The Role of Maps and Signage in Interior Wayfinding: An Exploratory Qualitative Study

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Abstract

Finding one's way around complex and large buildings, such as hospitals, airports, and educational facilities, can be challenging. Using maps and signage to address wayfinding issues in such buildings is one of the most common solutions. Despite extensive research on maps and signage, few studies have systematically explored how and when people use maps and signage in real-world situations during interior wayfinding. To address this gap, an exploratory, qualitative approach was adopted. Eleven participants were tasked with finding 12 targets within two university buildings. Participants were asked to voice out their thoughts (think-aloud protocol) while carrying out the tasks. Their think-aloud protocol and behavior were recorded and analyzed. The results revealed that the type of initial information available about the target could influence participants' preferences for maps over signage or vice versa. Maps were not often used as the first strategy during wayfinding. Participants were perplexed when they consulted maps in different corridors because each map rotated differently to align with the adjacent corridor. Design issues regarding maps and signage were identified and discussed.

Keywords

wayfinding, map, signage

INTRODUCTION

Wayfinding is "a goal-directed (Montello & Sas, 2006) spatial problem-solving process (Arthur & Passini, 1992) under uncertainty in which one finds a route to a particular target and recognizes the target when approaching it (Chen et al., 2009); this process depends on "perception, information processing, and decision execution" (Jamshidi & Pati, 2020, p. 2). While performing wayfinding in real-world situations may depend heavily on navigating within the environment, it is critical to differentiate these concepts. A critical part of wayfinding is the problem-solving process in which a user should find a route toward a target. However, a user can navigate in an environment where s/he does not need to perform the problem-solving process because the user already knows how to get to the intended target. Thus, wayfinding is essentially a cognitive process that may rely on other processes, such as navigation, to execute wayfinding decisions or gather more information within an environment.

Wayfinding can be challenging, especially in large, complex buildings such as airports, hospitals, and educational facilities. Two main approaches have been used to help people to deal with the challenges during the wayfinding process: (1) relying on wayshowing systems (e.g., signage and map) and (2) reducing the complexity of the environment (Jamshidi & Hashemi, 2020). The first approach aims to reduce the cognitive load associated with wayfinding by providing information regarding potential destinations within a building from a reliable source. Usually, in large and complex environments, targets are not visible from different locations within a building, which makes the wayfinding process challenging. To address this issue, maps and signage are the two most important elements that have been used to compensate for the lack of visibility of targets. This approach has been widely used in complex and large buildings

and its effectiveness has been extensively examined in the literature (e.g., Hashim et al., 2014; Richardson et al., 1999; Vilar, Rebelo, Noriega, Duarte et al., 2014).

In the second approach, however, the focus is on the global environmental elements (e.g., floor plan configuration, corridors, nodes, etc.) and their attributes (e.g., complexity, connectivity, visibility, brightness, color, etc.) to reduce the complexity of the environment, and hence reduce the cognitive load associated with the problem-solving process of wayfinding (e.g., Haq & Zimring, 2003; Li & Klippel, 2016; Lu & Ye, 2019). This paper expands the examination of the first approach. Accordingly, the purpose of this study is to enhance understanding of the wayfinding process in complex indoor environments. Specifically, it aims to explore the role that maps and signage play in aiding individuals to navigate these spaces.

LITERATURE REVIEW

Current evidence pertaining to maps and signage found in the literature is presented in the following sections. For a comprehensive review of environmental factors' role in wayfinding, see Jamshidi et al. (2020).

MAPS

Hölscher et al. (2009) found that novice wayfinders used maps more often than users familiar with the environment; however, the use of maps did not fill the spatial knowledge gap between them. Multiple studies found that using maps can negatively impact wayfinding performance because using maps is time-consuming (Butler et al., 1993; Hölscher et al., 2009; Wright et al., 1993). The evidence in the literature suggests that using signage can help people find targets faster than using maps (Butler et al., 1993; Chen et al., 2009; Wright et al., 1993). The level of detail provided on maps was also influential on wayfinding performance, such that participants who used a schematic map had better behavioral performances (i.e., shorter completion times and shorter route distances) compared to the ones who used a standard floor plan (Meilinger et al., 2006). Using maps was found to improve some measurements of spatial memory (such as estimating the relative locations of landmarks and the straight-line distance between them) more than navigating the real-world environment (Thorndyke & Hayes-Roth, 1982). In an experiment, Levine et al. (1984) found it was more challenging for participants to solve wayfinding tasks in a library building when You-Are-Here maps were misaligned with a building (i.e., the map was not oriented to match the viewer's position in relation to the adjacent corridor).

