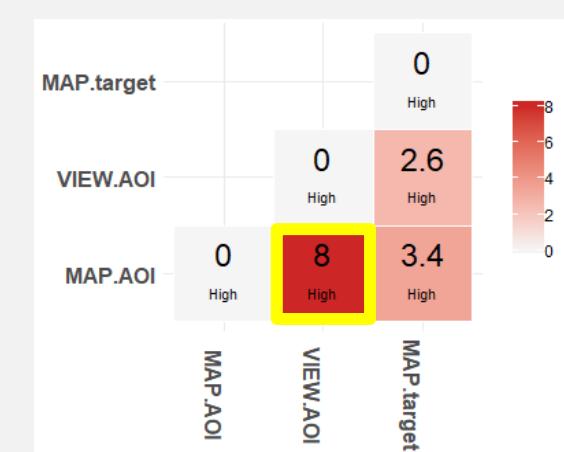
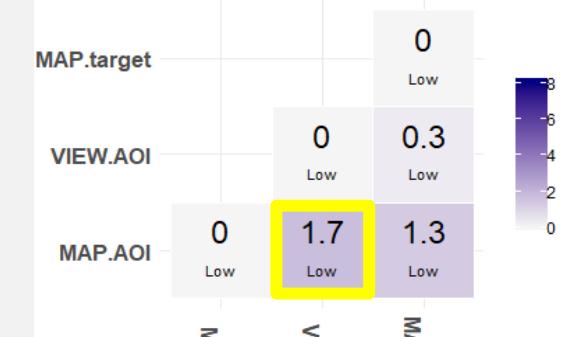
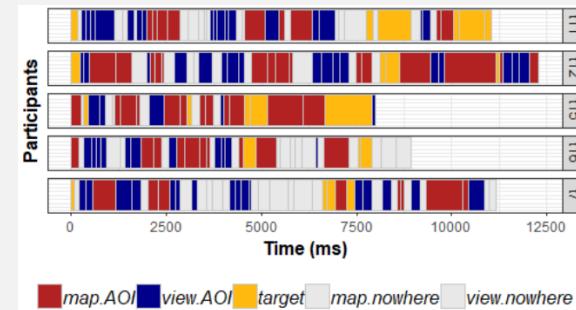
- More transition times between reading Map and Street-view.

→ **Imply the connection between two different coordinate systems**

## Group Low



## Group High





# Do you focus more on landmarks or street names?

2.

Matching **landmarks**:

Map  $\leftrightarrow$  Street view

Matching **street names**:

Map  $\leftrightarrow$  Street view

- Not much difference in matching **street names**.
- Significantly more times of **landmark-matching** in **Group High**.

→ Imply the importance of landmarks

## Group Low

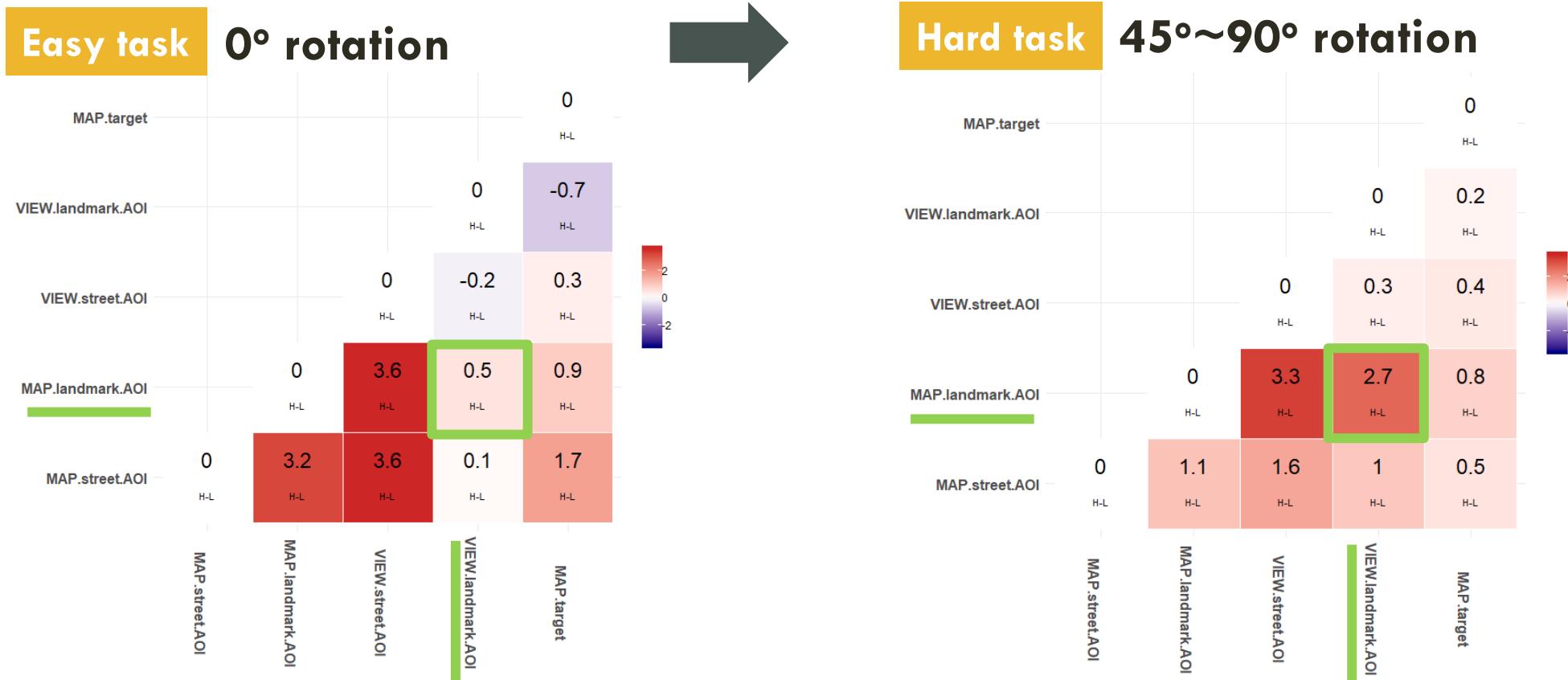


## Group High



# Measuring difference between Group High and Group Low in easy task and hard task

3.  $\Delta HL = \text{Pattern counts of } \underline{\text{Group High}} - \text{Pattern counts of } \underline{\text{Group Low}}$



- Matching landmarks between the map and street-view



# What we've learned...

- **Group High** shares similar patterns of map aligning process:  
→ Common rules of geospatial reasoning
- **Landmarks** could be better clues than street names for map alignment and building a sense of direction.
- **Group Low** spent more time to search map information in difficult tasks.  
→ It implies that better map design (e.g. **more landmarks**) may be the key to reading maps and can improve the reasoning of geospace.

Your eyes never lie!



# Thank you for listening 😊

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