A Correlation Analysis between the Sense of Direction and Spatial Visualization in the Wayfinding System of a Complex Environment

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Abstract

This paper presents the findings of an ongoing study that explores the potential relationship between visitors' sense of direction and spatial ability in the context of navigation experience on a university campus. A structured questionnaire and tests were administered to 57 visitors who were unfamiliar with the Universiti Teknologi MARA, Puncak Alam, Selangor campus. The findings suggest that visitors' sense of direction and spatial ability are not significantly correlated. Although previous research has demonstrated a positive correlation between spatial visualization ability and a sense of direction, the relationship between these two factors may be more complex. Effective wayfinding systems require the consideration of visitors' spatial ability, as well as other cognitive processes involved in wayfinding, such as attention, memory, and decision-making of visitors' spatial ability as well as other cognitive processes involved in wayfinding, such as attention, memory, and decision-making. The findings of this study arguably contribute to the discussion of navigation and wayfinding in a complex environment.

Keywords: Wayfinding; Spatial visualization; Wayfinding information system; Complex environment

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1.0 Introduction

Wayfinding information systems (WIS) are crucial in helping visitors navigate complex environments, including large public universities, hospitals, and airports. These systems, which include maps, signages, and directions, provide important cues to visitors about their position, location, route, and place identification (Mustikawati et al., 2018). With the help of wayfinding systems, visitors can easily find their destinations and navigate the environment without getting lost. This has greatly facilitated the navigation of complex environments (Shamsuddin et al., 2018).

Designers of complex environments have developed a variety of wayfinding strategies, including the use of signage, maps, and mobile applications. Signage is one of the most common and effective wayfinding tools and can include directional signs, maps, and symbols to help visitors navigate (Jiang et al., 2018). Maps, either in printed or digital formats, can provide visitors with an overview of the environment and help them plan their routes (Pellanda et al., 2019). Mobile applications that provide real-time navigation and location-based services have also become increasingly popular (Jiang et al., 2018). However, the effectiveness of these systems may be influenced by the spatial ability of the visitors who use them (Luo & Wang, 2021).

Research has shown that visitors who are unfamiliar with a complex environment may experience higher levels of stress and anxiety, and may have difficulty navigating efficiently (Shamsuddin et al., 2022; Jiang et al., 2018). Several barriers can hinder visitors' ability to navigate complex environments. These include inadequate signage and wayfinding systems, environmental factors such as poor lighting or noise, and cognitive impairments such as dementia or attention deficit disorders. Studies have found that poorly designed signage and wayfinding systems can lead to confusion and disorientation, especially for individuals with a low sense of direction and spatial visualization abilities (Evans & McCoy, 1998; Lengacher et al., 2007). Additionally, visitors with cognitive or sensory impairments may experience even greater challenges with wayfinding (Pellanda et al., 2019).

On the other hand, research has shown that individuals with higher spatial ability generally perform better on wayfinding tasks (Wang et al., 2018; Hegarty et al., 2006). Thus, the design of wayfinding information systems that consider visitors' varying spatial abilities may improve the effectiveness of these systems. Specifically, wayfinding information systems. Visitors with higher spatial ability may be better able to understand and utilize the information provided by the wayfinding system, while visitors with lower spatial ability may struggle to navigate the environment despite the availability of wayfinding information.

This article aims to explore the possible relationship between the sense of direction and spatial ability in navigation experience within a complex built environment, in this case, a university campus. It starts with exploring the crucial roles of a sense of direction and spatial ability in navigation, particularly in responding to wayfinding information systems. The analysis follows will focus on significant correlations between those aspects, employing the quantitative analysis based on the correlation coefficient values. This paper then highlights

the sense of direction and spatial ability as cognitive processes that contributes to effective wayfinding.

2.0 Literature Review

2.1 Wayfinding

Wayfinding is the process of navigating and orienting oneself in a physical environment. Wayfinding is about the action of searching visual cues while moving from one place to another, reading the surrounding environment using visual senses (Sengke & Mustikawati, 2019). It involves interpreting information from the environment to understand one's location, determine the direction and distance to a desired destination, and make decisions about how to reach that destination. Wayfinding is important in a variety of settings, including healthcare facilities, airports, and urban environments. Effective wayfinding can improve people's ability to find their way, reduce anxiety and stress, and enhance their overall experience (Pellanda et al., 2019).

