地下鉄駅における誘導サイン認知と経路探索行動に関する VR 実験

A VR experiment on Guide Sign Recognition and Wayfinding Behavior in Subway Station

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1. Introduction

In urban space represented by subway stations, people are often easily lost because of the increasingly complex lines and spaces. Because the guide sign provides the direction of the destination, the layout of guide sign determines the wayfinding behaviour of pedestrians in the subway station.

There has been a lot of research on sign recognition. Ohno's group has studied the sign detectability in the subway station considering pedestrians' flow direction in real experiment[1) 2)]. However, in the case of real-space experiments, it is difficult to accurately capture and record sign recognition and wayfinding behavior.

The advantages of VR equipment that can record data accurately and promptly provides us with new ideas for studying sign recognition and wayfinding behaviour. However, within a range of 9 meters, people's sense of distance to the object is shorter than the actual distance to the object in the VR environment, and the difference is less than one meter [3)]. Therefore, it is necessary to reconsider whether VR experiments can study the distance and angle between pedestrians and signs within 45 meters.

In this study, using the VR equipment with the eye-tracking function, we conducted a VR experiment the previous article mentioned [4)]. This article reports the results of the VR experiment about the sign recognition and wayfinding behaviour especially focusing on the impact of the sign layout on the walking trajectory, stop points and duration time of pedestrians.

2. Process of sign recognition

When pedestrians use signs as a clue to find their destination, the process of sign recognition can be roughly divided into four steps as Figure 1 [5)]. The time takes for the acquired visual information to move the mind is 0.3s [6)]. Pedestrians will recognize the sign existing if their sightline touches the sign more than 0.3s. The duration time from when the pedestrian's sightline touches the sign to the understanding of the sign information is defined as the reading time.

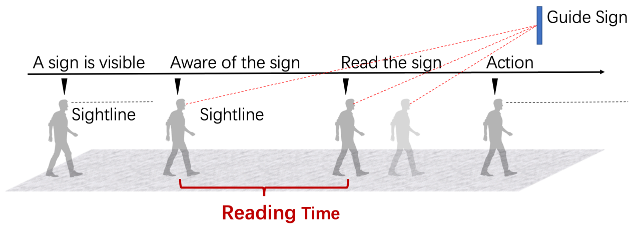

Figure 1. Sign recognition process during wayfinding behavior

3. Construction of a VR experiment system

Like the previous VR experiment, we also choose the Nagoya Sakae, Oasis 21 Square, and Sakae Station to build a spatial model on Unity (ver2019.2.8f).

Table1. The conditions of VR experiment

Subjects	The students from Nagoya Institute of Technology: 30 people（M:16, F:14） (About 15 minutes per person)	Date	2021/7/15 ~2021/7/28
Experiment Procedure	1) Explain the operation of the VR Controller Trackpad to the subjects. And adjust the pupil distance of the VR HMD lens according to the pupil distance of the subjects. 2) Set up a practice space to familiarize the subjects with the process of the VR experiment. Start the formal experiment after the subjects accustomed sufficiently. 3) Tell the subject a goal and ask him to reach and arrive at the goal before starting a case. Take off the HMD and take a rest after each case. (Each subject need to task three cases) 4) Record a video of the scene of the subject's field of view during the experiment. 5) Do a questionnaire and ask whether the subject is familiar with this subway station space. And check whether signs indicating the goal were recognized while watching the video after each case.		
Possible Motions	・Forward / Backward ・ Go to right /left ・Up /Down the stairs (VR Controller Trackpad)・Look up /down ・ Look left /right (VR HMD)・Read signs (VR HMD) and press the trigger button on the VR controller.		
Assumed Situations	・It is assumed that there are no other people in the square. ・This experiment didn't consider underground standard lighting situations that may affect the sign recognition.		

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Table2. The 6 cases implemented in the VR experiment

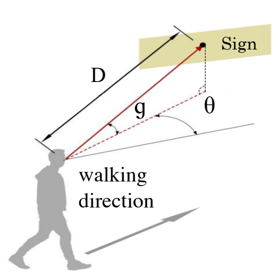
Case number	Strat Point -> Goal Point
Case1 (upstairs)	Meijyo Line Platform (Sakae Sta.) -> Seto Line Tickets (Sakaemachi Sta.)
Case2 (downstairs)	Seto Line Tickets (Sakaemachi Sta.) -> Meijyo Line Platform (Sakae Sta.)
Case3 (downstairs)	Sakae Sat. East Gate -> Aichi Arts Center Entrance
Case4 (upstairs)	Seto Line Tickets (Sakaemachi Sta.) ->Sakae Sat. East Gate
Case5 (upstairs)	Sakae Sta. East Gate -> Bus Terminal Tickets
Case6 (downstairs)	Meijyo Line Platform (Sakae Sta.) -> Sakae Sat. Exit 4A

Subjects were asked to press the trigger button on the VR controller when they got the goal direction from a sign. The experimental conditions are shown in Table 1 and Table 2.

