Differences in wayfinding performance across types of navigation aids and understanding of environmental information among travelers

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ABSTRACT
This study investigated the wayfinding strategy and efficiency. Experiments involving 44 participants (22 Japanese and 22 Taiwanese nationals) were conducted in Tamsui, Taiwan and Yokohama, Japan. Experimental tools included electronic and paper maps. Participants were in an unfamiliar environment, understood environmental information differently, and used different navigation tools. The researchers recorded the participants’ walking time, path, and the number of turns from the starting point to the destination. SPSS statistical software was used to conduct one-way and two-way analysis of variance (ANOVA). The findings revealed the following. First, when navigating linear roads and being uncertain about the accessibility of map-presented roads, relative to local participants, foreign participants were more likely to choose roads that were at the exit of the MRT station and take more identifiable roads. Second, all participants used landmarks when navigating intersecting parallel roads, but participants who used paper maps were more likely to use obvious buildings as landmarks. Third, in the wayfinding process, participants who used both electronic and paper maps made more turns when wayfinding in a familiar environment than in an unfamiliar environment. Participants familiar with the navigation tool exhibited a lower walking time.

1. Introduction
1.1. Wayfinding
The objective of wayfinding is the quick and effortless motion from place to place (Bruné et al. 2010); wayfinding is commonly used when individuals are in an unfamiliar environment (Chang 2015). In unfamiliar environments, individuals generally either seek help from others or use navigation tools to find the right direction toward their intended destination (Hund and Minarik 2006; Chang 2015).

Studies have noted that wayfinding behavior differs between cultures (Chang 2015; Ito and Sato 2011). The wayfinding times of Western travelers are shorter than that of East-Asian travelers. Moreover, relative to their Western counterparts, East-Asian travelers also exhibit a greater sense of loss, nervousness, and anxiety during the wayfinding process (Chang 2015). Ito and Sato (2011) revealed that Japanese participants were more certain of their position and direction when using paper maps than when following direction indicators, whereas the opposite is true for US participants.

In addition to cultural differences, studies have also revealed that different navigation tools yield different wayfinding efficiencies (Chang 2015; Ishikawa et al. 2008). Compared with participants who used local direction indications and GPSes, participants who used paper maps exhibited shorter walking times and a lower sense of loss (Chang 2015). Ishikawa et al. (2008) revealed that the average walking distance of participants who used GPSes was longer than that of participants who used maps or relied on their direct experience of routes. Furthermore, participants relying on their direct experience exhibited a faster walking speed than that of participants who used GPSes and maps. In addition, the frequencies of stopping to confirm their position and reassess the direction, in descending order, are those of participants who used GPSs, maps, and their direct experience of the route. Furthermore, the study revealed that among participants who used maps, participants with a greater sense of direction were more inclined to take shorter paths.

Xia, Packer, and Dong (2009) revealed that relative to other travelers, travelers who were familiar with the environment more frequently employed wayfinding strategies that have shorter paths and fewer turns. The study assumed that a traveler’s wayfinding strategy becomes more economical after being familiar with the environment. Ishikawa et al. (2008) also noted that a traveler’s walking distance becomes closer to the lowest possible travel distance after being familiar with the navigation tool. Furthermore, individuals with greater traveling experience are more likely to favor an orientation strategy over a route strategy. Studies have also revealed that participants who used
hand-drawn maps were more inclined to use the route strategy, whereas participants who used a GPS were likely to employ the orientation strategy (Chang 2013).

Studies have demonstrated that level of environmental understanding influences wayfinding behavior (Neill 1992; Muffato et al. 2017; Muffato and Meneghetti 2020). Wayfinders with greater environmental familiarity make fewer incorrect turns during wayfinding and arrive at their destination more quickly (Neill 1992). Spatial orientation performance in familiar environments was related to self-assessed wayfinding inclinations and object-based visuo-spatial abilities (both mental rotation ability and visuo-spatial working memory), but not with spatial anxiety. (Muffato et al. 2017). Muffato and Meneghetti (2020) revealed that familiarity does not have a moderating effect in the relationship between pointing out destinations on maps and the locating of actual landmarks. However, environmental familiarity influenced how successful participants were in finding the shortest path. Furthermore, studies have indicated that relative to their time needed to find destinations on maps for foreign countries, participants spent less time finding destinations on maps for their own country (Zheng and Li 2013). Yao and Zheng (2018) investigated the differences between Taiwanese and Japanese tourists with respect to knowledge of 37 tourism-related symbols. The study results indicated that among the 37 symbols, Taiwanese and Japanese tourists were most familiar with the symbols for parks, hot springs, and breastfeeding rooms. This similarity is due to the similar life experiences and use of the same symbols between Taiwanese and Japanese people. Alternatively, the participants were least familiar with symbols for flight check-ins, historic sites, and restrooms for parents with infants. This is because the words and images in the symbols unclearly reflect what the symbol means.