Signs

The literature suggests that signage can help people find targets faster than maps (Butler et al., 1993; Chen et al., 2009; Wright et al., 1993). However, signs cannot compensate for challenges caused by floor plan complexity (O'Neill, 1991b). The type of visual communication used on signs can also impact users' performance, such that graphic signs resulted in faster identification of targets than textual signs (O'Neill, 1991b). Combining icons and words was found to decrease the task completion time even more than signs with only texts or only icons (Cope et al., 1999). A study found that color trails on the floor can enhance multiple aspects of wayfinding performance more than color-coded signage panels; however, the difference was not statistically significant (Vilar, Rebelo, & Noriega, 2014).

People's psychological state appears to influence their preference to use signs or rely on environmental affordances such as brighter and wider corridors (Vilar, Rebelo, Noriega, Duarte et al., 2014). For example, in nonemergency egress, people tended to use brighter and wider corridors in the absence of signage; and they tended to follow signs if signage was available. However, in emergency egress, some people relied on environmental cues (e.g., the width of corridors) rather than signage (Vilar, Rebelo, Noriega, Duarte et al., 2014). Finally, people from different countries may comprehend signs differently. Levels of education and culture were found to contribute to this discrepancy (Hashim et al., 2014; Joy Lo et al., 2016).

RESEARCH OBJECTIVE AND QUESTIONS

Although maps and signage are among the environmental factors that have been extensively studied, most of the studies on wayfinding have used a confirmatory approach (Jamshidi et al., 2020). In the confirmatory approach, some known attributes or environmental elements are manipulated to investigate causation. Although

using a confirmatory approach is important, this approach cannot explore unknown attributes of maps and signage that may influence the wayfinding process. Relying solely on confirmatory methods, while neglecting exploratory strategies, can lead to several limitations. These include hindering a comprehensive understanding of the topic, discouraging theory formulation, obscuring the fundamental processes underlying observed events, and missing out on unexpected discoveries (Jamshidi & Pati, 2024).

Utilizing an exploratory approach can address this gap in the literature. Accordingly, this study addresses the following research questions, in an attempt to identify additional attributes of maps and signs, hitherto unknown, which may aid in wayfinding decision-making:

1. How do users use maps and signage in real-world interior wayfinding?
2. What attributes of maps and signage can facilitate or impede interior wayfinding?

The novelty of this study lies in its implementation of an exploratory qualitative method to address the discussed gap in the literature concerning the role of maps and signage in interior wayfinding. The findings of this study are expected to deepen our theoretical understanding of wayfinding, as well as to aid in the development of design recommendations for creating more effective maps and signage.

METHODS

This study adopted an exploratory, qualitative approach from a post-positivist perspective. The primary data sources were think-aloud protocols and observation of participants. The study was approved by the institutional review board (IRB) of the parent institution of the researchers.

Participants

A convenience sampling strategy, followed by purposive sampling was adopted. Students and staff of the university were invited to participate. The eligibility of interested potential participants was then assessed using the inclusion and exclusion criteria listed below. Participants had to be between the ages of 18 and 50 and capable of performing study tasks independently. This age range was specifically chosen because this study was conducted amidst the COVID-19 pandemic, and the IRB imposed limitations to mitigate the spread of the virus among high-risk populations. The participants had normal or corrected-to-normal vision and no hearing deficits. They had to be unfamiliar with the study setting. Participants were required to be fluent English speakers and not have a background in architecture or allied disciplines (e.g., interior design). All participants received monetary compensation for their participation (US $20).

Study Setting

The study was conducted in two buildings on the campus of a large university in western Texas. Building 1 (B1) consists of two parts: the older part has three levels (including a basement), and the newer part has seven levels (including a basement). The two parts are connected via the first and second floors, not the basements. Several you-are-here (YAH) maps are mounted on the walls of this building. However, they are not present on all levels. YAH maps are aligned with the adjacent corridors, so they match the viewer's position in relation to the corridor. Room numbers begin with the digit indicating the floor level, lacking distinction between building sections (old versus new) in their numbering system.

Building 2 (B2) has three levels, including a basement. The courtyard in the center of B2 is visible from various parts of the building. A collection of floor plans is posted on a board in the building's southwest area, while evacuation plans are mounted on the walls throughout the building. Room numbers begin with a digit indicating the floor on which they are located. See Figure 1 and Figure 2 for floor plans of B1 and B2, respectively.

Data Types and Instruments

This paper focuses on two primary data sources: (1) wayfinding thought processes and (2) wayfinding behaviors. As a spatial cognitive variable, "a wayfinding thought process consists of the mental processes underlying wayfinding as a spatial problem-solving process, which may result in learning new spatial information" (Jamshidi, 2021, p. 28). Participants were prompted to voice out their thoughts while searching for targets (think-aloud protocol) to collect data on the wayfinding process. If participants were silent

for an extended period, the researcher prompted them to think aloud. Participants' voices were recorded using a digital voice recorder (Sony ICD-PX370) and a microphone (Sony ECM-CS3).

