地下鉄駅における迷い問題と経路探索行動に関する実空間実験
A Real-Space Experiment on Problems of Getting Lost and Wayfinding Behaviors in Subway Stations

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1. Introduction

With the increase in the number of train lines and the expansion of subway stations, the station space has been becoming more and more complex. Visitors are unfamiliar with the station space, so they have a high probability of getting lost. However, getting lost directly leads to a series of problems, such as longer paths, longer walking distances, and longer stops at subway stations.

The guide sign is an indispensable wayfinding clue for the visitors to find their destinations because it provides the direction information of destinations. Last year, we did a wayfinding experiment in virtual space to research the impact of the layout of guide signs on pedestrians' wayfinding behaviors in subway stations[1)]. But we didn't study the problems of getting lost in subway stations. The roles and effects of guide signs on the problems of getting lost were also not clear. Apart from these, pedestrian flows weren't considered in the VR experiments.

This article aims to search the problem of getting lost by conducting wayfinding experiments in real space to explore those questions as follows:

1) When and where will visitors get lost?
2) Why do visitors get lost?
3) What do they do next, and how to find their way when they get lost?
4) What are the main wayfinding clues to find their destinations at subway stations?
5) How will the existence of a small number of other passengers affect their wayfinding behaviors?

2. Wayfinding in Subway Stations

Wayfinding[2)] is a process with the aid of environmental indicators, distance, and survey knowledge, by which people orient themselves and move from one location to another specific destination. The main factors affecting the wayfinding process are considered with spatial configuration[3)], external aids and spatial memories (or mental map) [4)].

Spatial configuration includes the arrangement of columns or walls, junctions, stairs, furniture arrangement, spatial character, etc. Among them, junctions and stairs are the main factors affecting the wayfinding process in subway stations, which are the focus of this article.

The external aids refer to the external wayfinding clues that help people find their ways through providing the destination information (such as guide signs and maps) or implying the direction of the destination (such as pedestrian flows). There are mainly three wayfinding clues in subway stations: guide signs, maps, and pedestrian flows. This article investigates roles of those clues in the wayfinding process within subway stations and their associations between the problem of getting lost. Visitors who are unfamiliar with the station space, always don't have enough mantel map for finding their designations. Accordingly, this article doesn't consider the mantel map.

Wayfinding behaviors are a series of specific behaviors during the wayfinding process, such as information judgment, cognition of the environment, and decision-making. These behaviors are finally mainly presented as behavioral results, such as walking trajectory, time, distance, and so on. Therefore, researching those wayfinding behavioral results can help us find the locations and reasons for getting lost, and explore the corresponding solutions.

3. Research Methods

This article conducted a real-space experiment in subway stations in Oasis 21 Square to study the problem of getting lost and investigate the wayfinding behavior in subway stations [5)], which includes the walking trajectory, walking distance and time. We used a GoPro camera to record the wayfinding process of subjects during the experiment. After each task, we did a questionnaire while watching the video we made during the experiment. We checked whether guide signs indicating the goals were recognized by subjects and asked them the questions as follows: Have you get lost during the experiment? When, where, and why were you lost? What did you do next, and why?

4. Real-Space Experiments

4.1. Selecting a site and setting Tasks

Oasis 21 Square is a comprehensive functional space located in the center area of Nagoya City. It provides a subway transfer space and connects entertainment facilities like an art gallery and shopping street, making it an important public space not only for people living in Nagoya City but also for new visitors.

Oasis 21 Square integrates two subway stations (Sakae Station and Sakaemachi Station) in underground space. There are two train lines (Higashiyama Line on Basement 2 and Meijo Line on Basement 3) in the Sakae Station. The space for transfer between Sakae Station and Sakaemachi Station is complicated due to too many junctions, exits, stairs, as well as symmetrical spatial configurations, making it difficult for visitors to orientate themselves. The space between those two stations, including the platform in Sakae Station, was selected to conduct the real-space wayfinding experiments.