In the wayfinding process, different methods for information acquisition afford different types of spatial knowledge (Afroz, White, and Parolin 2018; Brügger, Richter, and Fabrikant 2019). In particular, the active acquisition of environmental information by wayfinders was determined to yield information of greater depth and quantity (Afroz, White, and Parolin 2018). Brügger, Richter, and Fabrikant (2019) noted that for participants who used electronic navigators, greater automation in the electronic navigator resulted in a lesser acquisition of spatial information. Additionally, the study revealed that when returning to the starting point through the path taken, greater automation in the electronic navigator resulted in a greater frequency of stopping and hesitating in participants.

With respect to guidance information, Ito and Sato (2011) stated that relative to referral information, such as “continue walking for another two blocks” and “at the second traffic light,” information that described building types (e.g. a soccer field) enabled wayfinders to be more certain of their directions in the wayfinding process.

### 1.2. Navigation tools

Because of technological advancements, mobile phones and the Internet have enabled the electronic delivery of substantial spatial-geographical information. Relative to traditional paper maps that only allow for the one-way transmission of information from map producers, these new technologies allow users to freely collect and process information, thus expanding the scope of their acquired visualization information (Table 1) (Wakabayashi 2008b; MacEachren 2004; Wakabayashi and Suzuki 2003). In addition to being convenient to update, electronic maps have no limitations with respect to map scale and map size, and they can be integrated with 3D animations and sound effects to provide multimedia cues. Therefore, electronic maps augment the two-way interaction between users and map designers and allow for better flexibility in the presentation and application of maps (Wakabayashi 2008b; Longley et al. 2001). However, electronic maps have demonstrable disadvantages relative to paper maps; electronics maps can only be presented at specific resolutions and lack the characteristic of presenting all pieces of information all at once as paper maps do (Table 2) (Wakabayashi 2008a). Nonetheless, paper maps are less widely used because

| Map representation | Communication | Visualization |
|--------------------|---------------|---------------|
| User interaction   | Low           | High          |
| Map Use            | Open          | Personal      |
| Map information    | Prompt for known| Identify unknown |
| MacEachren (2004)  | and Wakabayashi and Suzuki (2003). |

### Table 2. Differences in features between paper maps and electronic maps.

| Feature                  | Paper map                  | Electronic map             |
|--------------------------|----------------------------|-----------------------------|
| Scale                    | Fixed                      | Adjustable                  |
| Representational range   | Fixed                      | Adjustable                  |
| Image                    | Static                     | Moving images can be incorporated |
| Dimension                | Generally two-dimensional  | Three-dimensional representations are possible |
| Updates                  | Difficult to correct and update | Easy to correct and update |
| Direction of Communication| One-way communication from map producers | Two-way interaction between users and map producers |

Wakabayashi (2008b) and Longley et al. (2001).
electronic maps are more convenient and always being improved upon.

The literature has discussed the influence of differences in culture and navigation tools on strategy, efficiency, and behavior in users’ wayfinding. However, few studies have explored how the understanding of environmental information influence wayfinding efficiency among travelers in unfamiliar environments. Therefore, this study aims to understand how wayfinding efficiency and strategy differ by navigation tools and the levels in understanding of environmental information.

2. Method

To ensure that the levels in understanding of environmental information differed between participants, this study employed local and foreign participants (relative to the experimental site). This study tested the following two hypotheses: (1) wayfinding behavior differs with the different navigation tools used; and (2) a greater understanding of environmental information results in higher wayfinding efficiency.

This study selected Taiwanese and Japanese citizens as study participants and Taiwan and Japan as the experimental site. Taiwan and Japan share the use of Chinese characters in their languages, and Taiwanese and Japanese people have had frequent interactions in recent years. In 2018, Japan was the top travel destination among Taiwanese travelers and was visited by 29% of Taiwanese travelers (TTB 2019a). Among Taiwanese travelers to Japan, 70.1% were independent travelers (JTA 2019). Similarly, among visitors to Taiwan between 2014 and 2018, Japanese travelers constituted the second-largest nationality after travelers from mainland China (TTB 2019b). The present study noted that the number of travel-related books sold differed between Taiwan and Japan. Therefore, this study inferred that citizens of both countries have different habits in their use of navigation tools, thus making them suitable as participants. To discuss the difference in using different navigation tools to conduct wayfinding, this study selected people aged 20–29 years, who are experienced in and familiar with operating electronic maps (ZENRIN 2018), as the research participants.