A handheld camcorder (GoPro Hero 8) was used to record participants' wayfinding behavior to collect data. Wayfinding behavior is "any sequence of consciously or subconsciously directed life processes that result in changes of location through time" (Golledge & Stimson, 1997, p. 155).

Data Collection and Analysis

Participants were taken to a room in B1, where they were fitted with a microphone and a voice recorder. Next, they were taken to the starting point in one of the two buildings and asked to find the first target within that building. Each participant was instructed to locate a total of six targets within each building (12 targets in total). Table 1 shows the list of targets. As each participant had to independently find their way to the targets, the path taken by each individual was unique. They were instructed to think aloud while performing tasks. The order of visiting buildings was determined based on the participants' availability and the buildings' operation hours.

To enhance the trustworthiness of the collected data, multiple measures were used. First, the think-aloud protocol data were triangulated with the data from observations (video recordings). Second, to address the carryover and tiredness effects, the order of buildings was altered for different participants. Third, participants were asked to explain their decisions in random locations to reduce their sensitivity to the researcher's inquiry about their behaviors throughout the trial. This technique was used to reduce the effect of the data collection process on participants' behavior.

A grounded theory approach was used to analyze the think-aloud protocol and participant behavior data to develop hypotheses about how participants used maps and signage and what attributes of maps and signage facilitated or hindered the wayfinding process. To that end, coding, interpreting, and analyzing collected data was done through a memoing technique. Memoing is a technique to analyze qualitative data and enables the researcher to explore the meanings within the data (Birks et al., 2008). To achieve this objective, the data collected from the think-aloud protocol were transcribed and analyzed to identify thematic codes. Subsequently, memos, which are analytical notes pertaining to these codes, were created. Following this, ideas that best interpreted the data were defined. It is worth noting that although grounded theory is a methodology for constructing theories, it does not necessarily result in the formulation of a specific theory (Charmaz, 2014).

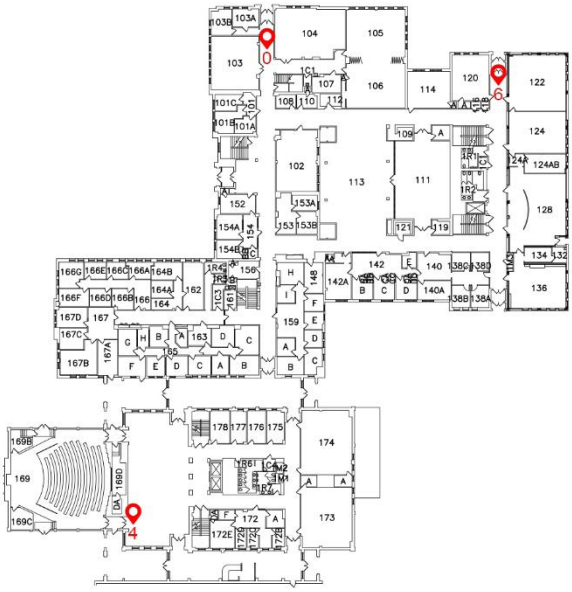
Table 1 / Starting Points and the Sequence of Destinations Used in the Wayfinding Tasks

Building name	Starting point	Sequence of destinations
Building 1 (B1)	Entrance 1H6	Room 211 A-I, Room 306, Room 61, Lecture Hall, Room 244, North-East Entrance
Building 2 (B2)	South-East Entrance	Room 73, Room 104, Dpt. of Political Science – Online and Graduate Center, Room 206, Room 136, South Main Entrance

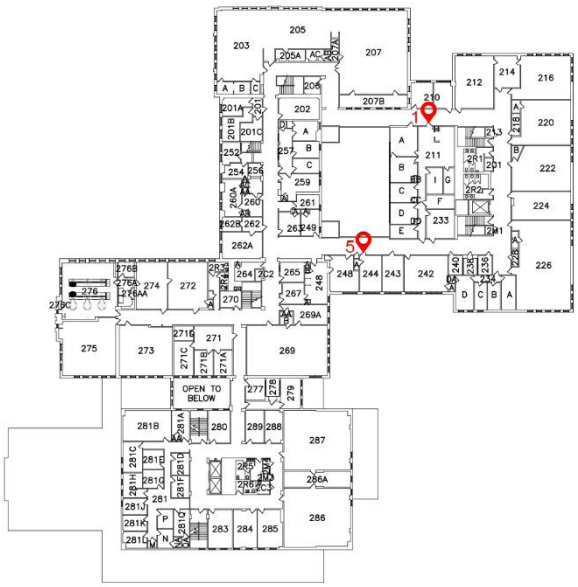
Figure 1 / Floor Plans of Building 1 (B1)

Note. This building consists of seven levels (including a basement). The floor plans of other levels are not provided because none of the tasks were performed on these levels.