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Two Tasks were set. The start point Sakaemachi Station, Seto Line Gate (B1b) and goal point Sakae Station, Higashiyama Line Gate (B1a) in Task 1 are on Basement 1, the straight distance is about 70m, and there is one staircase with a height difference of about 2.4m. In Task 2, the start point Sakae Station, Meijyo Line to Kanayama platform (B3a) is on Basement 3, and the goal point Sakaemachi Station, Seto Line Gate (B1b) is on Basement 1. The straight distance is around 100m, and the height difference between those two points is about 8m. There are 12 staircases and 5 forks. The setting of Task 2 is the same as the VR experiments[1)].

4.2. Wayfinding experiments in real space

To observe whether the presence of other passengers impacts the wayfinding behaviors, we selected weekdays (with other passengers about 0.3 persons /m^2) and weekends (without any other passengers) to conduct the experiment. Considering excluding the interference of pedestrian flows, we chose the time from 9:30 p.m. to 11:30 p.m.

The 20 people (M:11, F:9) participated as the subjects. The ages of the subjects were between 22 and 28. The subjects' heights are in the ranges [1.60m, 1.80m]. Most of them had been to the Oasis 21 Square no more than five times a year, but they use the subway to commute regularly (more than once a week). We considered that all of them have experience walking in subway stations but don't have mental map of this real space.

The subjects were divided into two groups, and each of them tested two tasks. One group tested on weekdays, and another one tested on weekends—about 15 minutes per subject. More details are shown in Table 1.

Table1. Wayfinding experiments in real space to study the wayfinding behavior and problems of getting lost

Subjects	20 people (M:11, F:9) Ages: 22~28	Date	2022/9/8&9/9 (weekday) 2022/9/10&9/11(weekend) At 9:30 p.m.~11:30 p.m.
Experiment Procedure	1) Tell the subject a goal and ask him to reach and arrive at the goal before starting a task. 2) Ask the subject to give a gesture representing the next direction once he made the next decision. 3)Record a video during the experiment, which needs include the subject's position, the floor tiles, and signs 4)Do a questionnaire about the direction choice at each function after each task. Ask whether the subject is familiar with this subway station space. Meanwhile, Check whether signs indicating the goal were recognized while watching the video after each task.		
Assumed Situations	Task number: Strat point, the number of start point => Goal point, the number of goal point Task1: Sakaemachi Station, Seto Line Gate, B1b => Sakae Station, Higashiyama Line Gate, B1a Task2: Sakae Station, Meijyo Line platform (to Kanayama), B3a => Sakaemachi Station, Seto Line Gate, B1b		

5. Results and Analysis

5.1. Locations, reasons, and solutions of getting lost

During Task 1, all subjects (20 subjects) reflected that they could easily and smoothly navigate themselves to the destination. No getting lost happened in Task1. However, during Task 2, almost all subjects (20 subjects) were lost in the subway station. Getting lost mainly occurred in three locations: (See Figure 3).

1) Stairs in Meijyo Line with an orange square. (20 subjects)
2) Junctions in Meijyo Line with a purple square. (18 subjects)
3) Meijyo Line Gate with a red square. (6 subjects)

The main reason for getting lost is the lack of guide signs in forks like stairs, junctions, and Gates. When they get lost, 15 subjects chose to go straight until finding the next guide sign. One of them went back and out of the station by stairs after he couldn't find the following sign when he went straight so far. 8 subjects directly chose upstairs to go out of the station. 5 subjects of them followed the pedestrian flows because they thought they will find the destination following them. Therefore, going straight is the most used solution, and upstairs to go out of stations is the final solution when they're lost. Subjects tend to follow the pedestrian flows when they are lost.