This study recruited 44 participants; 20 and 24 were men and women, respectively, and 22 and 22 were Taiwanese and Japanese nationals, respectively. The participants’ age range was 20–29 years. The participants’ mean Santa Barbara Sense of Direction Scale (SBSOD) score was 4.07 out of the maximum possible score of 7.

The two experiment sites were set in Tamsui, Taiwan and Yokohama, Japan. The Tamsui experimental site is situated between the Tamsui mass rapid transit (MRT) station and Fort San Domingo; it is a tourist region where the roads were mostly linear (Akiyama et al. 2010; Marshall and Garrick 2011; Marshall 2005). The Yokohama experimental site was at the Kannai area; it is within an urban tourist region (Akiyama et al. 2010) where the roads are intersecting and parallel with each other (Marshall and Garrick 2011; Marshall 2005). Table 3 and Figure 1 present the signpost indicators and residential address system of Tamsui and Yokohama. The signpost maps and indicators of Tamsui and Yokohama are presented in English and in the local language. In addition, Tamsui and Yokohama use different residential address systems. Addresses in Tamsui are labeled according to the street, whereas addresses in Yokohama are labeled according to block. The signpost maps and indicators are detailed in Figure 2. Tamsui and Yokohama are popular tourist sites with East-Asian and Western cultural attractions scattered around the cities. This study selected Tamsui and Yokohama as the experimental sites due to their aforementioned characteristics; 16 and 28 participants were involved in the experiments at the Tamsui and Yokohama sites, respectively.

To ensure that the participants were unfamiliar with the environment, this study asked participants how many times they have visited the place and how familiar they were with the environment. This study selected Japanese participants who have not visited Tamsui before and who had a self-assessed familiarity level of 2 or lower toward the region, with 1 being

| Table 3. Signpost map languages and residential address systems of Tamsui and Yokohama. |
|-----------------------------------------------|
| Signpost maps | Signpost indicators | Residential address system |
| Tamsui, Taiwan | Traditional Chinese, English | Traditional Chinese, English | Street address: Streets are numbered according to their direction. For example: |
| Yokohama, Japan | Japanese, English | Four languages: Japanese, Chinese, and Korean | City block address: the city blocks are labeled using numbers. |
| | | Two languages: Japanese and English | |

Act on Indication of Residential Address (Act No. 119 of 1962), Rules on Address Assignment and Plate Installation in New Taipei City (31 August 2012), COY (2019), and Wakabayashi (2018).
This study selected Taiwanese participants for the experiment in Yokohama from a pool of Taiwanese exchange students who were studying abroad in Japanese schools. Prior to the experiment, the Taiwanese participants had visited the experimental site less than twice and had a self-assessed familiarity level of 2 or lower toward the region.

The navigation tools and methods comprised electronic maps and paper maps as well as the simultaneous use of electronic and paper maps (hereafter referred to as the use of both maps). Among participants, the number of participants who used the electronic map, paper map, and both maps was 18, 18, and 8, respectively (Table 4).

The electronic map was Google Maps ver. 5.6, as presented on an iPhone 6s. The paper map was created using Google Maps as a basis. Participants at the Tamsui experiment site used an A4-sized color-printed map that included the names and locations of sightseeing spots, in addition to displaying the names of the sightseeing spots in 7 pt font. Participants at the Yokohama experiment site used an A3-sized color-printed paper map that displayed the names of sightseeing spots in 11 pt font (Figure 3). Participants were also provided with a guidebook that included the names, photos, descriptions, and summary of the reviews on the sightseeing spots left on Google (rated with a maximum score of five stars). The guidebooks are A4 sized, colored, and printed on a single side. The names and descriptions of the sightseeing spots are displayed in 12 pt and 10 pt fonts, respectively, with the picture of the sightseeing spot having the dimensions 31.8 mm × 36.3 mm (Figure 4).