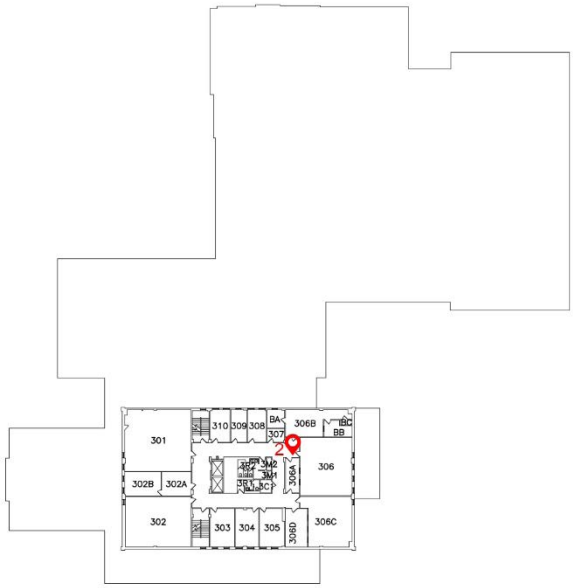
(a) Basement-floor plan



(b) First-floor plan

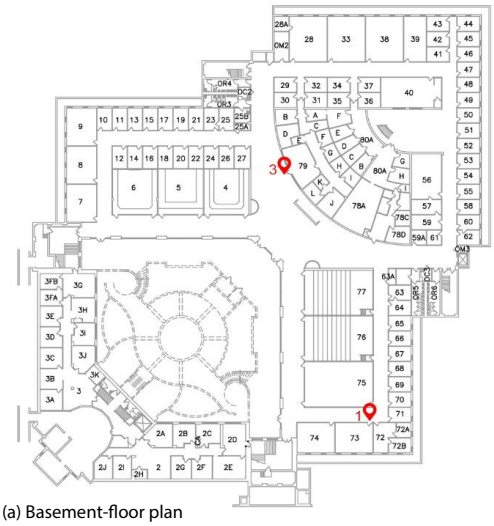


(c) Second-floor plan

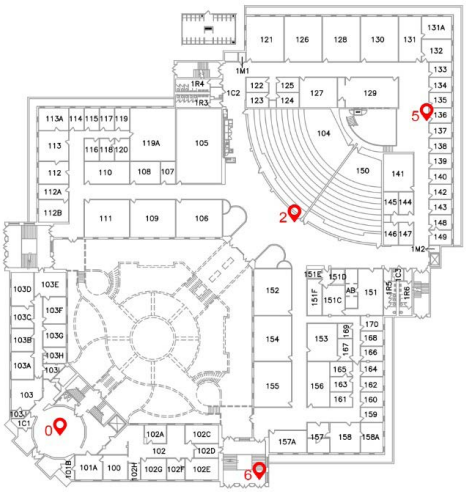


(d) Third-floor plan

Figure 2 / Floor plans of Building 2 (B2)



(a) Basement-floor plan



(b) First-floor plan

(c) Second-floor plan

RESULTS

Eleven participants finished all the tasks: six were females (55%) and five were males (45%). Subjects ranged in age from 18 to 33, with an average age of 23.2 years. Eight participants identified themselves as Caucasian, one Black/African American, one Latino, and one Asian (Table 2). Three participants started from B1, and eight started from B2.

Table 2 / Demographic Information of Participants

Subject ID	Sex	Age	Ethnicity	Task duration (minutes)
1	Female	18	Caucasian	113
2	Female	19	Caucasian	90
3	Female	19	Caucasian	92
4	Female	19	Caucasian	92
5	Female	21	Caucasian	106
6	Female	26	Caucasian	89
7	Male	20	Caucasian	81
8	Male	23	Black/African American	132
9	Male	28	Latino	106
10	Male	29	Asian	127
11	Male	33	Caucasian	88

Maps

In the following sections, results regarding maps are reported. Maps are a "diagrammatic, 2-dimensional representation of the global environment" (Pati et al., 2015, p. 50).

Information from Maps

The mismatch between the type of information provided by maps and the type of information participants had about the target determined whether maps were useful to them. For example, in B2, when participants had only room numbers, they could not use maps effectively because most were fire maps with no information regarding room numbers (Figure 3). Maps on each level often included information pertinent to that level. Thus, maps had low utility for participants searching for targets at a level other than their current one. However, maps were also instrumental for some participants to learn about other sections (regions) within a building and visualize the location of rooms.