5.2. Analysis of wayfinding clues

Two types of clues (guide signs and maps) were used on weekdays, and three types of clues (guide signs, maps, and pedestrian flows) were used on weekends. The Figure 1 and Figure 2 show the types of clues and number times of reading them during the wayfinding process on weekdays and weekends.

As we already observed, the guide signs are the most proportion of wayfinding clues. In Task 1, The average of times reading guide signs (5.8 times) on weekdays is more than (4.4 times) on weekends. In Task 2, same as Task 1, the average of times reading guide signs (11.1 times) on weekdays is more than (9.6 times) on weekends. Therefore, we report that the reliance on guide signs in an environment with other passengers is less than in an environment without other passengers. However, the dependency on pedestrian flows is increased in a subway station space with other passengers.

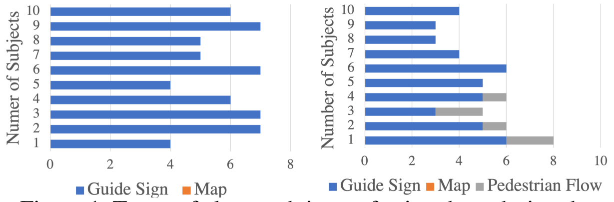


Figure 1. Types of clues and times of using them during the experiments of Task 1 on weekdays (left) and weekends (right)

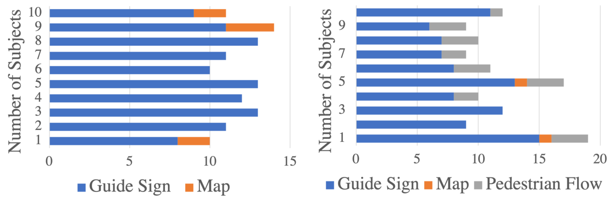


Figure 2. Types of clues and times of using them during the experiments of Task 2 on weekdays (left) and weekends (right)

We did the questionnaire after each task. As mentioned in Part 5.1, the main reason for getting lost is the lack of guide signs in the forks. Apart from it, there are also other reasons, like misread and miss signs (See Figure 3).

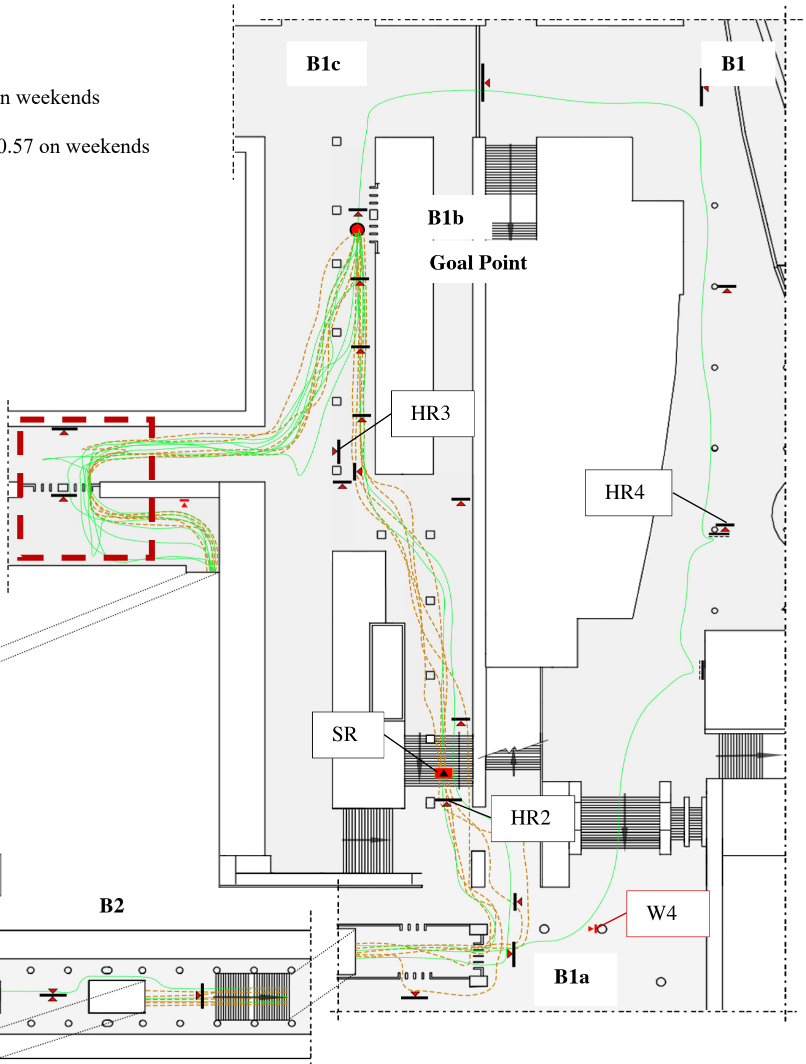
An unappropriated combination of two guide signs leads them confusing and easier to misread, like wall signs W1, W2, and W3. For instance, the wall signs W1 and W2 should be read as "the direction of Seto Line and Bus Terminal is the left front." While 14 subjects read them as "the direction of Seto Line and South Gate is right or back." In addition, some narrows on signs are also confusing, like wall sign W4. One subject misread it as "the direction of Seto Line is front left". But we judged it as "the direction of Seto Line is back left" based on the location of Seto Line Gate.