The starting point and destination of the wayfinding task for the Tamsui experiment site was the Tamsui MRT station and Fort San Domingo, respectively. The starting point and destination for the
Yokohama experiment site were the Ishikawacho MRT Station and Yokohama Zeikan, respectively. During the experiment, participants who used electronic maps were able to only use the electronic map application. Participants who used paper maps were provided with paper maps that marked the starting point and the destination and were allowed to make notes on the map. During the experiment, participants could use the navigation tool provided, in addition to on-site signpost maps and indicators, but they were prohibited from asking for help from others and could only travel by walking. The researchers recorded the participants’ walking time, path, and the number of turns from the starting point to the destination. SPSS statistical software was used to conduct one-way and two-way analysis of variance (ANOVA).

3. Results

This study recorded the participants’ time taken, distance walked, average speed, walking path, and number of turns taken. Subsequently, SPSS software used for one-way and two-way ANOVA to investigate the effects of navigation tools, understanding of environmental information, road characteristics, and nationality on wayfinding efficiency.

### 3.1. Experience in using navigation support tools

The mean SBSOD score of the 22 Taiwanese participants was 4.17, with 77%, 9%, 9%, and 5% of the participants stating that their regular wayfinding support tools were electronic maps, paper maps, signpost maps, and other tools, respectively. Alternatively, the mean SBSOD of the 22 Japanese participants was 3.95, with 59%, 23%, 9%, 5%, and 5% of the participants’ stating that their regular wayfinding support methods were electronic maps, paper maps, signpost maps, asking others for directions, and other methods, respectively (Figure 5). Thus, paper maps were more commonly used by Japanese participants than Taiwanese participants. Correlation analysis results revealed that SBSOD score and nationality were not significantly correlated \( r = 0.118, p = 0.445 \). The one-way ANOVA results also indicated that Japanese and Taiwan participants did not significantly differ with respect to SBSOD score – \( F(1, 42) = 0.594, p = 0.445 \).

### 3.2. Walking path

Figure 6 displays the walking path of participants at the Tamsui experiment site; every participant successfully arrived at the destination. According to Figure 6, participants of different nationalities selected different starting paths. Among the Taiwanese participants, 62.5% and 37.5% chose to start from Huanhe Road.
and Zhongzheng Road, respectively. Among the Japanese participants, 87.5% and 12.5% chose to start from Zhongzheng Road and Zhongshan Road, respectively.

This study inferred the following explanations for why Taiwanese and Japanese participants selected different starting paths. For most Taiwanese participants, they took Huanhe Road because they used the Tamsui River as a landmark. The participants probably reasoned that by walking alongside the Tamsui River, they could not only arrive at the destination but also enjoy the riverside scenery. By contrast, most Japanese participants took Zhongzheng Road because it was situated outside of the MRT station. This study inferred that the Japanese participants chose the road outside the MRT station as the starting point to avoid going in the wrong direction (and the consequent need to reposition themselves). Another possible reason is the presence of a signpost at the intersection between Zhongzheng Road and Zhongshan Road (Figure 8). Japanese participants may have chosen to follow the signpost instructions, taking the more noticeable Zhongzheng Road (labeled with a coffee symbol) rather than the Huanhe Road (labeled in white) in heading toward their destination. These behavioral differences indicate that when wayfinding in familiar

Figure 4. Guide book.

Figure 5. Taiwanese and Japanese participants’ experience in using navigation supporting tools.
environments, personal experience plays a role in path planning. However, when wayfinding in unfamiliar environments, individuals were more willing to rely on local indicators and map guidance over personal experience.

In addition, participants who used different navigation tools also chose different paths. Of the participants who used electronic maps, 16.6% and 83.3% took Huanhe Road, which was situated at the opposite end of the exit, and Zhongzheng Road, respectively. By comparison, 50% and 50% of the participants who used paper maps chose to take Huanhe Road and Zhongzheng Road, respectively. Among the participants who used both maps, 25% and 75% of the participants started from Zhongshan Road and Zhongzheng Road, respectively.

This study inferred that most participants who used electronic maps chose to start from Zhongzheng Road because the guided path displayed in the electronic map began from Zhongzheng Road after the exit from the MRT station. If these participants took Huanhe Road, they had to reposition themselves. Therefore, to reduce the possibility of getting lost, most participants chose to directly take the path stated on the electronic map.

In addition, 60% of the Taiwanese participants who chose to start from Huanhe Road changed their path after crossing the Starbucks (Riverside Store branch),

![Figure 6. Walking path of Taiwanese participants (a) and Japanese participants (b) at the Tamsui experiment site.](image)
as if you were reading it naturally.