When Maps Were Used

The evidence suggests maps were not often used as the first strategy. For example, in B1, the first wayfinding

task was introduced when participants stood by a map; however, only four out of eleven participants consulted the adjacent map. Observation suggests that participants tended to refer to maps more when given a room name (e.g., the lecture hall) or cardinal direction (e.g., the south entrance) as the target instead of a room number.

How Maps Were Used

Participants converted the information on maps into a series of route directions (i.e., actions).

Map Alignment

Maps were aligned with adjacent corridors at the study sites. However, some participants were perplexed because they were unaware of this fact. More importantly, when participants consulted maps in different corridors, they were confused because each map rotated differently to align with the adjacent corridor. One explanation for this confusion could be that to match the information on the two maps, participants needed to mentally rotate the memorized series of actions extracted from the first map, which imposed a cognitive load on them.

Map Design Issues

In B1, maps lacked a compass symbol indicating north, making it challenging for participants to identify targets with cardinal indicators. Contrary to participant expectations, the north did not correspond to the top of some maps because they were aligned with adjacent corridors. Also, it was not communicated on the maps that they aligned with the adjacent corridor, confusing some participants.

Some rooms were not labeled correctly on the maps. For example, the lecture hall in B1 was labeled as a classroom on the maps. Additionally, some participants had difficulties identifying stairs on the maps in B1 (Figure 4). In B1, some participants had difficulties distinguishing the inside from the outside when reading maps. For example, a participant thought the connecting hall in B1 was outside the building when consulting a map. For some participants, the icon used to indicate a person's current location on YAH maps (i.e., the university logo) was not easily perceived as the person's current location.

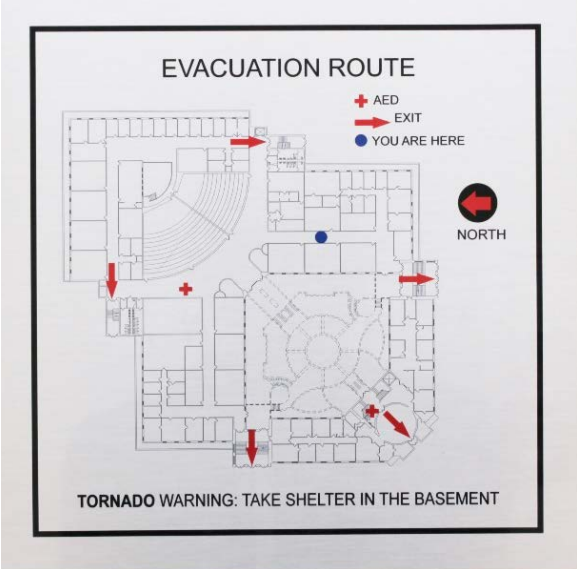


Figure 3

A Fire Map in B2

Figure 4

A Map in B1

Figure 5

A Room-Number-Range is an Example of a Categorical Sign in B2

Figure 6

An Example of a Factual Sign in B1

Signs

Signs are elements consisting of texts and graphics that provide directional (O'Neill, 1991a), identification, and instructional information about a building (Jamshidi, 2021). The following sections present results regarding signs.

Different Types of Signs

Four different types of signs were identified in the study sites: identification, categorical, factual, and directional signs. Identification signs are unique labels assigned to a spatial entity (e.g., room numbers). Categorical signs provide information regarding a group of spatial entities. For example, in B2, the signs of different departments and the room-number-range signs (Figure 5) were considered categorical signs. Factual signs provide a description of the circulation network. An example of a factual sign in B1 was a sign stating that "Rooms 63 and 69 are not accessible from this stairway" (Figure 6). Finally, directional signs suggest a course of action at decision points to move toward a target (e.g., a sign with an arrow).

Signs and Direction Type

The evidence suggests that the type of information participants were provided about targets influenced their preference for the type of signage they sought. For example, when participants' only information regarding targets was room names rather than room numbers, they tended to look for a directory. The following verbal protocol illustrates this point: "I am just going to wander until I see some kind of directory."

Understanding the Signs' Numbering System

Several participants did not initially recognize that the first digit of room numbers corresponded to the level of the building on which the room was located, negatively impacting their wayfinding performance.

Signs and Maps

Some participants used the information from signs (e.g., see the sign shown in Figure 7) and maps together to successfully perform wayfinding tasks. However, since maps were not necessarily located close to signs, participants probably memorized the information from the signs before finding a map. Some participants forgot what they had memorized by the time they found a map.