4. Recording data and calculation of sign detectable ratio

4.1DEFINITION OF SIGN RELATIVE COORDINATES

In this study, we defined the Sign Relative Coordinates to study the sign recognition as Figure 2. The "reading distance" is the distance between the pedestrian and the sign when the sign is read.



Sign Relative Coordinates (D, θ, g)

θ : The angle between the direction of pedestrian's motion and the direction to the sign in the horizontal angle

g : The angle between the direction of pedestrian's motion and the direction to the sign in the vertical angle

D: The distance between the pedestrian's position and a sign.

Figure 2. Sign Relative Coordinates in sign recognition

4.2 THE SETTING FOR RECORDING DATA

There're three micro-behavior states of pedestrians defined in this VR experiment: C, a sign is visible; B, a sign is touched by sightline; A, a sign is touched by sightline for more than 0.3 seconds. The states were judged every 0.3 seconds, and the Sign Relative Coordinates of signs in state A and state B were recorded. Figure 3 shows the definition of reading time and the changes in micro-behavior states during wayfinding behavior.

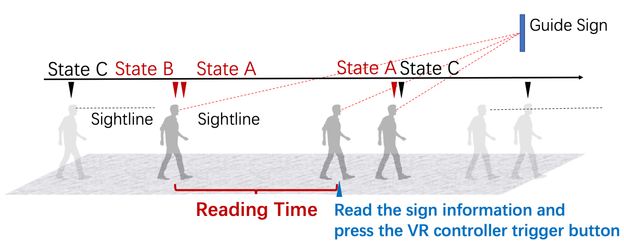


Figure 3. Measurement of micro-behavior states and reading time

4.3 CALCULATION OF SIGN DETECTABLE RATIO

Sign detectable ratio was studied in a hemispherical area the was divided into 729 cubes as Figure 4. And the sign detectable ratio in each cube was calculated by Formula 1.

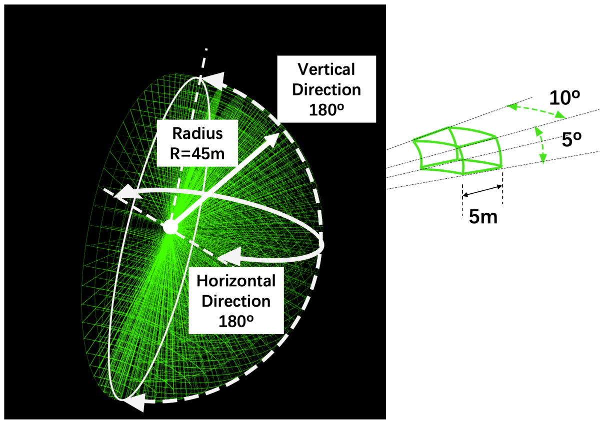


Figure 4. Area for calculation of sign detectable ratio

$$\text{Sign Detectable Ratio in Each Cube} = \frac{A}{A+C} \quad (1)$$

A/C: the number of Sign Relative Coordinates of state A/C in each cube

5. Result and analyses

5.1 OVERVIEW OF EXPERIMENT AND WALKING TRAJECTORY

We visualized the walking trajectory and walking speed of the subjects in the VR experiment. Figure 5 shows the walking trajectory and walking speed of Case1. We defined the probability that the sign indicating the goal is read as the sign-read rate. The sign-read rate directly affects the walking trajectory. We can't find the relationship between walking speed and the sign layout.

5.2 ANALYSES OF STOP POINT

Figure 6 shows the location, number, and duration time of pedestrians' stop points in Case1. We defined five space types to study the effect of sign layout on the number of stop points (NSP) and average duration time (ADT): A, sign; B, junction; C, junction +sign; D, junction +stairs; E, junction +stairs +sign. (The plus "+" means that several elements exist at the same time, and "sign" represents the sign indicating the goal)

We used a square equivalent to an area of 200 square meters to select as many points as possible in the different type spaces and calculated the average value of each unit square. There are three findings of the stop points and average duration time:

1. Stop points are mainly distributed in three places, around the sign indicating the goal, at the junction, and the stairs.
2. The number of stop points in front of signs is the most, and in space type E (junction + stairs + sign) is the least (Table 3).
3. The average duration time in space type B (junction) is the longest, and in space type E (junction + stairs + signs) is the shortest (Table 3).