According to Kevin Lynch (1960), wayfinding in a built environment can be supported by five elements: paths, edges, districts, nodes, and landmarks. Paths are routes of travel, edges are boundaries or barriers that separate different areas, districts are areas with a common identity or character, nodes are points of decision-making or orientation, and landmarks are distinctive features that can be easily recognized (Lynch, 1960). These elements are used to create mental maps, which help individuals navigate and understand their environment (Lynch, 1960).

However, it is noteworthy that wayfinding is a multidimensional task that involves several cognitive processes (Luo & Wang, 2021). The cognitive processes include attention, memory, and decision-making, contributing to effective wayfinding (Luo & Wang, 2021). Attention plays a crucial role in identifying and processing environmental cues that are relevant to wayfinding, while memory allows visitors to recall relevant spatial information and landmarks to navigate effectively. Decision-making, on the other hand, involves choosing the most suitable route or direction based on the available environmental cues and spatial information. It can be seen that how wayfinding is largely dependent on the spatial ability of the visitors and this will be discussed further.

2.2 Wayfinding Information System (WIS) in a Complex Environment

Wayfinding information systems play a significant role in helping visitors navigate complex environments such as airports, shopping malls, hospitals, and university campuses. Large public universities can be complex environments for visitors to navigate, particularly if they are unfamiliar with the layout of the campus. These environments typically consist of multiple buildings and outdoor spaces, interconnected by a network of roads, sidewalks, and other pathways. Visitors need to be able to orient themselves within this environment and navigate to their desired destinations.

However, it is important to note that other factors can also influence visitors' spatial ability to navigate in a complex environment such as large public universities. For example, familiarity with the environment, cognitive strategies, and prior experience with similar environments can all play a role in navigation ability. Additionally, the complexity of the environment itself, including the presence of obstacles and other barriers to navigation, can also impact visitors' ability to navigate successfully. The more complex the built environment, the more obstacles and barriers to navigation will be.

In the context of large public universities, visitors with higher spatial visualization ability may be better able to mentally represent the layout of the campus and navigate to their desired locations. They may also be better able to use landmarks and other visual cues to orient themselves within the environment. Visitors with a higher sense of direction may be better able to use their innate sense of direction to navigate through the environment, even if they are not familiar with the layout of the campus.

Numerous studies have demonstrated that spatial ability is significantly related to wayfinding performance among visitors, with those who possess higher spatial ability demonstrating better performance on wayfinding tasks (Wang et al., 2018; Hegarty et al., 2006). Spatial ability refers to the cognitive capacity to understand, interpret, and manipulate spatial information in the environment (Lohman, 1996). Visitors who exhibit higher levels of spatial ability are likely to be more proficient in spatial perception and orientation, which can improve their wayfinding performance in various settings, including indoor and outdoor environments, large-scale facilities, and public spaces.

Based on the above elaboration, the sense of direction and spatial visualization abilities are essential for visitors to navigate from one place to another in the context of wayfinding. Thus, in this study, we will discuss two crucial aspects: the sense of direction and spatial visualization ability of the visitors and the correlation. Both arguably often become decisive aspects in the wayfinding and navigation experience, which will be further elaborated on in the section below.

2.2.1 Sense of Direction

The sense of direction is a crucial factor for visitors who navigate in complex environments, and research has shown that individuals vary in their sense of direction, with some people having a better ability to orient themselves in space than others (Hegarty & Montello, 2011). This ability may be influenced by factors such as age, gender, and experience with navigating different environments (Hegarty & Montello, 2011). As wayfinding occurs through movement, it is then crucial to have a sense of direction in experiencing spatial continuity throughout complex environments.