Signs and Regions

In B2, signs indicated the range of room numbers located in different building parts. This type of sign facilitated participants' wayfinding performance because they could find the correct region first, reducing the area they needed to search to identify a particular room. Additionally, in B2, the signage of different departments (i.e., a conceptual category type of region) on each floor was not visible from the main lobby, negatively impacting participants' performance.

Signs and Attention

In B2, a sign in the middle of one of the corridors was meant to prevent students from crossing the line on which the sign was placed (see Figure 8). Despite the intention for the sign's extreme visibility, the majority of participants walked past the sign.

Sign-Design Issues

In a directional sign in B1 (see Figure 7), two types of information were unclear to participants: (1) the use of cardinal directions and (2) the reference to the old part of the building when no other signs indicated the old and new parts of the building.

Participants tried to check room signs from a distance while standing at either end of the corridor. They did so to determine whether room numbers were increasing or decreasing without walking along the corridor. However, in study sites, signs were wall-surface mounted, making it difficult for participants to use this strategy. Using projecting signs rather than surface-mounted signs might have facilitated this process.

Figure 7

The Sign Instructed People to Walk Past the Dean's Office but Did Not Clarify its Location

Figure 8

A Sign in the Middle of One of the Corridors Meant to Prevent Students From Crossing the Line on Which the Sign was Placed. Despite the Intention for the Sign's Extremely Visibility, the Majority of Participants Walked Past the Sign

DISCUSSION

Four noteworthy findings emerged from this study, each meriting further examination. First, it was observed that maps were not frequently used as the primary wayfinding strategy. However, the reasons behind this trend remain unclear. Two plausible explanations can be put forth to elucidate this observation. The first explanation suggests the maps available on each level predominantly contained information relevant only to that specific level, thereby decreasing their utility for participants engaged in multi-level wayfinding. Alternatively, the second explanation proposes that, in real-world wayfinding scenarios, individuals may display a preference for seeking assistance from other people to locate their target rather than relying on a map. Both of these explanations warrant deeper investigation to better understand the factors influencing wayfinding strategy choices and their implications for design and implementation of wayshowing systems.

The second noteworthy finding pertains to the confusion experienced by certain participants when consulting two maps that were rotated differently to align with their respective adjacent corridors. This finding contradicts the results of Levine et al.'s study (1984). However, it is plausible that Levine et al. (1984) did not account for the real-world complexity where multiple maps in a building may be oriented differently based on their specific locations, and individuals may need to refer to several maps during their wayfinding journey. This particular factor warrants further in-depth research to explore the impact of map orientation variations on users' wayfinding efficiency and cognitive processes.

Third, when participants did not have any information about the floor on which the target was located, maps had low utility since they only had access to the map of their current floor. Accordingly, providing a complete set of building maps at all levels may better facilitate wayfinding. To that end, digital screens can be used to save space. Furthermore, it is suggested that, along with maps, a three-dimensional bird's-eye view of the building be used to introduce the different parts and regions of the building. This strategy can be especially important in buildings with multiple parts with a different number of levels in each part. These suggestions constitute design hypotheses that could be the subject of future studies.

Finally, in this study, participants found targets relatively more easily when given room numbers instead of room names or cardinal directions. This phenomenon may be explained by the fact that the initial digit in room numbers indicates the vertical region (i.e., the level) in which the room is located. Thus, participants could focus their efforts on a smaller region. Accordingly, it can be hypothesized that dividing each level into different regions and incorporating them into the numbering system can improve wayfinding performance. For example, room 3B10 would be in region B of the third floor, and the room number would be 10. This is yet another hypothesis for examination in future studies.

Limitations

This study employs a grounded theory approach to explore the role of signage and maps in interior wayfinding. While this methodology facilitates the generation of rich, in-depth insights and theories emerging directly from the data, it also brings inherent limitations that must be acknowledged. Notably, the findings derived from a grounded theory approach are inherently exploratory and conceptual in nature. They serve as a foundational step toward understanding complex phenomena, providing a theoretical framework that captures the nuances and dynamics observed within the data. However, the generalizability and applicability of the findings of the current study are subject to limitations. Grounded theory constructs are not meant to assert universal truths but to propose hypotheses and theoretical insights that require further empirical testing and validation. In this vein, it is imperative to approach the application of the findings with caution in different or broader contexts. Therefore, it is strongly recommended that the propositions and conceptual frameworks derived from this study be subjected to rigorous empirical testing in diverse settings and populations.

Apart from that, this study has four other limitations. The first limitation of this study relates to the study setting. In this study, participants performed wayfinding tasks in only two buildings, both of which were university buildings. Having a greater number of buildings with different attributes can enrich the findings of this study. Additionally, including other building types, such as hospitals and

airports, can result in different findings because different types of signs and maps are possibly used in other building types that are different from those used in university buildings.