Table 3. Stop points and duration time of each space type in the VR experiment

Space Type	A (sign)	B (junction)	C (junction +signs)	D (junction +stairs)	E (junction +stairs+signs)
Number of Stop Points	98	36	13	43	3
Average Duration Time (s)	2.7	6.3	2.9	4.6	2.1

5.3 COMPARISON WITH REAL-SPACE EXPERIMENT

We calculated the detectable ratio and cumulative percentage of horizontal angles to compare with the real-space experiment (Figure 7). The value of cumulative percentage obtained from the VR experiment is very similar to the real-space.

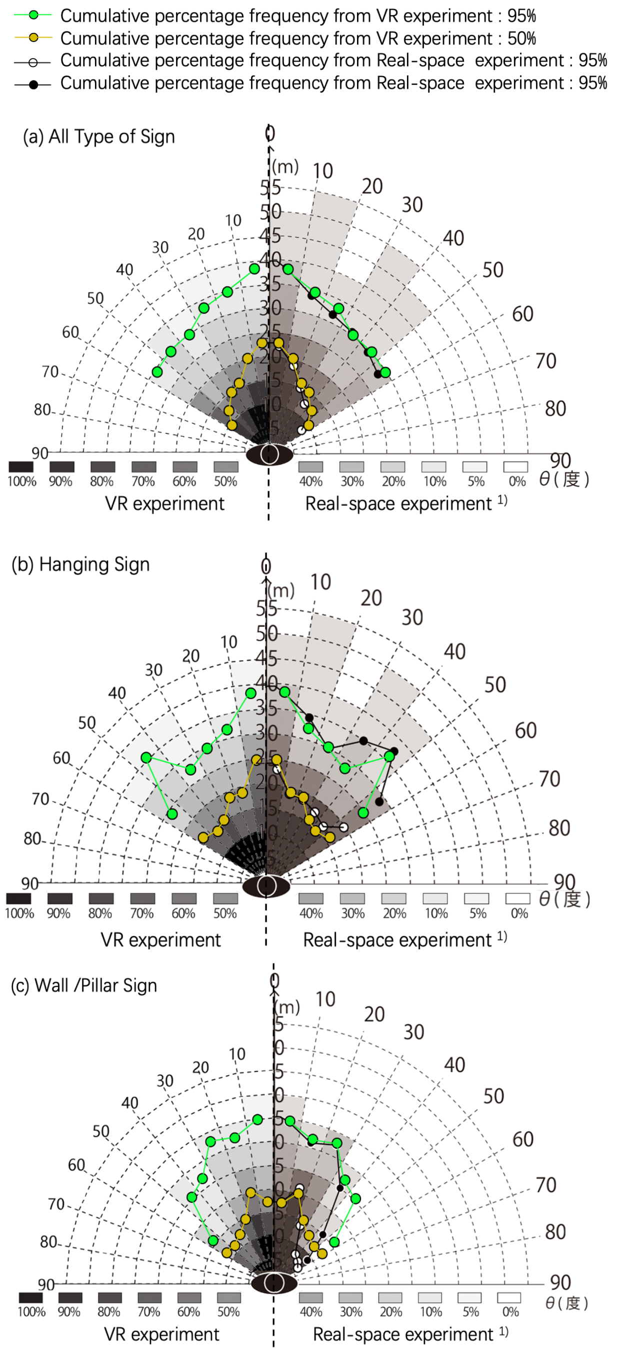


Figure 7. Sign detectable ratio and cumulative percentage frequency from VR experiment and the real-space experiment of (a)all sign type, (b)hanging sign, and (c) wall/pillar sign