In complex environments, visitors may use a variety of strategies to help them navigate and grasp a sense of direction, including visual cues, memory, and landmarks. For example, visitors may rely on familiar landmarks, such as distinctive buildings or sculptures, to help them orient themselves (Jiang et al., 2018). They may also use memory, such as recalling the route they took on a previous visit, to navigate more efficiently (Jiang et al., 2018). However, relying solely on visual cues and memory may not be sufficient for visitors

who are unfamiliar with the environment. In such cases, wayfinding strategies such as signage and maps can be particularly helpful (Jiang et al., 2018).

Various methods can be used to measure the sense of direction in visitors. One of the commonly used measures is the Santa Barbara Sense of Direction Scale, which consists of 15 items that assess various aspects of the sense of direction, such as the ability to use maps and spatial language, and the tendency to get lost in familiar and unfamiliar environments (Hegarty et al., 2002). Other measures include the Mental Rotation Test, which assesses the ability to mentally rotate objects (Vandenberg & Kuse, 1978), and the Perspective Taking Test, which measures the ability to take different perspectives in spatial tasks (Hegarty & Waller, 2004).

However, it is important to note that these measures assess various aspects of spatial ability and may not necessarily provide a complete picture of an individual's sense of direction in a specific environment (Hegarty & Montello, 2011). In complex environments, factors such as wayfinding strategies and environmental cues may also play a significant role in visitors' ability to navigate (Jiang et al., 2018).

2.2.2 Spatial Visualization Ability

Spatial visualization refers to the ability to mentally manipulate and transform spatial information. It involves the ability to form mental images and to perceive the spatial relationships between objects in space (Sengke & Mustikawati, 2019). Studies have found that spatial visualization abilities are strongly related to wayfinding performance (Hegarty et al., 1999; Montello et al., 1999). People with strong spatial visualization skills are better at remembering spatial information and creating mental maps, which are essential for successful wayfinding.

Spatial ability or spatial visualization refers to the cognitive ability to mentally manipulate and transform visual-spatial information, which is essential for navigation and wayfinding. A Wayfinding Information System (WIS) is a technological tool that provides people with information about their current location, destination, and route guidance. The use of spatial ability instruments for WIS can improve the efficiency and effectiveness of wayfinding systems, particularly for individuals with a low spatial ability (Din et al., 2020).

There is a significant correlation between spatial visualization ability and the effectiveness of wayfinding information systems (WIS) among visitors in large public universities. Research has shown that individuals with high spatial ability are more effective at using WIS to navigate complex environments, while those with low spatial ability may struggle to understand and follow WIS instructions (Hegarty & Waller, 2004).

In a study conducted by Kim and Lee (2018), researchers examined the relationship between spatial visualization ability and WIS use among visitors to a large public university in South Korea. The study used a survey to collect data on participants' spatial visualization ability, WIS use, and navigation success. The results showed that participants with higher spatial visualization ability scores were more likely to use WIS and were more successful at navigating the university campus using WIS. Participants with low spatial visualization

ability scores, on the other hand, were less likely to use WIS and had a lower rate of navigation success.

These findings suggest that incorporating spatial ability measures into WIS design and implementation could help improve the system's effectiveness, particularly for individuals with lower spatial ability. By tailoring WIS to users' cognitive abilities, universities and other large public spaces can help ensure that all visitors can navigate their facilities efficiently and effectively (Kim & Lee, 2018).

Accordingly, the sense of direction and spatial visualization ability can play an important role in visitors' ability to navigate in such complex environments. For example, a study by Montello and Pick (1993) found that participants with higher spatial visualization ability were better at navigating through a virtual environment than those with lower spatial visualization ability. Similarly, a study by Ishikawa and Montello (2006) found that participants with a higher sense of direction were better at navigating through a real-world environment than those with a lower sense of direction.

While spatial ability is a vital factor that contributes to effective wayfinding performance, it is essential to recognize that wayfinding in complex environments is a multidimensional task that requires the engagement of other cognitive processes. In conclusion, the sense of direction and spatial visualization ability are important factors that can influence visitors' ability to navigate large public universities. While research has shown that these factors can be important predictors of navigation ability, it is important to consider other factors that can also impact navigation success in complex environments like large public universities. Therefore, a comprehensive understanding of the various cognitive processes involved in wayfinding can improve the visitor experience and facilitate effective navigation in various settings.