Figure 7. Walking path of Taiwanese (left) and Japanese (right) participants at the Yokohama experiment site.

thus turning to take Zhongzheng Road to the destination. Among Japanese participants, some participants changed to take Huanhe Road, whereas some also turned after crossing the Starbucks to take Zhongzheng Road to the destination. Some participants who used only electronic (40%) or paper maps (66.6%) and who started from Zhongzheng Road also chose to take Huanhe Road. However, all of these participants turned back at the Starbucks to take Zhongzheng Road.

This study inferred that for participants who originally took Huanhe Road and subsequently chose to take Zhongzheng Road upon crossing the Starbucks, they did so because the path indicator after the Starbucks on Huanhe Road was marked in dotted lines. This use of dotted lines likely made the participant uncertain as to whether the path was available on foot, making them choose more apparent paths.

As for the Yokohama experimental site, Figure 7 displays the walking paths of the Yokohama participants; all participants successfully arrived at the destination. Among Taiwanese participants, 35.7%, 35.7%, 21.4%, and 7.1% chose to take Nishimon Street, Osanbashi Street, Minato-Odori Street, and Bay Stars Street. By comparison, 35.7%, 57.1%, and 7.1% of the Japanese participants chose to take Nishimon Street, Osanbashi Street, and Minato-Odori Street. The results revealed that participants for both countries mainly took Nishimon Street and Osanbashi Street, accounting for a total of 23 participants and exceeding half of the total number of participants. In addition, according to Figure 7 displaying the walking path, only Japanese participants took Nihonodori Avenue.

The following are the routes chosen in relation to the navigation tool used. For the participants who used electronic maps, 58.3%, 33.3%, and 8.3% took Nishimon Street, Osanbashi Street, and Minato-Odori Street, respectively. For participants who used paper maps, 25%, 50%, 16.6%, and 8.3% took Nishimon Street, Osanbashi Street, Minato-Odori Street, and Bay Stars Street, respectively. Finally, 75% and 25% of the participants who used both maps chose to take Osanbashi Street and Minato-Odori Street, respectively. Thus, participants who used electronic maps were more inclined to choose Nishimon Street, whereas participants from the other two groups were likely to choose Osanbashi Street.

The distinctive feature of Yokohama is its intersecting parallel roads. This study inferred that when wayfinding in intersecting parallel roads, individuals will select obvious and easily identifiable landmarks as an indicator reminding themselves to make a turn. Both Nishimon Street and Osanbashi Street have obvious and easily identified landmarks; Nishimon Street has a three-way intersection between Nishimon Street, Chouan Way, and Kitamon Street; and Osanbashi Street has Yokohama Park. These results are consistent with those of Afroz, White, and Parolin (2018), who demonstrated that conspicuous visual hints in the environment function as useful information for wayfinders.
3.3. Statistics and result analysis

This study divided participants in relation to the four factors of the navigation tools used, understanding of environmental information, road characteristics, and nationality. SPSS statistical software was employed to analyze whether each factor significantly influenced wayfinding efficiency. This study referenced the wayfinding indicators analyzed by both Vaez, Burke, and Yu (2019) and Ishikawa et al. (2008) and used them as dependent variables; they are walking time, walking distance, walking speed, and the number of turns made. This study employed ANOVA to discuss the causal relationship between the factors and dependent variables. First, this study conducted two-way ANOVA prior to one-way ANOVA. SBSOD score was not significantly correlated with walking time, walking distance, walking speed, and the number of turns made (Table 5).

Table 6 displays the two-way ANOVA results. Interaction effects were observed between the effects of navigation tools and understanding of environmental information on the number of turns made (F (2,38) = 4.539, p = .016), effects of navigation tools and road characteristics on walking speed (F (2,38) = 3.518, p = .04), effects of navigation tools and participant nationality on walking time (F (2,38) = 3.323, p = .047), and effects of nationality and understanding of environmental information on walking distance (F (1,40) = 28.044, p = .000) and the number of turns made (F (1,40) = 4.466, p = .041).

The results revealed the following significant differences:

1. For numbered lists among the participants who used both maps, local participants (5.25 turns) made more turns than foreign participants (2 turns) (Table 7). This result revealed that the use of the two navigation tools for wayfinding in an unfamiliar environment resulted in wayfinding strategies with fewer turns. The simple main effect analysis results are depicted in Table 8.
This study inferred the reason for this to be better understanding of environmental information of local participants. Such greater knowledge allowed them to quickly pick out relevant information, thus enabling them to quickly confirm their position and direction. This allowed the participants to make more turns and have walked faster relative to other participants. Foreign and local participants differed in their results, albeit non-significantly so. Those who took the most number of turns were local participants who used the two navigation tools, whereas those who took the least number of turns were foreign participants who also used the two navigation tools. This result indicates that wayfinding strategies differ according to environmental familiarity.