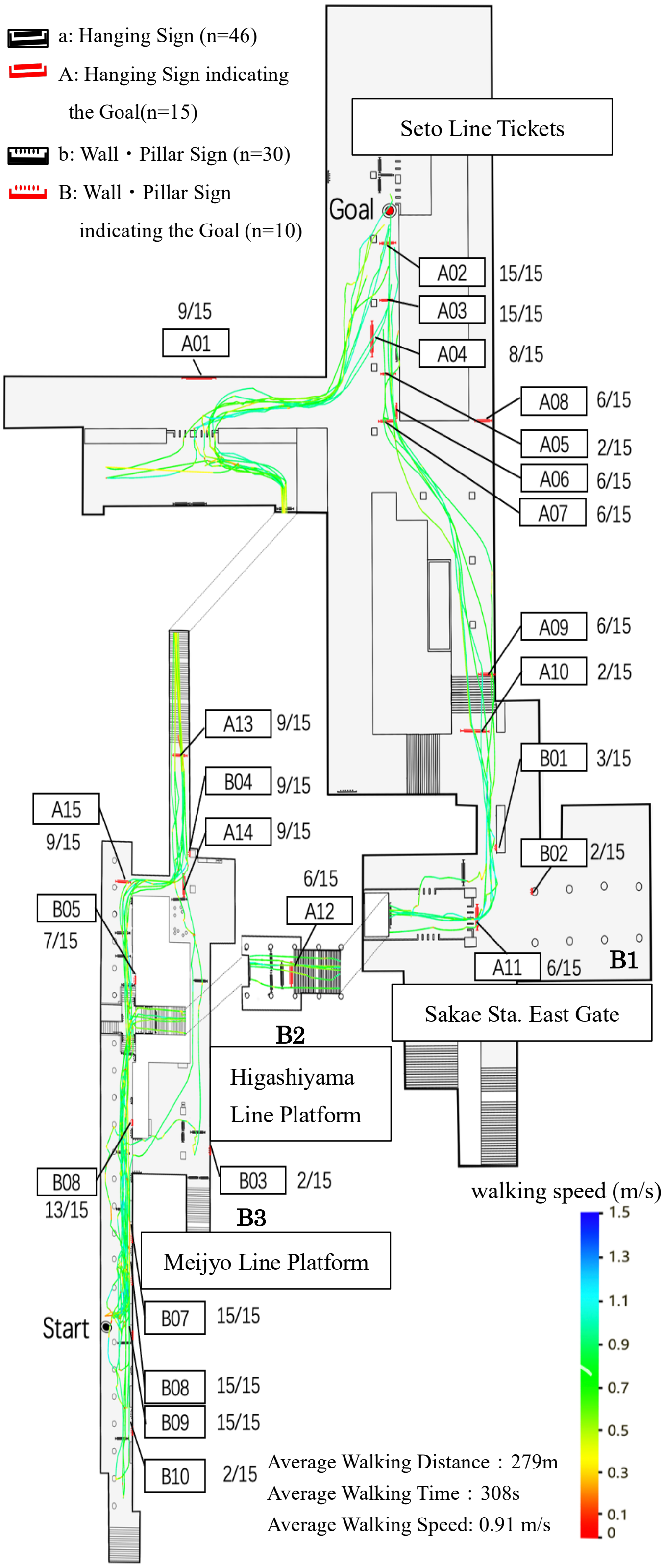


Figure 5. Sign-read rate, walking trajectory, and walking speed of Case1in the VR experiment (N=15)

Figure 7 shows that the similarity between VR experiment data and the real-space experiment data has slightly deviated with the increase of the horizontal angle. Especially for wall sign and pillar sign, the data in the range of [40°, 60°) is larger than the value of the real-space experiment. We think that is because of too few sample points.

5.3 ANALYSES OF READING TIME AND READING DISTANCE

We analyzed the effect of sign type on reading time and reading distance. The sign type does not affect the reading time (Figure 8), but it will affect its reading distance (Figure 9). The hanging sign is the farthest, and the floor sign is the closest.

Figure 8 shows the reading time in three sign types. More than 80% of reading time points are within 3.6 seconds, 90% are within 4.2 seconds, and 95% are within 5.0 seconds in all sign types.

Figure 9 shows the reading distance in three sign types. More than 80% of reading distance points are within 17 meters, 90% are within 23 meters, and 95% are within 27 meters in hanging sign. There are more than 80% reading distance points within 6 meters, 90% within 11 meters, and 95% within 13 meters in floor sign.