3.0 Methodology

The primary objective of this study was to explore the potential relationship between visitors' sense of direction scores and spatial ability scores, with a specific focus on whether significant correlations exist between these variables. To address the research questions, this study employed a quantitative approach to describe the correlation between two aspects of wayfinding, particularly related to the sense of direction and spatial visualization. Thus, an interpretive table was constructed to measure the respective levels of Santa Barbara sense of direction and spatial visualization ability.

To obtain the results and achieve the objectives of this study, a quantitative approach was employed, and the methodology implemented by the researcher to collect the data is discussed in this paper. A structured questionnaire and tests were administered to visitors who were unfamiliar with the Universiti Teknologi MARA, Puncak Alam, Selangor campus to obtain the data required for the analysis. The visitors who visited the campus are willing to participate in a wayfinding task and answered the survey given by the researcher.

This study employed quantitative research methods to investigate the relationship between visitors' sense of direction and spatial ability test scores. After the wayfinding task

was recorded, the data collected from the respondents were analysed using the Statistical Package for the Social Sciences (SPSS) in this study. SPSS is a widely used software for statistical analysis that enables researchers to analyse large datasets and generate accurate results. This study employed SPSS to analyse the data and establish any significant relationships that exist between visitors' sense of direction and spatial ability scores.

3.1 Procedure

Participants are adults with normal vision who are willing to participate in the wayfinding task and navigate the Universiti Teknologi MARA (UiTM), Puncak Alam campus, located in the state of Selangor. In addition to these requirements, the participant must own a driving license, must be able to drive, have access to a smartphone, and is unfamiliar with the UiTM Puncak Alam campus in Selangor. Fifty-seven participants from the total sample of individuals took part in this activity. The researchers indicated their appreciation to every one of them individually by presenting them with a memento in recognition of their participation in the activities.

The participant was given two different tasks to accomplish to successfully finish the wayfinding activity. The first task (Navigation activity) was to navigate to twelve different sites that had been predetermined by the researcher using either wayfinding or navigation skills. The locations are (1) Fakulti Seni Lukis dan Seni Reka (1st checkpoint), (2) Dewan Berlian, (3) Tadika, (4) Hospital UiTM, (5) Kompleks At-Tijarah, (6) Hotel UiTM, (7) Unit Kesihatan UiTM, (8) Perpustakaan Tun Abdul Razak, (9) Pejabat Rektor, (10) Fakulti Farmasi, (11) Padang Kawad) and (12) Surau Alam Bina.

After the participant had completed the navigation activity, they were instructed to proceed to the second task (survey). They had a total of thirty minutes to complete answering questions via a paper-and-pencil test that were based on two instruments. The instruments are demonstrated in Table 1.

Table 1: The sense of direction and visual-spatial instruments

Test	Purpose	Administration	Scoring	Validity and Reliability
SBSD (Hegarty et al., 2002)	Measures sense of direction ability	Self-administered paper-and-pencil test	Participant estimates orientation and distance from the target	A valid and reliable measure of sense of direction ability (Hegarty et al., 2002)
CRT (Ekstrom et al., 1976)	Measures spatial visualization ability	Self-administered paper-and-pencil test	Participant mentally rotates a set of cards to match a target card	A valid and reliable measure of spatial visualization ability (Hedley, Brewer, & Heyes, 2016;

				Vandenberg & Kuse, 1978)

The SBSD (Santa Barbara Sense of Direction) (Hegarty et al., 2002) and CRT (Card Rotation Test) (Ekstrom et al., 1976) are both paper-and-pencil tests that can be self-administered. The SBSD assesses an individual's sense of direction ability, while the CRT assesses spatial visualization ability. The SBSD requires participants to estimate their orientation and distance from a target, while the CRT requires participants to mentally rotate a set of cards to match a target card. Both tests are valid and reliable measures of their respective constructs. The SBSD has been validated in various populations, including visitors to complex environments (Hegarty et al., 2002), while the CRT has been used to assess spatial visualization ability in various populations, including visitors to museums (Hedley, Brewer, & Heyes, 2016).