1. Among the participants who used both maps, participants at Tamsui (68.81 m/min) had a faster walking speed than did participants at Yokohama (49.99 m/min). (Table 9). The simple main effect analysis results are depicted in Table 10.

This study inferred that this difference was because wayfinding is easier with linear roads than with intersecting parallel roads. Thus, participants in Tamsui walked faster than did participants in Yokohama.
Furthermore, participants wayfinding in regions with intersecting parallel roads had to find their bearings more often, resulting in longer walking time and slower walking speed.

Walking speed differed, albeit nonsignificantly, between the navigation tools used. When wayfinding in regions with linear roads, participants who used both maps had the fastest walking speed. However, when wayfinding in regions with intersecting parallel roads, participants who used paper maps had the fastest walking speed. This result indicates that the design of navigation tools should consider the road characteristics to provide more suitable tools and information for navigation.

(1) When traveling domestically, the walking distance of Taiwanese participants (1576.34 m) was greater than that of Japanese participants (1307.86 m). However, when traveling overseas, the walking distance of Taiwanese participants (1386.43 m) was lesser than that of Japanese participants (1566.94 m). Finally, for Taiwanese participants, the walking distance was greater when traveling domestically (1576.34 m) than when traveling overseas (1386.43 m). For Japanese participants, the walking distance was smaller when traveling domestically (1307.86 m) than when traveling overseas (1566.94 m) (Table 11). The simple main effect analysis results are depicted in Table 12.

The two-way ANOVA results revealed interaction effects between the influence of navigation tools and participant nationality on walking time. The simple mean effect analysis indicated that the influences did not significantly differ (Table 14). However, the statistical results indicated that the walking time of Taiwanese participants (27.9 mins) who used paper maps was greater than that of Japanese participants (23.44 mins) who used paper maps. In addition, the walking time of Taiwanese participants (23.56 mins) who used electronic maps was shorter than that of Taiwanese participants who used paper maps (27.9 mins) (Table 13).

This result is attributable to the participants’ varying experience in using each navigation tool. According to their self-reported characteristics, Taiwanese participants were more likely to be familiar with the use of electronic maps than paper maps, and Japanese participants were more likely to be familiar with the use of paper maps than Taiwanese participants were (Figure 5). Ishikawa et al. (2008) noted that the more familiar participants became with the use of a navigation tool, the closer their walking distances approached the shortest possible walking distance.

According to the results, among participants who used paper maps, the walking distance of Taiwanese participants (1524.86 m) was greater than that of Japanese participants (1299.07 m). In addition, the walking distance of Taiwanese participants who used electronic maps (1377.7 m) was shorter than Taiwanese participants who used paper maps (1524.86 m). These results imply that walking times are reduced when the participant is familiar with the navigation tool used.

Table 15 displays the one-way ANOVA results. According to the results, road characteristics significantly affected walking distance and the number of turns made. Additionally, the walking distance at Tamsui (1571.64 m) was greater than at Yokohama (1347.14 m) (F (1,42) = 27.79, p = .000), and the number of turns was fewer at Tamsui (3.31 turns) than at Yokohama (4.36 turns) (F (1,42) = 4.58, p = .038). This result on walking distance was similar to that depicted in Table 11. Thus, the results in Tables 11 and 15

### Table 9. Navigation performance for different navigation tools and different road characteristics.

|                        | Electronic map | Paper map | Both (electronic and paper maps) |
|------------------------|----------------|-----------|----------------------------------|
| Linear roads (Tamsui)  | 26.83          | 29.33     | 23.25                            |
| Walking time (min)     | 1550.21        | 1605.14   | 1553.54                          |
| Walking speed (m/min)  | 57.82          | 55.93     | 68.81                            |
| Number of turns        | 3.33           | 3.67      | 2.75                             |
| Intersecting parallel roads (Yokohama) | | | |
| Walking time (min)     | 24.08          | 23.83     | 26.75                            |
| Walking distance (m)   | 1321.79        | 1390.37   | 1295.54                          |
| Walking speed (m/min)  | 55.89          | 59.35     | 49.99                            |
| Number of turns        | 4.25           | 4.41      | 4.2                             |