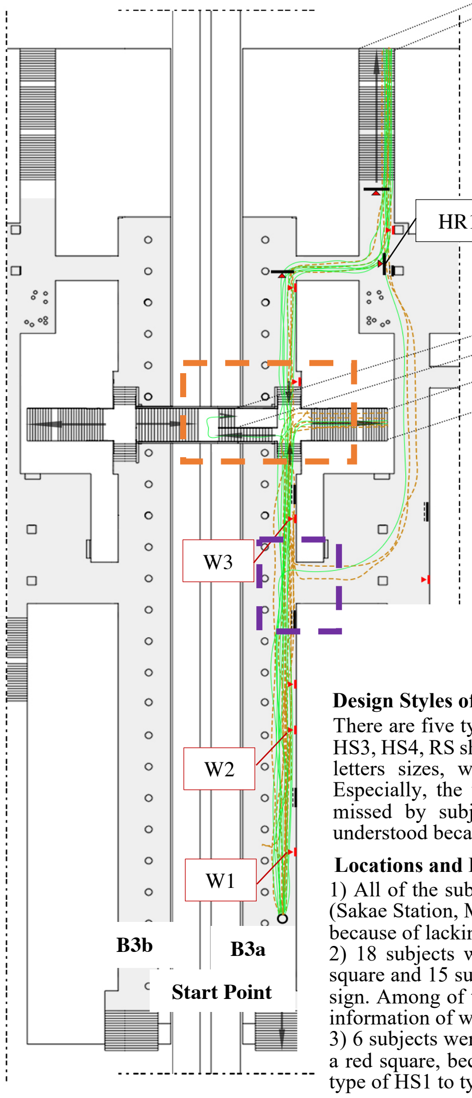
The difference in guide signs designs leads to miss signs. There are five design types of hanging signs, HS1, HS2, HS3, HS4, and RS. In this real space experiment, 6 subjects missed some guide signs because of the different designs of hanging signs from type of HS1 to type of HS2.