This study followed a quantitative research design and involved survey and field study methods. The data collected were descriptively and inferentially analysed. Descriptive statistics were used to measure the propensity to centralize and the dispersion of the data, as indicated by the mean value and standard deviation. To achieve the research objectives, the collected data were analyzed using statistical methods. The SPSS software was used to conduct inferential analysis to establish the correlation between visitors' sense of direction and spatial ability test scores. The results of the inferential analysis were presented in tables and graphs for ease of interpretation.

4.0 Results

This article presents the outcomes of the data analysis conducted to achieve the objective of the research. The objective was to investigate the potential correlation between visitors' sense of direction and spatial ability test scores in navigation experience. Participants were chosen at random from among 57 visitors from the Klang Valley who visited the UiTM Puncak Alam campus in Selangor to collect data for the study.

This study focused on a random selection of male and female visitors to the Universiti Teknologi MARA, Puncak Alam campus, aged between 18 to 49 years old, who were unfamiliar with the campus and were tasked to navigate without using any navigation applications (Waze/ Google Map). The participants had answered a survey of wayfinding and sense of direction questionnaire after the navigation. The results of the study revealed a correlation between visitors' sense of direction and spatial ability test scores in navigation experience. Interestingly, the descriptive statistics showed that the mean value of spatial ability scores was higher than that of the sense of direction scores, indicating that visitors' spatial ability is relatively more developed than their sense of direction. This finding holds important implications for the design of navigation systems in complex environments, such as university campuses.

The results of the data analysis established a significant correlation between the two variables. The study findings can be used to inform navigation design in complex

environments such as university campuses. Since the data for the variable sense of direction of the ordinal scale and the spatial ability data are ratio-scale or nominal then the type of correlation used is Spearman's 'rho'. The value of the correlation coefficient used in this study is the value of the modified correlation coefficient of the value of the Jackson Correlation Coefficient (2006), Table 2 shows the correlation value according to the level interpretation.

Table 2 Correlation Coefficient Values by Level

Coefficient Value	Level
0.7 – 1.0	Very strong
0.5 – 0.69	Strong
0.3 – 0.49	Medium strong
0.10 – 0.29	Weak
0.01 – 0.09	Very weak

Source: Modified from Jackson (2006)

Table 3 presents the relationship between visitors' sense of direction scale and spatial ability score. The results of this study revealed a non-significant correlation between the two variables, with r = -.068 and sig .616 (p> .05). Therefore, the research question that aimed to investigate the potential correlation between visitors' sense of direction and spatial ability test scores in navigation experience is rejected. The findings suggest that visitors' sense of direction and spatial ability are not significantly correlated in the context of the navigation experience.

Table 3 Relationship Between Sense of Direction Scale and Spatial Ability Score Among Visitor

Variable	Spearman's Correlation 'rho'	Sig (2-Tailed)
sense of direction scale * spatial ability score among visitors	.068	.616

These results imply that navigation design should consider both factors separately and not assume that an improvement in one will lead to an improvement in the other. The lack of a significant relationship between the sense of direction scale and spatial ability score among visitors might be due to other cognitive processes such as attention and memory that are also involved in navigation tasks. Further studies could investigate the role of these cognitive processes in the navigation experience and their potential relationship with visitors' sense of direction and spatial ability.

Even though this study found no significant relationship between visitors' sense of direction and spatial ability test scores in navigation experience, it suggests a further idea that might be useful for wayfinding information system. The results suggest that navigation

design should take into account both factors separately and not assume a relationship between them. Further studies could explore other cognitive processes involved in navigation tasks and their relationship with visitors' sense of direction and spatial ability.