The second limitation relates to the similarity of participants' experience with the actual wayfinding process. Users may have different experiences depending on the situation in which they are performing wayfinding. For example, evidence suggests people might use signage differently depending on whether they are in an emergency or a non-emergency situation (Vilar Rebelo, Noriega, Duarte et al., 2014). Accordingly, the generalizability of this study's findings to other situations is limited.

The third limitation of this study relates to the participants of this study. All participants were young, educated adults. Including participants with other characteristics (such as older adults or less educated people) may result in different findings.

Finally, the data collection process might have impacted participants' thought processes. Since participants were asked to think aloud, this process might have taxed their cognitive processing capacity and altered their wayfinding performance.

CONCLUSION

The findings presented in this study shed light on the potential inaccuracies of assumptions governing the design and placement of maps and signages, ultimately impacting their effectiveness in aiding users during wayfinding. In light of these revelations, it becomes evident that additional exploratory studies are imperative to thoroughly assess the efficacy of these wayshowing systems within diverse building types and real-world scenarios.

By acknowledging the limitations of current practices, future research endeavors can delve deeper into the intricacies of wayfinding processes and develop more informed strategies to enhance user experiences. Investigating the actual navigation behavior of individuals within various architectural environments will offer valuable insights and inform the refinement of wayshowing elements to better align with users' cognitive processes and expectations.

Furthermore, the implications of this study extend beyond academic circles, reaching architects, designers, and facility managers responsible for creating user-friendly spaces. Understanding the impact of wayshowing systems on individuals' navigation can significantly contribute to the creation of more efficient, accessible, and user-centric built environments.

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DECLARATION OF CONFLICTING INTERESTS

The Authors declare that there is no conflict of interest.

REFERENCES

Arthur, P., & Passini, R. (1992). *Wayfinding: People, signs, and architecture*. McGraw-Hill Book Co.

Birks, M., Chapman, Y., & Francis, K. (2008). Memoing in qualitative research: Probing data and processes. *Journal of Research in Nursing*, 13(1), 68–75. DOI: http://dx.doi.org/10.1177/1744987107081254

Butler, D. L., Acquino, A. L., Hissong, A. A., & Scott, P. A. (1993). Wayfinding by newcomers in a complex building. *Human Factors*, 35(1), 159–173. DOI: http://dx.doi.org/10.1177/001872089303500109

Charmaz, K. (2014). *Constructing grounded theory* (2nd ed.). Sage.

Chen, C.-H., Chang, W.-C., & Chang, W.-T. (2009). Gender differences in relation to wayfinding strategies, navigational support design, and wayfinding task difficulty. *Journal of Environmental Psychology*, 29(2), 220–226. DOI: http://dx.doi.org/10.1016/j.jenvp.2008.07.003

Cope, J., Lutz, J., Ironsmith, M., & Elbert, E. (1999). Use of signs to enhance way-finding in a university bookstore. *Perceptual and Motor Skills*, 88(3), 1271–1279. DOI: http://dx.doi.org/10.2466/pms.1999.88.3c.1271

Golledge, R. G., & Stimson, R. J. (1997). *Spatial behavior: A geographic perspective*. Guilford Press.

Haq, S., & Zimring, C. (2003). Just down the road a piece: The development of topological knowledge of building layouts. *Environment and Behavior*, 35(1), 132–160. DOI: http://dx.doi.org/10.1177/0013916502238868

Hashim, M. J., Alkaabi, M. S. K. M., & Bharwani, S. (2014). Interpretation of way-finding healthcare symbols by a multicultural population: Navigation signage design for global health. *Applied Ergonomics*, 45(3), 503–509. DOI: http://dx.doi.org/10.1016/j.apergo.2013.07.002

Hölscher, C., Büchner, S. J., Meilinger, T., & Strube, G. (2009). Adaptivity of wayfinding strategies in a multi-building ensemble: The effects of spatial structure, task requirements, and metric information. *Journal of Environmental Psychology*, 29(2), 208–219. DOI: http://dx.doi.org/10.1016/j.jenvp.2008.05.010

Jamshidi, S. (2021). *Identifying elements of the interior environment that contribute to wayfinding cognitive processes* [Unpublished doctoral dissertation]. Texas Tech University.

Jamshidi, S., Ensafi, M., & Pati, D. (2020). Wayfinding in interior environments: An integrative review. *Frontiers in Psychology*, 11. DOI: http://dx.doi.org/10.3389/fpsyg.2020.549628

Jamshidi, S., & Hashemi, S. (2020, October 9). *Interior wayfinding: Two different approaches in addressing wayfinding problems within interior environments* [Conference presentation]. IDEC Virtual Symposium.