Number of Subjects:
10 people on weekdays / 10 people on weekends
Walking Distance:
Ave:197 m, SD:24.75 on weekdays /Ave:203m, SD=21.76 on weekends
Walking Time:
Ave:3.56 min., SD=0.28 on weekdays /Ave: 4.10 min., SD=0.57 on weekends
Walking Speed:
Ave:0.89 m/s on weekdays /Ave: 0.80 m/s on weekends

Wall Sign (n=10)
Hanging Sign (n=25)
Map(n=7)
Roof Sign (n=1)
Up Stairs
Walking Trajectory of Weekdays
Walking Trajectory of Weekends

B1a: Sakae Station, Higashiyama Line Gate
B1b: Sakaemachi Station, Meitetsu Seto Line Gate
B1c: Central Park (shopping streets)
B1d: Oasis 21 Square
B2: Sakae Station, Higashiyama Line Platform
B3a: Sakae Station, Meijyo Line Platform to Kanayama
B3b: Sakae Station, Meijyo Line Platform to Shiyakusho





Four Confusing Wall Signs:
The wall signs numbered in here are the signs that was read incorrectly more than subjects. These wall signs were read incorrectly by these people, respectively: W1:14subjects; W2: 14subjects; W3: 5subjects; W4: 1subject.

Design Styles of Hanging Sign (HS) and Roof Sign (RS):
There are five types of hanging signs in our site, like HS1, HS2, HS3, HS4, RS shown with the different designs, colors, sizes, and letters sizes, which affect the finding and reading of sign. Especially, the type of hanging sign HS2, most of them were missed by subjects and they also needed more time to be understood because of small letters.

Locations and Reasons of Getting Lost:
1) All of the subjects (20 subjects) were lost in the stairs in B3a (Sakae Station, Meijyo Line to Kanayama) with an orange square because of lacking guide signs.
2) 18 subjects were lost in the junctions in B3a with a purple square and 15 subjects chose to go straight, until finding the next sign. Among of them, 4 subjects were lost, because the direction information of wall signs W2 and W3 were confusing.
3) 6 subjects were lost in the Meijyo Line Gate and junction with a red square, because of different designs of hanging signs from type of HS1 to type of HS2.

Figure 3. Walking trajectories of Task 2 on weekdays (green solid lines) and weekends (orange dotted line)

5.3. Analysis of walking trajectory

All subjects could find their destinations very quickly in Task1, and the walking trajectories were also very simple. While in Task 2, it was a little difficult for the subjects because of getting lost. Hence, in this part, we only analysed the results of walking trajectories of Task 2.

Three patterns of walking trajectories of Task 2 were defined (See Figure 4). The result of pattern proportions is shown in Table 2. Figure 3 shows the details of the walking trajectories of Task 2, which was drawn based on the videos we made during the experiments.

Proportions of Pattern 1 and 2 on weekdays are more than on weekends, which we consider was caused by the pedestrian flows. Corresponding to the results of Part 5.1, when the subjects were lost, they followed pedestrian flows and went upstairs to out of the stations. In addition, as we can see, one subject took a detour in Oasis 21 Square, because of misreading the sign W4.

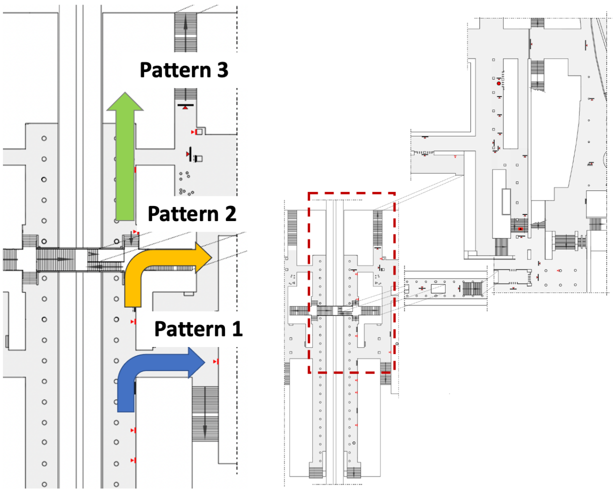


Figure 4. Definition of patterns of walking trajectories of Task 2

Table2. Pattern proportions of walking trajectories of Task 2

Pattern Proportions	Pattern 1	Pattern 2	Pattern 3
Weekdays	2/10 (20%)	5/10 (50%)	3/10 (30%)
Weekends	1/10 (10%)	3/10 (30%)	6/10 (60%)

5.4. Analysis of walking distance and time

Based on the size and number of tiles in steps of subjects, we made the following estimates: subjects with heights in the range of [1.6m, 1.7m) and [1.7m, 1.8m] have an average stride of 0.60m (length of 3 tiles, 0.2m per tile) and 0.70m (length of 3.5 tiles, 0.20m per tile) separately.