### Table 10. Simple main effect of navigation tool and road characteristics on walking speed.

| Source                      | SS    | df | S       | F     | P     | Post Hos test |
|-----------------------------|-------|----|---------|-------|-------|---------------|
| Navigation tool             |       |    |         |       |       |               |
| (independent factor)        |       |    |         |       |       |               |
| Linear roads (Tamsui)       | 438.352 | 2 | 219.176 | 2.303 | .114  |               |
| Intersecting parallel roads (Yokohama) | 271.34 | 2 | 135.67 | 1.426 | .253  |               |
| Road characteristic         |       |    |         |       |       |               |
| (independent factor)        |       |    |         |       |       |               |
| Electronic map              | 14.917 | 1 | 14.917 | 0.157 | .694  |               |
| Paper map                   | 46.784 | 1 | 46.784 | 0.492 | .487  |               |
| Both (electronic and paper maps) | 708.347 | 1 | 708.347 | 7.443* | .0095 | Tamsui > Yokohama |
| Error                       | 3616.212 | 38 | 95.163 |       |       |               |

To control for Type I Error, alpha was set to .01 for each simple effect. *p < .01.
Table 11. Navigation performance for different levels in understanding of environmental information and different nationalities.

| Greater level understanding of environmental information (local travelers) | Taiwanese participants | Japanese participants |
|---|---|---|
| Walking time (min) | 26.75 | 23.79 |
| Walking distance (m) | 1576.34 | 1307.86 |
| Walking speed (m/min) | 61.17 | 55.99 |
| Number of turns | 3.25 | 4.64 |

| Less level understanding of environmental information (foreign travelers) | Taiwanese participants | Japanese participants |
|---|---|---|
| Walking time (min) | 24.93 | 27 |
| Walking distance (m) | 1386.43 | 1566.94 |
| Walking speed (m/min) | 57.07 | 58.54 |
| Number of turns | 4.07 | 3.38 |

Table 12. Simple main effect of nationality and understanding of environmental information on walking distance.

| Source | SS | df | MS | F | P | Post Hos test |
|---|---|---|---|---|---|---|
| Nationality (independent factor) | 366,978.820 | 1 | 366,978.820 | 20.056 | .000 | Taiwanese > Japanese |
| Less level understanding of environmental information (foreign travelers) | 165,870.541 | 1 | 165,870.541 | 9.065 | .004 | Taiwanese < Japanese |
| Understanding of environmental information (independent factor) | 183,610.271 | 1 | 183,610.271 | 10.035 | .003 | local travelers > foreign travelers |
| Japanese | 341,712.907 | 1 | 341,712.907 | 18.675 | .000 | local travelers < foreign travelers |
| Error | 731,902.598 | 40 | 18,297.565 |

To control for Type I Error, alpha was set to 0.0125 for each simple effect. *p < .0125.

Table 13. Navigation performance for different navigation tools and different nationalities.

| Source | Electronic map | Paper map | Both (electronic and paper maps) |
|---|---|---|---|
| Taiwanese | Walking time (min) | 23.56 | 27.9 |
| | Walking distance (m) | 1377.7 | 1524.86 |
| | Walking speed (m/min) | 58.9 | 56.13 |
| | Number of turns | 3.78 | 4 |
| Japanese | Walking time (min) | 26.44 | 23.44 |
| | Walking distance (m) | 1418.15 | 1399.07 |
| | Walking speed (m/min) | 54.16 | 60.29 |
| | Number of turns | 4.11 | 4.33 |

Table 14. Simple main effect of navigation tool and nationality on walking time.

| Source | SS | df | MS | F | P | Post Hos test |
|---|---|---|---|---|---|---|
| Navigation tool (independent factor) | 86,207 | 2 | 43.104 | 2.348 | .109 | – |
| Taiwanese | 40.51 | 2 | 20.255 | 1.103 | .342 | – |
| Japanese | 37.556 | 1 | 37.556 | 2.046 | .161 | – |
| Electronic map | 88.889 | 1 | 88.889 | 4.842 | .034 | – |
| Paper map | 3.944E-31 | 1 | 3.944E-31 | 0.000 | 1 | – |
| Both (electronic and paper maps) | 697.556 | 38 | 18.357 |

To control for Type I Error, alpha was set to 0.01 for each simple effect. *p < .01.

indicate that pathfinding performance differed with road characteristics.