Jamshidi, S., & Pati, D. (2020). A Narrative review of theories of wayfinding within the interior environment. *HERD: Health Environments Research & Design Journal*, 14(1) 290–303. DOI: http://dx.doi.org/10.1177/1937586720932276

Jamshidi, S., & Pati, D. (2024). Identifying environmental elements and attributes that contribute to indoor wayfinding: An exploratory study utilizing think-aloud protocol. *Journal of Interior Design*, 49(2), 117–138 DOI: http://dx.doi.org/10.1177/10717641231207031

Joy Lo, C.-W., Yien, H.-W., & Chen, I.-P. (2016). How universal are universal symbols? An estimation of cross-cultural adoption of universal healthcare symbols. *HERD: Health Environments Research & Design Journal*, 9(3), 116–134. DOI: http://dx.doi.org/10.1177/1937586715616360

Levine, M., Marchon, I., & Hanley, G. (1984). The placement and misplacement of you-are-here maps. *Environment and Behavior*, 16(2), 139–157. DOI: http://dx.doi.org/10.1177/0013916584162001

Li, R., & Klippel, A. (2016). Wayfinding behaviors in complex buildings: The impact of environmental legibility and familiarity. *Environment and Behavior*, 48(3), 482–510. DOI: http://dx.doi.org/10.1177/0013916514550243

Lu, Y., & Ye, Y. (2019). Can people memorize multilevel building as volumetric map? A study of multilevel atrium building. *Environment and Planning B: Urban Analytics and City Science*, 46(2), 225–242. DOI: http://dx.doi.org/10.1177/2399808317705659

Meilinger, T., Hölscher, C., Büchner, S. J., & Brösamle, M. (2006). How much information do you need? Schematic maps in wayfinding and self localisation. In T. Barkowsky, M. Knauff, G. Ligozat, & D. R. Montello (Eds.), *Spatial Cognition V Reasoning, Action, Interaction* (pp. 381–400). Springer Berlin Heidelberg. DOI: http://dx.doi.org/10.1007/978-3-540-75666-8_22

Montello, D. R., & Sas, C. (2006). Human Factors of Wayfinding in Navigation. In W. Karwowski W. (Ed.), *International Encyclopedia of Ergonomics and Human Factors* (pp. 2003–2008). CRC Press/Taylor & Francis, Ltd. DOI: http://dx.doi.org/10.1201/9780849375477.ch394

O'Neill, M. J. (1991a). A biologically based model of spatial cognition and wayfinding. *Journal of Environmental Psychology*, 11(4), 299–320. DOI: http://dx.doi.org/10.1016/s0272-4944(05)80104-5

O'Neill, M. J. (1991b). Effects of signage and floor plan configuration on wayfinding accuracy. *Environment and Behavior*, 23(5), 553–574. DOI: http://dx.doi.org/10.1177/0013916591235002

Pati, D., Harvey, T. E., Willis, D. A., & Pati, S. (2015). Identifying elements of the health care environment that contribute to wayfinding. *HERD: Health Environments Research & Design Journal*, 8(3), 44–67. DOI: http://dx.doi.org/10.1177/1937586714568864

Richardson, A. E., Montello, D. R., & Hegarty, M. (1999). Spatial knowledge acquisition from maps and from navigation in real and virtual environments. *Memory & Cognition*, 27(4), 741–750. DOI: http://dx.doi.org/10.3758/bf03211566

Thorndyke, P. W., & Hayes-Roth, B. (1982). Differences in spatial knowledge acquired from maps and navigation. *Cognitive Psychology*, 14(4), 560–589. DOI: http://dx.doi.org/10.1016/0010-0285(82)90019-6

Vilar, E., Rebelo, F., & Noriega, P. (2014). Indoor human wayfinding performance using vertical and horizontal signage in virtual reality. *Human Factors and Ergonomics in Manufacturing & Service Industries*, 24(6), 601–615. DOI: http://dx.doi.org/10.1002/hfm.20503

Vilar, E., Rebelo, F., Noriega, P., Duarte, E., & Mayhorn, C. B. (2014). Effects of competing environmental variables and signage on route-choices in simulated everyday and emergency wayfinding situations. *Ergonomics*, 57(4), 511–524. DOI: http://dx.doi.org/10.1080/00140139.2014.895054

Wright, P., Hull, A. J., & Lickorish, A. (1993). Navigating in a hospital outpatients' department: The merits of maps and wall signs. *Journal of Architectural and Planning Research*, 10(1), 76–89. http://www.jstor.org/stable/43029277