The walking distance and time of Task 1 and Task 2 were measured based on the videos (See Figure 5 and Figure 6). The t-test was used to compare those two groups' data on weekdays and weekends.

In Task 1, the values of walking distance on weekdays are significantly more than on weekends (p=0.002). The average of walking time on weekdays is less than on weekends, while we could find difference in the values of walking time between weekdays and weekends (p=0.08).

In Task 2, the values of walking distance on weekdays aren't significantly different from those on weekends (p=0.22). In contrast, the values of walking time on weekdays are less than those on weekends (p=0.02).

Even through, the p-value of walking time in Task 1 and walking distance in Task 2 are more than the significance threshold value 0.05, we boldly speculate the following results: the values of walking distance on weekdays are more than on weekends, and the values of walking time on weekdays are less than on weekends. That is because pedestrian flows will reduce subjects' walking distance and increase their walking time due to avoiding collisions with other passengers.

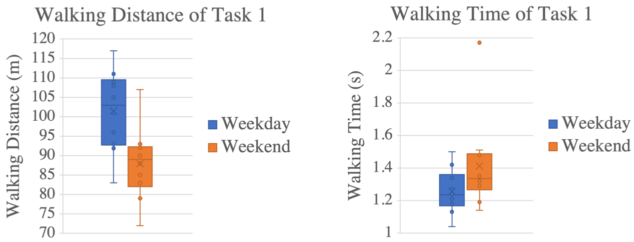


Figure 5. Walking distance (left) and time (right) of Task 1

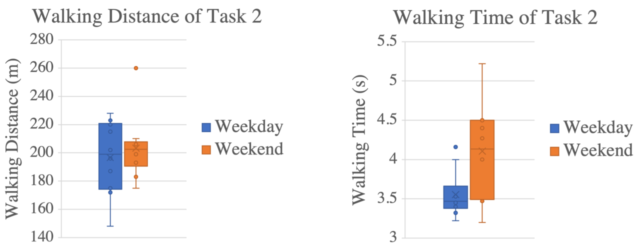


Figure 6. Walking distance (left) and time (right) of Task 2

6. Conclusions

In this article, intending to search the problem of getting lost in subway stations, we conducted a wayfinding experiment in the real space of subway stations in Oasis 21 Square.

Firstly, we analysed the wayfinding problems of getting lost in subway stations. Those results were summarized as follows: 1) Visitors have a high probability of getting lost at forks, such as junctions, stairs and gates; 2) The main reasons leads them lost are lack of guide signs in the forks, missed and misread guide signs; 3) Go straight is the most used as a solution and upstairs to go out of the station is the final solution when they're lost; 4) Guide sign is the main wayfinding clue for them to find their destinations; 5) They tend to follow the pedestrian flows when they are lost.

Secondly, we recorded the walking trajectories, walking distances and time on weekdays and weekends. The results were summarized as follows: 1) Pedestrian flows affect the patterns of visitors' walking trajectories. The existence of other passengers affects their decision-making in subway stations; 2) The average of walking distance on weekdays is more than on weekends; 3) The average of walking time on weekdays is less than on weekends. Those difference is because that pedestrian flows reduce visitors' walking distance and increase their walking time due to avoiding collisions with other passengers.

In future work, we will explore the possibility of applying VR technology to research wayfinding behavior within subway stations by comparing the results of Task 2 in this real space experiment with the results of Task 2 in the VR experiments[1)].

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