5.0 Discussion

Spatial visualization ability and sense of direction are both related to spatial abilities, which involve understanding and manipulating spatial relationships between objects and environments. Spatial visualization ability refers to the ability to mentally rotate and manipulate objects in space, while the sense of direction refers to the ability to orient oneself and navigate through the environment. Previous research has suggested that there is a positive correlation between spatial visualization ability and the sense of direction. In other words, people who are better at mentally manipulating objects in space are also better at navigating through real-world environments. However, the study suggested that there may not be a significant relationship between a spatial ability test scores and visitors' sense of direction in a navigation experience.

There could be several reasons for this apparent contradiction. First, it is possible that the specific spatial ability test used in the study may not have been a good measure of participants' spatial visualization ability. There are many different spatial ability tests and some may be better suited to measuring different aspects of spatial abilities than others.

Second, the study may have used a navigation task that was not challenging enough to reveal differences in sense of direction between participants with different levels of spatial ability. In other words, the navigation task may have been too easy, allowing participants with a lower spatial ability to perform well and obscuring any differences between them and those with higher spatial ability.

Finally, there may be other factors that influence the sense of direction and navigation ability, such as experience with the specific environment or individual differences in cognitive strategies. These factors may have played a stronger role in the study than participants' spatial ability test scores. It demonstrates that while previous research has suggested a positive correlation between spatial visualization ability and sense of direction, the relationship between these two factors may be more complex than previously thought. Further research is needed to understand the factors that influence the sense of direction and navigation ability and how they interact with spatial ability.

6.0 Conclusion

The main objective of this study was to explore the potential correlations between visitors' sense of direction and spatial ability test scores during navigation. Using a quantitative approach, the researcher randomly selected 57 visitors from the Klang Valley who visited the UiTM Puncak Alam campus in Selangor and administered a structured questionnaire and tests to collect data. Through the inquiry into the correlation between the sense of direction and spatial visualization abilities, we can identify that those two aspects are crucial

in wayfinding in a complex environment. According to the theoretical exploration, both aspects constitute the cognitive process that occurs during the visitor's navigation experience. It is important to recognize that wayfinding in complex environments is not solely dependent on spatial ability, but also the sense of direction.

Aside from the importance of the Wayfinding Information System (WIS) of the environment, this study found that a sense of direction and spatial ability are both influential and potentially correlated in the wayfinding mechanism of the visitors. Based on quantitative inquiry of the gathered data, the findings signify that the visitor's spatial visualization ability is a variable that is relatively more developed than their sense of direction during the wayfinding. However, after further analysis through Spearman's rank correlation, both variables suggest a non-significant relationship. The two variables have a small relation association in wayfinding towards each other, which would be a different finding from existing research. It demonstrates that while previous research has suggested a positive correlation between spatial visualization ability and sense of direction, the relationship between these two factors may be more complex than previously thought.

This becomes an important insight that would shift our perspective in considering both variables in developing WIS in a complex environment. To improve the visitor's wayfinding experience, designing effective WIS requires consideration of the varying spatial abilities of visitors and engagement of other cognitive processes involved in wayfinding, such as a sense of direction. Several barriers can hinder visitors' ability to navigate complex environments, including inadequate signage and wayfinding systems, environmental factors, and cognitive impairments. By recognizing the multiple processes of wayfinding, designers can create wayfinding systems that improve the visitor experience and facilitate efficient navigation.

The study raises further questions on how a WIS of a complex environment should be improved, particularly as visual cues that can be aid of better sense of direction and spatial visualization ability. This would be a challenge for designers of complex environments that have developed a variety of wayfinding strategies, including the better use of signage, maps, and mobile applications, that can help the sense of direction through the legibility of the built environment or objects as visual cues and creating a visual continuity of the WIS through the employment of technological tools and techniques.

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Article Contribution to Related Field of Study

This research has the potential to make contributions in various fields. Firstly, by exploring the relationship between sense of direction and spatial ability, it may inform the

development of new spatial visualization tools and techniques to enhance visitors' wayfinding abilities in complex environments. Secondly, the findings could aid in the creation of wayfinding information systems that are better tailored to visitors' strengths and limitations in wayfinding. Thirdly, the research offers insights into the cognitive processes involved in navigation experience, potentially contributing to the development of theories and models of navigation.

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