4. Conclusions

This study revealed that when wayfinding in regions with linear roads, relative to local participants, foreign participants were more inclined to start from roads that were at the exit of the MRT station. When participants were uncertain as to whether a road on the map was accessible by walking, participants were more likely to choose alternative roads to the destination. In addition, users commonly generally used landmarks to determine their current path when wayfinding in regions
with intersecting parallel roads. Paper map users were more inclined to select obvious and easily identifiable buildings as landmarks relative to electronic map users. Although landmark support is crucial in the wayfinding process, because linear roads constitute simple wayfinding environments, participants who correctly judged the distance to the destination do not rely on landmarks. In other words, landmarks are more important when wayfinding in regions with intersecting parallel roads than in regions with linear roads.

In the wayfinding process, participants who used both electronic and paper maps made more turns when wayfinding in a familiar environment than in an unfamiliar environment. Furthermore, the walking time of participants who were familiar with their navigation tools were lower than those who were less familiar.

The one-way ANOVA results indicated that the wayfinding efficiency resulting from the navigation tool used or the participant’s understanding of environmental information did not significantly differ. However, the overall wayfinding efficiency of local participants, who had a greater level understanding of environmental information, was higher than that of foreign participants, who had a less level understanding of environmental information. To enable users to more readily understand guidance information, the design of navigation tools should emphasize wayfinding efficiency-enhancing information on maps through the most appropriate presentation methods.

This study also revealed that the design of navigation tools should consider road characteristics in the provision of suitable information. The design objective of any wayfinding navigation tool is the provision of users with an excellent wayfinding navigation system, thereby increasing user satisfaction and enhancing their willingness to visit revisit the destination.

This study endeavored to accurately capture the behavioral differences of participants in the experiment. This study selected Taiwanese and Japanese citizens as participants. However, cultural similarities (e.g., the use of Chinese characters in the Japanese language) between Taiwanese and Japanese people may influence the experiment results. Future studies on wayfinding behavior and efficiency must be further analyzed with respect to the interaction of road characteristics with navigation tools and individual differences. In addition, further research is necessary to identify the differences between local and foreign travelers with respect to their spatial knowledge acquired. This study provides useful insights into the wayfinding behavior of users of navigation tools. The findings of this study can be used to improve the design and popularity of navigation tools, thus enabling users to arrive at their destinations more quickly and efficiently.

**Disclosure statement**

No potential conflict of interest was reported by the authors.

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**Table 15. One-way ANOVA analysis results.**

|                          | Mean Walking time (min) | Mean Walking distance (m) | Mean Walking speed (m/min) | Mean Number of turns | F-value (P-value) Walking time | F-value (P-value) Walking distance | F-value (P-value) Walking speed | F-value (P-value) Number of turns |
|--------------------------|-------------------------|----------------------------|----------------------------|----------------------|---------------------------------|-----------------------------------|----------------------------------|-----------------------------------|
| **Navigation tool**      |                         |                            |                            |                      |                                 |                                   |                                  |                                    |
| Electronic map           | 25                      | 1397.93                    | 56.53                      | 3.94                 | 0.118                           | 0.609                             | 0.246                            | 0.305                             |
| Paper map                | 25.66                   | 1461.96                    | 58.21                      | 4.17                 | (0.889)                         | (0.549)                           | (0.783)                          | (0.739)                           |
| Both maps                | 25                      | 1423.54                    | 59.40                      | 3.63                 |                                 |                                   |                                  |                                    |
| Understanding of environmental information (local travelers)         | 24.86                   | 1405.49                    | 57.87                      | 4.14                 | 0.377                           | (0.543)                           | (0.378)                          | (0.932)                           |
| Less level understanding of environmental information (foreign travelers) | 25.68                   | 1452.07                    | 57.6                       | 3.82                 |                                 |                                   |                                  |                                    |
| Road characteristics     |                         |                            |                            |                      |                                 |                                   |                                  |                                    |
| Linear roads (Tamsui)    | 26.88                   | 1571.64                    | 59.86                      | 3.31                 | 3.548                           | (0.067)                           | (0.000)                          | (0.301)                           |
| Intersecting parallel roads (Yokohama)                             | 24.38                   | 1347.14                    | 56.53                      | 4.36                 | (0.543)                         | (0.000)                           | (0.036)                          | (0.038)                           |
| Nationality              |                         |                            |                            |                      |                                 |                                   |                                  |                                    |
| Taiwanese                | 25.59                   | 1455.49                    | 58.56                      | 3.77                 | 0.227                           | (0.636)                           | (0.312)                          | (0.597)                           |
| Japanese                 | 24.95                   | 1402.07                    | 56.92                      | 4.18                 | (0.636)                         | (0.312)                           | (0.597)                          | (0.699)                           |

*: p <0.05.
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