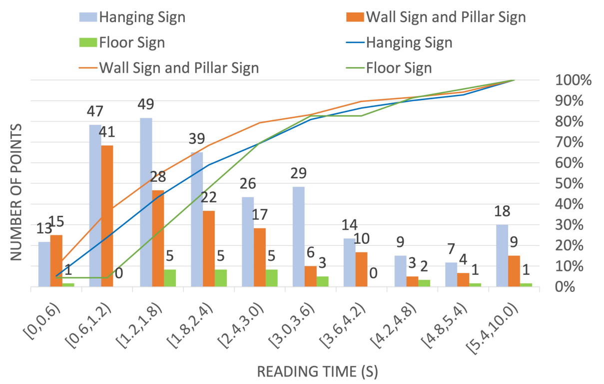


Figure 8. Cumulative percentage of reading time

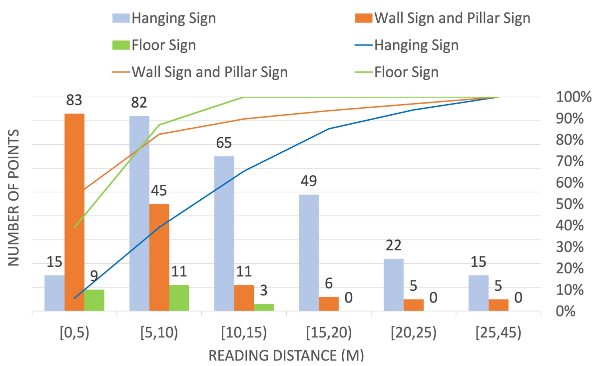


Figure 9. Cumulative percentage of reading distance

6.Concluding remarks

This article suggests the effectiveness of using VR equipment with eye tracking function to study sign recognition from distance and angle within 45 meters. And the sign type does not affect the reading time, but it greatly affects its reading distance.

In addition, we studied sign recognition and wayfinding behavior of pedestrians in the subway station. The sign-read rate affects the walking trajectory directly. The sign layout will affect the stop points and duration time of pedestrians in the subway station. An appropriate layout of the sign indicating the goal can effectively reduce pedestrians' stop points and duration time.

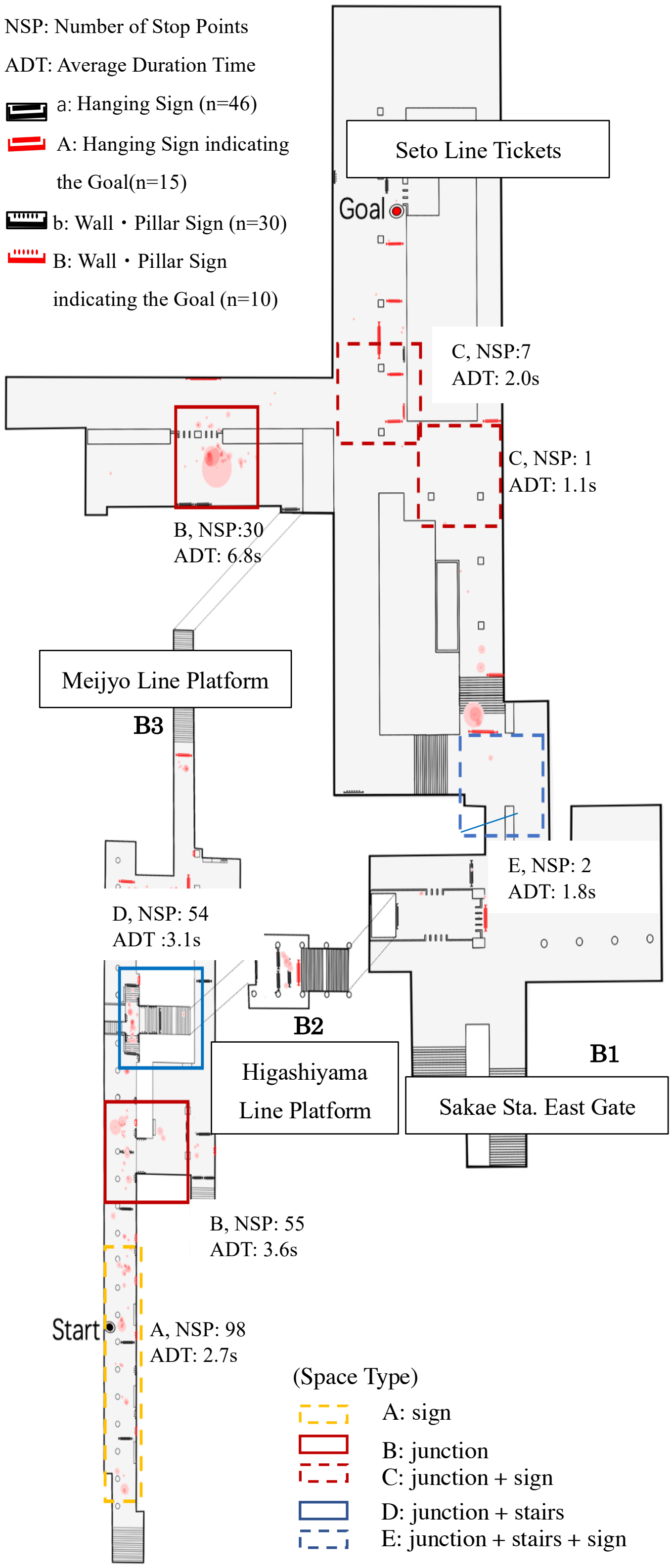


Figure 6. Location and number of stop points, and duration time of each point of Case1in the VR experiment　(N=15)

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